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REVIEW ARTICLE

Biology, ecology and management of fruit piercing moths (Lepidoptera: Noctuidae)

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ABSTRACT: Moths of the genus *Eudocima* (=*Othreis*) are the dominant primary fruit piercers, accompanied by several secondary fruit feeders resulting in extensive damage to pomegranate in the south and orange in the central India. The damage is mostly observed during September to November. None of the earlier recommended methods such as catching the adult moths by hand net, smoking of the orchard in the evening, spraying the fruits with insecticides, baiting the adult moths with arsenic compounds, baggaging of the fruits, deterring the moths by the bright light source and destroying the larval host plants are adequately effective in reducing the damage caused by these insects. The egg and larval parasitoids hold good promise for the suppression of fruit piercing moths damage. Enclosing whole orchard with nylon net also advisable. The recent advances in the bioecology and management of fruit piercing moths is reviewed.

Keywords: *Eudocima*, fruit piercing moth, bioecology

1. INTRODUCTION

It is well known that fruit trees all over the world are susceptible to attacks of the caterpillars of numerous lepidopterans such as leaf miners, flower webbers, flower, bud, bark, stem and fruit borers. But it was not known until 1869, that adult lepidopterans cause damage to fruits, when a French botanist Thozet observed for the first time *Eudocima (=Othreis) fullonia* (Clerck) moths sucking juice from ripe orange fruits at Rockhampton in Australia (Baptist, 1944). Later this was confirmed by the observation of Kunckel in 1875 in Australia. *Eudocima fullonia* was redescribed by Moore (1887) in his "Lepidoptera of Ceylon" and subsequently by Hampson (1892) in the "Fauna of British India". Fruit piercing moths attained importance and significance as pests in various countries according to the development and degree of introduced fruit cultivation, particularly of citrus and pomegranate. Thus in India, fruit piercing moths were first recorded as serious pests in 1903 by Stebbing and later in 1909 by Lefroy and Howlett, in Tropical Africa in 1916 by Gunn, and in Sri Lanka as recently as 1934 (Baptist, 1944).

Eudocima fullonia (Clerck), *Eudocima materna* (Linnaeus), *Eudocima homaena* Hübner and *Eudocima cajeta* (Cramer) and others are known to occur in India (Susainathan, 1924a, 1924b; Ayyar, 1944). Scanning of Indian literature on fruit piercing moths reveals that there exist clear gaps of long years between two successive workers during 1909 23, 1924 36, 1945 60, 1960 68 and 1973 80. The fungi, *Oospora* sp. (Muller, 1939), *Fusarium* sp., *Colletotrichum* sp., and bacteria (Hargreaves, 1936) gain entry through the hole pierced by the moths and/or inoculated by the infected proboscis (Dodant, 1953) causing the fruit to rot and fall. An extensive review on the fruit piercing moths occurring in New Caledonia and their control is provided by Cochereau (1977). Similar review is also provided by Bänziger (1982) with reference to species of Thailand.

2. SPECIES COMPOSITION

Many workers in India and abroad have collected and documented several fruit piercing moths. Hargreaves (1936) recorded 46 species of fruit piercing noctuids from Sierra Leone whereas Cotterell (1940) reported 27 species from Gold Coast. Box (1941) added another 88 species from Gold Coast. Golding (1945) collected 23 species of fruit piercing moths from Nigeria whereas Hattori (1969) listed 24 species from Japan. Bänziger (1982) recorded 86 species of fruit piercing moths from Thailand and grouped them as primary and secondary fruit piercers. Sands and Schotz (1989) reported 331 Australian fruit piercing moth species represented in the Australian National Insect Collection, CSIRO, Canberra and a further 156 undescribed species, making a total of 497 species placed in 166 genera. While only a few species are known to initiate damage to firm-skinned fruits i.e. those referred to as primary fruit piercing moths, the remaining 300 species in the subfamily Catocalinae are all potentially secondary fruit feeding moths.

Susainathan (1924a, 1924b) listed 17 species of fruit piercing moths while Ayyar (1944) reported 20 species from eastern Andhra Pradesh. Sundarababu and David (1973) recorded 16 species of fruit piercers from Coimbatore. According to Rakshpal (1945), Bajpai (1955) and Atwal (1963), the dominant fruit piercing moths at Gwalior (Madhya Pradesh), Nagpur (Maharashtra) and Punjab, respectively were *E. fullonia* and *E. materna*. *Achaea janata* (L.) was recorded as a serious fruit piercing moth on citrus and pomegranate in Nagpur (Bajpai, 1955) and Cuddapah (Ramachandrachari and Padmanabham, 1960b). Studies of Cherian and Sundaram (1936) revealed that *E. materna* was the most dominant species comprising 95% of total moth catches as compared to 5% constituted by *E. fullonia* in Cuddapah. Mote *et al.* (1991) also mentioned the relative abundance of each species of fruit piercing moths. According to them the composition of *E. fullonia*, *E. materna* and *A. janata* was 2%, 8% and 90%, respectively at Sangola (Maharashtra) but at Rahuri (Maharashtra) the relative abundance of *E. fullonia*, *E. materna*, *E. homaena* and *A. janata* was 9%, 75%, 5% and 11%, respectively on pomegranate. *E. fullonia* was the most dominant among the fruit piercing moths with maximum frequency of appearance of 69.1% in the composite population whereas it was 10%, 7%, 5%, 4.5%, 3%, 1% and 0.5% for *A. janata*, *E. materna*, *E. homaena*, *Parallelia algira* L., *E. cajeta*, *Ophiusa coronata* (F.) and *Thyas honesta* Hübner, respectively, at Rajampet (Andhra Pradesh) (Ramachandrachari and Padmanabham, 1960a).

Bhumannavar and Viraktamath (2001a) recorded 29 species of moths on guava and pomegranate in Karnataka. Of this, nine species belong to subfamily Ophiderinae, 19 to subfamily Catocalinae and one to subfamily Amphipyrinae. *E. fullonia*, *E. homaena* of Ophiderinae and *M. undata* and *O. tirhaca* of Catocalinae were dominant on guava at Dharwad (Karnataka) whereas *E. materna*, *E. homaena*, *A. flava* and *E. fullonia* of Ophiderinae and *A. janata*, *M. frugalis* of Catocalinae were dominant on pomegranate at Raichur and Bijapur (Karnataka). *Eudocima fullonia, E. materna* and *E. homaena* were the major fruit piercing moths on pomegranate in Karnataka (Baliki *et al.,* 2011) and on guava in Coimbatore (Saravanan *et al.,* 2005).

The relative abundance of six fruit piercing moths in Sri Lanka was *E. fullonia* > *E. homaena* > *E. salaminia* > *E. materna* > *R. hypermnestra* > *Khadira aurantia* (Baptist, 1944). In New Zealand, *E. fullonia* was the dominant species followed by *E. paulii* and *E. materna* (Maddison, 1982). *Eudocima fullonia* and *E. salaminia* were most dominant in subtropical Australia and *E. materna* and *E. jordani* in tropical Australia, respectively (Sands and Schotz, 1989). *Eudocima fullonia* was most destructive in Nigeria (Golding, 1945) and Sierra Leone (Hargreaves, 1936) while *Adris tyrannus amurensis* in Japan (Hattori, 1969). Other most abundant fruit piercers were *Calpe lata* Butler and *Calpe gruesa* Dra. in northern parts and *Oraesia excavata* Butler and *Oraesia emarginata* (Fabricius) in southern parts of Japan (Hattori, 1969). Bänziger (1983) revised the fruit piercing and blood sucking moth genus *Calyptra* Ochsenheimer (=*Calpe* Treitschke). Park *et al.* (1988) used light trap and sweep nets and collected 15 primary and 22 secondary fruit feeders from Korean Republic. Bänziger (1987) reported 24 species of fruit piercing moths from Nepal near Kathmandu. Atachi *et al.* (1989) reported seven species of the genera *Eudocima*, *Ophideres*, *Achaea* and *Enmonodia*, previously unknown in Benin as important fruit piercing moths of citrus. A monograph on *E. fullonia* was written by Cochereau (1977) with an extensive coverage on the feeding habits, larval food plants, development and the number, duration and overlapping of generations, methods of counting the different stages in a population, numerical studies of counts and fluctuations of populations of the various stages and the factors affecting mortality and natural enemies and population management.

3. SEASONAL INCIDENCE

According to Rakhpal (1945) fruit piercing moths were found during the rainy season only, i.e. from the first week of July to the last week of September at Gwalior. Similar trend was observed in southern Andhra Pradesh (Susainathan, 1924a, 1924b), Nagpur (Sontakay, 1944; Bajpai, 1955), Punjab (Atwal, 1963), Sangola and Rahuri (Maharashtra) (Mote *et al.*, 1991). But in Coimbatore (Sundarababu and David, 1973) and Cuddapah (Ramachandrachari and Padmanabham, 1960a; 1960b) the fruit piercing moths were abundant during October. According to Ramachandrachari and Padmanabham (1960a), damage *by A. janata* was more in August-September and reduced in the later part of September whereas *Eudocima* spp. damage started from October-November in Cuddapah. After October, the fruit piercing moths were not active, even larvae of these moths were not found on their host plants (Rakhspal, 1945; Sontakay, 1944). Bhumannavar (2000) also observed higher moth activity during October of 1998 and 1999 at Raichur and Dharwad when maximum damage to pomegranate and guava was done.

In Sri Lanka (Baptist, 1944), there was a minor peak in June July and a major peak in November December, but in Japan the active period of moths was from July to November (Hattori, 1969), however in Queensland, Australia, high moth activity was observed from November to March coinciding with rainy season (Tryon, 1924; Sands and Schotz, 1989; Fay and Halfpapp, 1993a, 1999). In African countries like Sierra Leone and Nigeria (which are located nearer to equator) the highest moth activity was recorded during April to June (Hargreaves, 1936; Golding, 1945), which appears to be the beginning of the rainy season. Though heavy rains were received after July, the moth activity was practically nil (Hargreaves, 1936). In Fiji, higher numbers of larvae were collected from June to August with a peak in July (Kumar and Lal, 1983).

4. BIOLOGY OF *Eudocima* spp.

4.1 *Eudocima fullonia*

Rakshpal (1945) mentioned the duration of egg, larval and pupal stages of *E. fullonia* as 3 4, 15 and 21 days, respectively in Madhya Pradesh on *Tinospora cordifolia* Miers. On the same host Atwal (1963) reported the duration of egg, larval and pupal stages as 2, 4 and 2 weeks, respectively, with five larval instars. Patel and Talgeri (1956) had mentioned about general biology of *Eudocima* spp. Sevestopulo (1940) gave morphological description of *E. fullonia* larva. Bhumannavar (2000) and Bhumannavar and Viraktamath (2004) studied detailed biology on five Menispermaceae. Comstock (1963, 1966) illustrated and described the life stages of *E. fullonia*. Cantrell (1978) provided the coloured illustration of *E. fullonia* along with notes on its biology in Queensland. Detailed biology of *E. fullonia* was studied by Hargreaves (1936) on *T. smilacina*, Cochereau (1977) on *Erythrina* sp., Maddison (1982) at Sierra Leone, Kumar and Lal (1983) on Erythrinathe in Fiji, Denton *et al.* (1989) on *E. variegata* at Guam and Muniappan *et al.* (1995) on *Erythrina variegata* L. and *Cocculus* sp., in Guam.

4.2 *Eudocima materna*

The duration of egg, larval and pupal stages of *E. materna* reared on *T. cordifolia* was 3, 18 and 9 days, (Cherian and Sundaram, 1936), 8 10, 28 35 and 14 18 days (Ayyar, 1944), 3 4, 12 15 and 8 10 days (Sontakay, 1944) and 3.5-4.0, 11.5-15.5, 12.5-14.0 days (Bhumannavar, 2000), respectively. Srivastava and Bogawat (1968) and Lolage and Khaire (1998) studied detailed biology of *E. materna* on *T. cordifolia*. Bhumannavar (2000) studied detailed biology on *T. cordifolia* and mentioned that *E. materna* larvae did not feed on other Menispermaceae. Mohite *et al.*, (2004) mentioned that at Nagpur, the period from the egg stage to adult death ranged from 35 to 52 days in males and 35 to 56 days in females of *E. materna*. Sevestopulo (1940) described the larval stages of *E. materna*. Hargreaves (1936) studied the biology of *E. materna* on *Rhigiocarya racemifera* Miers in Sierra Leone. In a laboratory study, it was revealed that adult longevity, fecundity, oviposition period, larval period and pupal period of *E. materna* were inversely affected by elevated temperature of 33°C (Mohite *et al.,* 2005).

4.3 *Eudocima homaena*

The pupal period of *E. homaena* was 12 15 days when reared on *Quisqualis indica* L. during July September (Yadav *et al.*, 1983). *Eudocima homaena* larvae refused to feed on *T. cordifolia*, *Cyclia peltata, Stephania japonica* and *Q. indica* indicating that these are not their host plants (Bhumannavar, 2000). Bhumannavar and Viraktamath (2001c) studied detailed biology of *E. homaena* on five Menispermaceae.

4.4 *Eudocima salaminia*

Sands and Schotz (1989) studied the biology of *E. salaminia* on *Stephania japonica* Miers in Australia. According to them *E. salaminia* bred only in cool, sheltered areas as the immature stages were susceptible to desiccation. In India, though the adults of *E. salaminia* were collected only from Mudigeri (Karnataka), efforts to trace its larval host plant failed (Bhumannavar, 2000).

4.5 *Eudocima divitosa*

Hargreaves (1936) studied the biology of *Eudocima divitiosa* Wlk. The duration of the first, second, third, fourth and fifth instar larvae was 3, 2, 2-3, 3, and 3-5 days, respectively, with a total larval period of 14-16 days when reared on *R. racemifera*. The duration of pupal stage varied from 14-18 days. He also gave description of the larval stages.

4.6 *Rhytia hypermnestra*

Bhumannavar (2000) collected five larvae of *R. hypermnestra* feeding on the aerial roots of *T. cordifolia*. He further found that *R. hypermnestra* larvae fed only on *T. cordifolia* and *T. sinensis* and refused to feed on other Menispermaceae. Adults of *R. hypermnestra* were collected at Bangalore and Raichur (Karnataka).

5. LARVAL POLYMORPHISM

Several workers reported colour variation in different larval instars of species of *Eudocima* (Tryon, 1924; Baptist, 1944; Ayyar, 1944). Sevestopulo (1940) was the first to report three colour morphs in *E. materna*. Ayyar (1944) reported the general body colour as velvety blue whereas it was black according to Hargreaves (1936) and Srivastava and Bogawat (1968). Many workers mentioned that the larvae of *E. fullonia* were vividly coloured (Tryon, 1924; Margabandhu, 1933; Rakshpal, 1945). Colour of full grown caterpillar was rich brown, with varying intensity (Tryon, 1924; Baptist, 1944; Margabandhu, 1933) or velvety black (Sevestopulo, 1940; Rakshpal, 1945). Some workers observed two colour morphs. The grown up larva was either dark brown to black or pale yellow to green (Comstock, 1963; Hargreaves, 1936; Maddison, 1982; Denton *et al.*, 1989). According to Cochereau (1977), the dark coloured larvae were typical of gregarious larvae whereas the lighter colour was found in isolated larvae. Apte (1999) claimed that male and female of *E. fullonia* could be easily distinguished at the larval stage and the adults showed little colour variation. Bhumannavar (2000) obtained both male and female adults from the green forms during monsoon and from dark forms during post monsoon and found that white band connecting different body segments did not have any relationship to the sex thereby disproving the claims of Apte (1999).

6. LARVAL HOST PLANTS

In India, larvae of *E. fullonia* were reported to feed on leaves of *T. cordifolia* and *Cocculus hirsutus* Diels (Rakshpal, 1945; Nair, 1975; Ayyar, 1944; Susainathan 1924a; Bajpai, 1955). The larvae also fed on *T. sinensis* (Lour.) Merr. (= *T. malabarica* Miers.), *Anamirta cocculus* W. & A. (Rakshpal, 1945), *T. smilacina* Benth. , *C. hirsutus*, *Cissampelos pareira* L., *Convolvulus arvensis* L., *Trichisia pattens* Oliv. and *Pericampylus glaucus* Blatter in Punjab (Atwal, 1963). Bhumannavar and Viraktamath (2004) reared the larvae of *E. fullonia* on *T. cordifolia, T. sinensis, C. hirsutus, Anamirta cocculus, Tiliacora acuminate* and *Diploclisia glaucescens*. Further they reported that the larvae of *E. fullonia* refused to feed on *Cissampelas pareira*, *Cyclea peltata*, *Stephania japonica* and *S. wightii* and *Erythrena indica*. According to Ramkumar *et al.,* (2010) the larvae of *E. fullonia* could feed on *T. crdifolia*, *Tiliacora acuminate* and *Diploclisia glaucescens*.

Except in the Pacific, *E. fullonia* larvae are known to feed only on plants belonging to the family Menispermaceae. Atleast 30 species of this family serve as hosts, though the species vary from country to country, they frequently belong to the genera *Anamirta*, *Cocculus*, *Dioscoreophyllum*, *Legnephora*, *Hypserpa*, *Pericampylus*, *Stephania*, *Tiliacora*, *Tinospora* and *Triclisia* (Hargreaves, 1936; Comstock, 1963; Mosse Robinson, 1968; Bänziger, 1982). By contrast, in the Pacific Islands, larvae are known to feed almost exclusively on coral trees of the genus *Erythrina* (Fabaceae), the single exception being the creeper *Stephania japonica* (Thumb.) Miers, a native plant in New Caledonia (Cochereau, 1977). The preference of *Erythrina* and Menispermaceae was thought to be due to the similar alkaloids they possess (Thornber, 1970). In this regard, Cochereau (1977) postulated that the occurrence of the alkaloid cocculobidine in *Cocculus* and *Erythrina* was responsible for the oviposition and larval feeding behaviour of *Eudocima*. Recently, however, Amar *et al.* (1991) identified over 90 closely related tetracyclic alkaloids in *Cocculus* and *Erythrina*, suggesting that more than one chemical might be involved in providing the stimulus for oviposition.

Larvae of *O. materna* fed only on host plants of the genus *Tinospora*. In India, it fed on *T. cordifolia* (Sontakay, 1944, Bajpai, 1955; Srivastava and Bogawat, 1968; Lolgae and Khaire, 1998; Bhumnnavar and Viraktamath, 2001; Ramkumar *et al.,* 2010), *T. sinensis* (Bhumnnavar and Viraktamath, 2001) and in Australia on *T. smilacina* (Fay and Halfpapp, 1993a). However, Hargreaves (1936) listed *Desmonema caffra* Miers (at Natal) and *R. racemifera* (at Sierra Leone) as larval host plants of *O. materna*. Yadav *et al.* (1983) reared *O. homaena* on *Q. indica* in India, this is an unusual report as no other *Eudocima* are known to feed on *Q. indica*. In Sierra Leone, the larvae of *O. divitiosa* fed on *Dioscoreophyllum tenerum* Engl. and *R. recemifera* and larvae of *Serrodes partita* on *Deinbollia pinnata* Sch. Et. Th. and larvae of *Serrodes trispila* on *Lecaniodiscus cupanioides* Planch. (Hargreaves, 1936). In Australia the larvae of *E. salaminia* fed almost exclusively on the forest vine, *Stephania japonica* (Sands and Schotz, 1989), but in Thailand, it fed on other species of *Stephania* (Sands *et al.*, 1991). Bhumannavar and Viraktamath (2004) reared the larvae of *E. homaenaa* on *C. hirsutus, A. cocculus, T. acuminate C. pareira* and *D.glaucescens*. Further they reported that the larvae of *E. homaena* refused to feed on *T. cordifolia, T. sinensis, Cyclea peltata*, *S. japonica* and *S. wightii* and *E. indica*. The larvae of *E. homaena* could feed on *Cocculus* *hirsutus*, *T. acuminate* and *D. flaucescens* (Ramkumar *et al.,* 2010).

Rhytia hypermnestra larvae fed on *T. smilacina* in Queensland and *T. sinensis*, *T. baenzigeri* and *T. crispa* in Thailand (Fay and Halfpapp, 1993a) on *T. cardifolia* (Bhumannavar, 2000; Ramkumar *et al.,* 2010) and on *T. sinensis* (Bhumannavar, 2000) in India. Fay and Halfpapp (1993a) recorded that the larvae of *O. jordani* feeding on *T. smilacina*, *P. novoguineensis* and larvae of *R. cocalus* on *T. smilacina* and larvae of *K. aurantia* on *T. smilacina*, *Legnephora moorei* Miers, *S. harveyanum* and *S. japonica* var. *timoriensis* in Queensland. According to Fay and Halfpapp (1993a*)*, *R. cocalus*, *O. jordani* and *K. aurantia* preferred rainforest habitat while *O. materna* and *O. fullonia* preferred dry inland habitat in Australia and there was considerable temporal separation of any two species utilizing *T. smilacina* in any habitat. Ramachandrachari and Padmanabham (1960b) recorded larvae of *A. janata* on pomegranate, castor and *Strychnos nuxvomica* L. leaves around Caddapah. Iwabuchi *et al.* (1979) reared *O. emarginata* for 10 generations on artificial diet containing *Cocculus trilobus* DC. and Chlorella. Bhumannavar and Viraktamath (2001d) described a rearing technique for three species of *Eudocima* and their parasitoids.

7. ADULT FEEDING AND HOST RANGE

7.1. *Morphology of proboscis*

Studies on morphology of mouth-parts of these moths were carried out by Kunckel (1875) while the most recent of numerous later studies being that of Johannsmeier (1976). The piercing mouthparts are very well developed and provided with sharp spines, which help in piercing citrus and other fruits (Atwal, 1963). Susainathan (1924b) provided the figures of proboscis of *E. fullonia*, *E. materna*, *E. coronata*, *A. dotata*, *E. tirrhaca*, *A. janata*, *P. algira*, *P. quenavadi*, *E. emarginata* and *E. hieroglyphica*. Further he mentioned that species of *Othreis* possess stout saw-like proboscis with which they are able to puncture oranges, mangoes and even pomegranate. The feeding apparatus of these moths appears to be specially provided at the tip with minute sharp spines, which help them to puncture the fruit and suck the out flowing juice (Ayyar, 1944). The proboscis is adapted for piercing the rind of fruits, being very strong and armed in the distal part with numerous minute tooth like spines and ending in a sharp point (Baptist, 1944). Hattori (1969) classified the proboscis into 'drilling or piercing type' and Sucking type**.** Hattori (1969) provided illustrations of proboscis of representatives of four groups of fruit piercing moths of Japan. Yoon and Lee (1974) provided the illustrations of proboscis of 11 species of fruit piercers occurring in south Korea. Denton *et al.* (1999) provided the photographs of proboscis of primary piercers i.e. *Platyja umminia* (Cr.), *Ercheia dubia* (Btlr.), *Pericyma cruegeri* (Btlr.), *E. fullonia* and secondary feeders i.e. *Ophiusa coronata* Fabricius, *Dysgonia absentimacula*, *Ericeia inangulata* (Guenée) and *Anomis flava* Fabricius.

Bänziger (1980) who studied the morphology of mouth parts of several species of fruit piercing moths had provided good information. Bhumannavar and Viraktamath (2001a) also studied the morphology of proboscis of fruit piercing moths and classified the moths based extent of sclerotisation and type of fruits damaged.The proboscis of *A. janata* did not possess any sclerotised structures, but had only stiff hairs (Bhumannavar and Viraktamath, 2001a). Without looking into the morphology of the mouthparts, *A. janata* was erroneously claimed as primary piercer of hard and thick skinned fruits by several workers (Ayyar, 1944; Rakshpal, 1945; Bajpai, 1955; Ramachandrachari and Padmanabham, 1960b; Vevai, 1969; Sundarababu and David, 1973; Mote *et al.* 1991), but after studying the morphology of the proboscis and exposing several kinds of fruits to moths, *A. janata* was categorised as primary piercer of very soft skinned fruits such as *Rubus* sp. by Bänziger (1982) and as a secondary fruit feeder by Denton *et al.* (1992). Among the Indian workers only Susainathan (1924b) studied the morphology of proboscis and opined that the proboscis tip of *A. janata* did not resemble the saw and file-like proboscis tip of *Eudocima*, and the adults swarm around the damaged fruits, both on the ground and on the trees.

Adults of *Eudocima* spp. fed on the fruits throughout night, but peak feeding period was from 7 to 11 pm and 4 to 6 am (Mote *et al*., 1991). *A. janata* usually appeared late after midnight for feeding and continued till morning (Rakshpal, 1945). According to Rakshpal (1945), there was no difference in the attack by the moths during moonlit nights or dark nights. The moths were active between 1930 – 2330 h with a peak at 2300 h on guava and pomegranate (Bhumannavar & Viraktamath, 2001a). Fruit fall observed in citrus varieties like orange (*Citrus reticulata* Blanco) and mosambi (*Citrus sinensis* Pers.) in Punjab (Atwal, 1963), Maharashtra (Bajpai, 1955; Mote *et al*., 1989), Andhra Pradesh (Susainathan 1924a, 1924b; Ayyar, 1944; Ramachandrachari and Padmanabham, 1960a, 1960b), Madhya Pradesh (Rakshpal, 1945), Rajasthan (Srivastava and Bogawat, 1968), Gujarat (Yadav *et al.*, 1983) and Tamil Nadu (Cherian and Sundaram, 1936) during July-October was due to the fruit piercing moth feeding activity. Serious infestation on pomegranate was recorded in Maharashtra (Mote *et al.,* 1991), Andhra Pradesh (Ayyar, 1944) and Tamil Nadu (Cherian and Sundaram, 1936). Other fruits damaged by these moths included guava in Andhra Pradesh (Ayyar, 1944), Rajasthan (Srivastava and Bogawat, 1968), Tamil Nadu (Cherian and Sundaram, 1936) and Gujarat (Yadav *et al.,* 1983), grapes in Tamil Nadu (Sundararaj and David, 1973), tomato, mango, cashew and cactus in Tamil Nadu (Cherian and Sundaram, 1936; Pruthi and Mani, 1945; Pruthi, 1969; Butani and Jotwani, 1975; Yadav, 1969) and apple, peach, pear and plum in northern India (Bindra, 1957). The moth had been observed to puncture banana, custard apple, grape, mango, peach, pineapple and tomato in Gwalior (Rakshpal, 1945). Rakshpal (1945) further observed dried fruit beetle, *Carpophilus hemipterus* L. inside the bored and fallen fruits. Adults of *A. janata* preferred to feed on fruit slices (when provided) than on intact fruits in Cuddapah (Ramachandrachari and Padmanabham, 1960b).

Citrus, mango and tomato were severely damaged by the piercing activity of these moths in Nigeria (Golding, 1945), Sierra Leone (Hargreaves, 1936) and Australia (Sands and Schotz, 1989). In addition, these moths inflicted serious injury to *Eugenia uniflora* L., *Ficus anomani* Hutchinson and guava in Nigeria (Golding, 1945), jack fruit, bread fruit and cashew in Sierra Leone (Hargreaves, 1936), banana, guava, carambola, papaya, mango, pomegranate and citrus in Guam (Denton *et al.*, 1989), chinese gooseberry, peach, litchi and capsicum in Australia (Sands and Schotz, 1989) and apple, loquat, plum, peach, pear, grape and citrus in Japan (Hattori, 1969). A wide range of cultivated and native fruits and vegetables may be damaged by *E. fullonia*. Damage was frequently inflicted on oranges, mosambi, grapefruit, guava, star fruit, mango, banana, cashew nut, custard apple, fig, litchi, longan, passion fruit, coffee, pineapple, kiwi fruit, apple, apricot, peache, plum, persimmon and nectarine. During outbreaks green tomatoe, capsicum, melon, pawpaw and breadfruit also sufferred serious damage (Cochereau 1974a, 1977; Kumar and Lal, 1983; Lever, 1941; Maddison, 1982). When free choice was given, *Achaea* sp. preferred ripe mango to banana and grape fruit and the percentage of feeding holes was 60%, 28% and 12%, respectively on mango, banana and grape fruit (Golding, 1945).

Eudocima fullonia preferred sweet, aromatic fruits (e.g. banana, grape) to those with a low sugar content (e.g. tomato, bell pepper) (Sands and Schotz, 1989). Denton *et al.* (1989) confirmed this and further mentioned that ripe fruits were preferred to unripe fruits and given a formulae to work out the preference index. According to Denton *et al.* (1989) the descending order of of fruit preference was banana (100), guava (89), mango (54), papaya (45), tomato (31), pear (30), black plum (13), naval orange (10), red apple (10), egg-plant (0), plum (0) and pomegranate (0). Bhumannavar (2000) studied the adult moth food preference of *E. materna*, *E. fullonia* and *E. homaena*. *Eudocima materna* adult food preference index was highest for tomato (100) followed by banana (38.7) during 1998 and for guava (100) followed by tomato (40.2) during 1999. *Eudocima fullonia* adult food preference index was highest for banana (100) followed by brinjal (21.07) during 1998 and guava (100) followed by banana (11.5) during 1999. *Eudocima homaena* adult food preference index was highest for guava (100) followed by tomato (40.9) and banana (21.0). The cumulative food preference index for all the three species on these fruits indicated that guava had the highest cumulative index of 323.09 followed by tomato (199.29) and banana (195.51).

7.2. *Extent of damage*

Among the citrus varieties, orange (mandarin) sufferred more damage by the feeding activity of fruit piercing moths compared to other fruits and the loss ranged from 20% to 80% in different years in Nagpur (Bajpai, 1955; Sontakay, 1944). The damage was 3.8 to 9.8% on mosambi (sweet mandarin) in Cuddapah (Andhra Paradesh) (Ramchandrachari and Padmanabham, 1960b) and 90% in Madhy Pradesh (Baghel *et al.*,1987). The damage on grapes was 10% (Sundarababu and David, 1973) and on tomato 50% (Cherian and Sundaram, 1936) at Coimbatore. The damage was 57% on pomegranate at Rahuri (Mote *et al.,* 1991). Mote *et al.* (1991) observed that the damage was maximum on ripe pomegranate fruits (21.06 to 47.62%) than on unripe fruits (2.86 to 13.86%) at Rahuri (Mahashtra). Sontakay (1944) recorded 30 to 40% damage to orange fruits in India. Bhumannavar and Viraktamath (2001a) studied the nature and extent of damage by the fruit piercing moths. Observation on the total number of fruits and fruits damaged by fruit piercing moths on pomegranate revealed that the fruit damage ranged from 0 to 8.67% at Bijapur and 18.45% to 33.9% at Raichur during 1999. The undamaged fruits were unripe at the time of observation and were not fed by the moths.

In Sri Lanka, 21 to 42% of oranges were lost every year due to fruit piercing moths (Baptist, 1944). In an average year, the damage caused to oranges and mosambi in New Caledonia was relatively unimportant (less than 4%). This low level of damage was considered to be the result of control of *Eudocima* spp. by natural enemies. However, in the outbreak year of 1969, 95% of orange and mosambi and 100% of tomato were damaged. In 1964 (outbreak year), 70% to 100% of fruits were damaged on East coast of New Caledonia (Cochereau, 1972b, 1977). The tomato crop in American Samoa was totally destroyed in 1961 (Comstock, 1963) and again in 1973 (Cochereau, 1977). These moths were serious pests of orange, mosambi and other fruits in Vanua Levu and Fiji where 10 to 15% of ripe fruits were lost every year (Kumar and Lal, 1982) and damage rose to 73% (Fullerton, 1982). In northern Australia, 50% or more of the litchi and carambola fruits were frequently damaged (Waterhouse and Norris, 1987). In South Korea, fruit piercing moths damaged 8.9% grapes and 3.4% pears (Lee *et al.*, 1970). Hargreaves (1936) conducted a field experiment to know the effect of piercing fruit with needle. The first fruit fall occurred 15 days after piercing (1 inch deep), the second after 21 days (0.75 inch deep), both oranges and in the latter case there was a rotted area of 1 inch diameter. In Ghana, 90% of the mangoes were damaged by the outbreaks of *A. lienardi* and *A. faber* (Gupta, 1974). According to Syna (1983), fruit piercing moths were a major constraint in the cultivation of citrus in Fiji. Highly significant differences in fruit weight, colour, brix and pH were recorded between damaged and undamaged *Averrhoa carambola* Adams (Fay and Halfpapp, 1993b).

8. NATURAL ENEMIES

8.1. *Egg parasitoids*

Sontakay (1944) recorded 30 per cent egg parasitisation by a chalcid parasitoid at Nagpur (Maharashtra). *Trichogramma chilonis* Ishii could parasitise eggs of *Eudocima* spp. in the laboratory in Gujarat (Dodia *et al.,* 1986). *Ooencyrtus* sp. was the most important egg parasitoid of *E. fullonia* in New Caledonia accounting for 20-55% parasitisation (average 30%) of solitary eggs and 26.8% of eggs laid in groups (Cochereau, 1974a, 1977). One to four parasitoids emerged from a single *Eudocima* egg. *Ooencyrtus* sp. also parasitised eggs of *Papilio ilioneus amyntho* and *P. montrouzieri* Boisd. Eggs of *E. fullonia* were parasitised by *Telenomus* sp. and *Trichogramma chilonis* in New Caledonia (Cochereau, 1974a, 1977). Egg parasitisation by *T. chilonis* was only 14%. Muniappan *et al.* (1993) reported that egg parasitoids *Telenomus* sp., *Ooencyrtus* sp. and *Trichogramma* sp. were among the most successful biological control agents of *E. fullonia* in Micronesia. Further they mentioned that the eggs and pupae of *P. cruegeri* were parasitised by *Trichogramma* sp. and *Exorista xanthaspis* (Wiedemann) (=*Exorista civiloides* Baranov) and *Brachymeria* sp., respectively. Denton *et al.* (1989) studied the emergence hole made by different egg parasitoids of *E. fullonia*. Per cent egg parasitisation by *Telenomus* sp., *Ooencyrtus* sp., and *Trichogramma* sp. was 47.6, 15.5 and 0.6 %, respectively, on solitary eggs (n=2170) and 54.6, 23.9 and less than 0.1 % on egg masses (235 egg masses; 7508 total eggs), respectively (Denton *et al.*, 1989). *Chelonearus* sp. (Encyrtidae) and *Marietta* sp. (Aphelinidae) were known as hyperparasites of *Trichogramma* sp. on eggs of *E. fullonia* in Guam (Denton *et al.*, 1992).

Trichogramma sp. nr. *papilionis* could parasitise 7.7 to 54.3% eggs of *O. fullonia* in Fiji. Six to 18 parasitoids were observed to emerge from a single parasitised egg. However, this parasitoid was unable to maintain *E. fullonia* population below economic injury level (Kumar and Lal, 1983). *T. chilonis* which was introduced into Hawaii in 1929 against Asiatic rice borer, could parasitise eggs of *E. fullonia* (Heu, 1985). However, 95% eggs of *E. fullonia* were parasitised by *T. astriniae* (Teramoto, 1985) and the moth was not causing economic damage in Hawaii (Waterhouse and Norris, 1987). Sands and Liebregts (2005) recorded up to 95% egg parastisation by *Telenomuslucullus* and *Ooencyrtus* sp. on eggs of *E. fullonia* in the Pacific islands field releases of these two parasitoids has brought down the population of adult fruit piercing moths and their damage on in Fiji and Cook Islands. An unidentified chalcid parasitised eggs of *E. fullonia* in Sri Lanka (Baptist, 1944). In Tonga, two unidentified wasps accounted for 30 40% parasitisation of *E. fullonia* eggs (Crooker, 1979). Sands *et al.* (1993) reported the establishment of *Telenomus* sp. in Western Samoa in 1988 (introduced from Papua New Guinea) and the abundance of eggs of *E. fullonia* had declined since then. *Anastatus* sp. (Eupelmidae), *Ooencyrtus papilionis* Ashmead (Encyrtidae), *Telenomus* sp. (Scelionidae) and *Trichogramma chilonis* Ishii (Trichogrammatidae) were recorded parasitising eggs of *E. materna* (Bhumannavar, 2000). Mean per cent parasitization of eggs of *Eudocima* by *T. chilonis* and *Telenomus* sp. during 1998 was 21.45±27.45 and 6.57±11.56 and during 1999 was 50.40±34.08 and 4.93±8.99, respectively (Bhumannavar and Viraktamath, 2001b).

8.2. Egg predators

In New Caledonia, two lygaeid bugs, *Germalus montandoni* and *Nesogermalus dissidens*, one reduviid, *Ploiaria glabella* Wygadzinsky, five chrysopid larvae, *Mallada noumeana* (Navas) (=C*hrysopa noumeana* Navas*)*, *Chrysoperla otaltis* (Banks) (=*Chrysopa otalatis* Banks), *Mallada basalis* (Walker) (=*C. basalis* Walker), *Italochrysa*(=*Nothochrysa*) *chloromelas* (Girard) and *Synthochrysa montrouzieri* (Girard), a hemerobiid, *Nesomicromus tasmaniae* and two formicids, *Monomorium* sp. and *Tetramorium* spp. fed on eggs of *E. fullonia* (Cochereau, 1974a, 1977). All the predators together accounted for only 15% of egg predation. In the laboratory, each large chrysopid larva could consume seven eggs of *E. fullonia* but both eggs and larvae of the chrysopid were heavily parasitised in the field.

8.3. *Larval parasitoids*

Ayyar (1944) observed two or more parasitoid grubs on young caterpillars of *E. materna* in India. Bhatnagar (1957) described an eulophid *Euplectrus maternus* Bhatnagar on *E. fullonia* and *E. materna* from Uttar Pradesh (India). *Euplectrus* sp. was reported on *E. fullonia* from East Indies (Thompson, 1946). *Euplectrus indicus* Ferriere (Eulophidae) parasitised the last instar larva of *E. materna* whereas *E. maternus* Bhatnagar parasitised first three larval instars of *E. materna*, *E. fullonia* and *E. homaena* (Bhumannavar, 2000). Bhumannavar and Viraktamath (2000) studied the life history and behaviour of *E. maternus*. Muniappan *et al.,* (2004) studied the biology of *E. maternus* on *E. fullonia* larvae in Guam and their attempts to establish this parasitoid in the field failed. Jayanthi and Verghese (2010) recorded up to 40% parasitisation of *E. materna* larvae by *Euplectrus* sp. and *Winthemia* sp.

Euplectrus platyhypenae Ashmead and two ichneumonids, *Echthromorpha agrestoria agrestoria* Swederus and *Lissopimpla pacifica* Morley parasitise larvae of *E. fullonia* in New Caledonia (Cochereau, 1977). In Australia *Euplectrus melanocephalus* Girault parasitised second and third instar larvae of species of *Eudocima* (*Khadira aurantia* (Moore), *Rhytia cocalus* (Cramer), *E. fullonia*, *Eudocima iridescens* (Lucas) and *Eudocima jordani* (Holland)) (Jones and Sands, 1999). An eulophid wasp, *Euplectrus* sp. (Gahan, 1922) had been reported to parasitise *Othreis* sp. larvae in Java (Indonesia). An unidentified braconid larval parasitoid was reported from Sri Lanka on *E. fullonia* (Baptist, 1944). Sands and Schotz (1989) reported one pupal parasitoid, *E. agrestoria agrestoria* from *E. salaminia* in Australia. Jones and Sands (1999) studied the biology of *Euplectrus malanocephalus* Ferriere which parasitised second and third instars of *Khadira aurantia* (Moore), *Rhytia cocalus* (Cramer), *E. fullonia*, *E. iridescens* (Lucas) and *E. jordani* (Holland) in Australia.

Winthemia caledoniae Mesnil, a tachinid fly was the key larval parasitoid accounting for 25 46% parasitisation in New Caledonia (Cochereau, 1977). At times, the parasitisation may go up to 100%. According to Maddison (1982), *W. caledoniae* laid eggs on fifth (or rarely fourth) instar *E. fullonia* larvae. Kumar and Lal (1983) studied the biology of this tachinid fly. This tachinid also attacked larvae of *A. janata* and *Spodoptera* sp. which fed on *Erythrina* sp. (Cochereau, 1977). In American Samoa, a tachinid fly, *Carcelimyia* (=*Winthemia*) *dispar* Macquart parasitises the larvae of *E. fullonia* and *S. litura* (Hoyt, 1955) and in Java (Indonesia) *Carcelia iridipennis* (Wulp) (=*Zenillia modicella* Wulp) was reported to parasitise *Eudocima* larvae (Bezzi, 1925). In Western Samoa, a small midge of the genus *Forcipomyia* sucked the blood of *E. fullonia* larvae (Hopkins, 1927). *Winthemia* sp. parasitised 51.5±24.07 per cent of fifth instar larvae of *E. materna* and it did not parasitise other species of *Eudocima* (Bhumannavar and Viraktamath, 2001b). Chinniah and Mohanasundaram (1995) reported *Blattisocius othreisae* Chinniah and Mohansundaram (Acari) on *Eudocima* sp. from Tamil Nadu. A rearing technique for *Eudocima* and their parasitoid *E. maternus* was detailed by Bhumannavar and Viraktamath (2001d).

8.4. *Larval predators*

In New Caledonia, *Tenodera costalis* (Mantodea), *Platynopus melacanthus* (Boisduval) (Pentatomidae) and *Polistes olivaceus* (De Geer) (Vespidae) were found to prey on larvae of *E. fullonia* (Cochereau, 1977). In an insectary experiment in New Caledonia, a nest containing one hundred adults of *P. olivaceus* consumed seven second instar, 15 third instar and 10 fourth instar larvae of *E. fullonia* every day (Cochereau, 1977). Several birds including *Megalurulus mariei*, *Rhipidura spilodera verreauxi*, *Zosterops lateralis griseonota* and the Indian mynah *Acridotheres tristis* (L.) at times destroyed large numbers of *Eudocima* larvae (Cochereau, 1977).

9. MANAGEMENT

9.1. *Hand collection of moths*

According to Baptist (1944) this method is best accomplished with the help of a hand net and torch light. The moths have a relatively slow and heavy flight and could be easily followed in flight at night with torch light and netted. While feeding they are not easily disturbed and a beam of light stupefied them therefore could be beaten gently or caught into a wide mouthed poison bottle and killed. The mothod was also suggested by Susainathan (1924b), Cherian and Sundaran (1936), Ayyar (1944), Dodial *et al.* (1986) and Swart *et al.* (1975).

9.2. *Regulating fruit season*

This is possible in citrus which produce fruits in two seasons. Rakshpal (1945) and Bindra (1957) suggested sto remove flowers in January to avoid rainy season crop which was subjected to moth attack. According to Rakshpal (1945) this was best acieved by with-holding irrigation for one month, followed by profuse irrigation. According to Bindra (1957), all the flowers produced in January-March should be mechanically/ chemically (by spraying ethryl etc.) removed and a heavy flush of flowers may be obtained in June-July by light root-prunning and manuring followed by very light irrigation shortly before the rainy season. Citrus fruit obtained during winter season were sweet and yield was high due to absence of damage by fruit piercing moths.

9.3. *One-time fruit harvest*

In Nigeria, the fruit harvest season continues for a period of two months. This resulted in the total damage to fruits harvested at a later date. Golding (1945) and Box (1941) recommended for harvesting all the fruits at one time when 25% of fruits were ripened so that no fruits were left for the moths damage at a later date. Though this created a glut in the market and reduced the price, this method was better than having no fruits. By this method the loss was reduced from 93 to 10.7% in grapes and 98.5% to 23% in grape fruit (Golding, 1945).

9.4. *Bagging of fruits*

Susainathan (1924b) was first to suggest this method. Bagging of fruits was done with dry lotus leaves (Susainathan, 1924b), leaves of palash (*Butea monosperma* Kuntze and *B. frondosa* Wall.) Baghel *et al.*, 1987; Deshpande *et al.*, 1991), *Palmyra* leaves (Margabandhu, 1933), brown paper bags (Baptist, 1944) and polyethylene bags (Fujimura, 1972). Insect proof netting reduced fruit damage from 38.3 to 9.4% on plum, from 53 to 2.5% on peach and from 29 to 10% on grapevine whereas polyethylene bags protected the fruits from fruit piercing moths but caused severe rotting and delayed ripening. Paper bags were less effective and permitted 17.5% damage (Yoon and Kim, 1977). Bagging of fruits was cumbersone, costly, labour intensive but very effective (Fujimura, 1972). Some innovative farmers at Bijapur (Karnataka) covered their entire orchard with nylon net having one centimeter hole to create physical barrier to the moth which was reported to be economical.

9.5. *Removal of larval host plants*

Susainathan (1924a) was the first to suggest destruction of larval host plants to reduce moth population. According to him this should be done at least two months before the actual damage is done by the adults tol fruits i.e. June-July. Mass destruction of larval host plants was done on village community basis for better results. All the uprooted host plant/vines should be burnt properly as many of the Menispermaceae root easily if left unburnt. This method although did not reduce 100% damage by moths, the fruits were relativey safe. Removal of host plants was also suggested by Margabandhu (1933), Cherian (1942), Rakshpal (1945), Bajpai (1955), Bindra (1957; 1969), Yadava (1969) and Atwal (1963) for reducing damage by fruit piercing moth. Chaturvedi (1950) recorded saving of 75 per cent of the citrus crop through this method. However cleaning of all known wild creepers (Nair, 1975; Yadava, 1969) in and around orchards upto a half a mile radius is not effective, because the moths were strong fliers and could fly long distance in search of food (Lal, 1949, 1953).

9.6. *Smoking of orchard*

The method obscure or drown the odour of the mature fruit with smoke after dusk, so that the moths fail to detect fruits and do not enter the orchard (Baptist, 1944). All the fallen and rotten fruits were first collected and burried deep before actual smoking. Thick, copious smoke was produced by burning green leaves over oil sprinkled dry coconut shells or dry grass. Smoking was done at wind entering edge of the orchard at least half an hour before dusk and continued for two or three hours after dusk. Smoking the orchard could prevent moths entry into the orchard only on the night of smoking. Hence was a recurring job. Gupta (1955), Pruthi (1969) and Atwal (1976) also suggested this method.

9.7. *Trap crops*

Cherian Sundaram (1936) observed no damage to orange fruits when ripened tomato was available in the fruit orchard. The moths attacked oranges immediately after the removal of tomato crop. They suggested that tomato could act as a trap crop to attract the moths, which can be killed. Rakshpal (1945) suggested hanging of ripe banana fruits in orange orchard to reduce moths damage on oranges as moths preferred banana over orange.

9.8. *Spraying chemical deterrents*

Susainathan (1924b) suggested spraying of crude oil emulsion at the rate of 450 ml oil in 40 l of water on the ripening fruits. This prevented moth visit to orchard for 3-4 day. Cherian and Sundaram (1936), Gupta (1955), Bindra (1957) and Atwal (1963) also recommended this.

Spraying fruits with a strong solution of tobacco decoction to which resin had ben added at 450 ml per 20 l of water also kept moths away for 2-3 days (Susainathan, 1924b). Spraying with fish oil soap at 450 ml in 40 l of water did not deter the moths (Susainathan, 1924b). Bosch (1971) found that no moths visited the apple trees whose branches were suspended with cotton wool soaked in citronella oil on the previous day as compared with up to 8 adults of *E. emarginata*, *E. materna*, *E. fullonia*, *C. latona*, *S. chlorea* and other species of untreated trees in Rhodesia. According to Fijimura (1972) use of chlorinated fumigants, the mammal repellent WAM, and many commercial insecticides and repellents gave no benefit and did not prevent damage by fruit piercing moths on apple.

9.9. *Light raps*

When light traps were tested the moths were not caught, but it was noticed that the fruits near the light trap suffered less damage than those located away from it. This gave an indication that the moths did not like light. Nomura *et al.* (1965) were the first to test the effect of light in deterring the moths and to their surprise 50% damage was reduced when lights were provided in the orchard. Swart *et al.* (1975) reviewed the control of *S. partita* by orchard illumination in South Africa. Myburgh *et al.* (1973) obtained 50% reduction in fruit damage by providing two side illumination. Whitehead and Rust (1971) observed that illuminating the peach, plum and pear orchards with paraffin pressure lamps, mercury vapour lamps (160w) or yellow incandescent lamps (100w) reduced the activity of *S. partita* by 50-90%. One side illumination reduced moth number by 50% and two sides illumination by 75%. Whtehead and Rust (1972) obtained a reduction of 43% and 78% moth number by one side and two sides tree illumination (paraffin pressure lamps) in south Africa respectively. In Japan, Hattori (1969) found that blue fluorescent lamp was found more effective for the control of *C. excavata* in orange groove than the orange lamp used in peach orchard for the control of *A. tyrannus amurensis*. The migration index of pigment of the compound eye increased directly with intensity and period of illumination depressing moth activity in *E. emarginata* F. (Sakanoshita and Oga, 1972). In Rhodesia, green yellow lights which can provide light intensity exceeding 0.2 lumen repelled *S. partitus*, *Calpe* spp. *Eudocima* spp. in grape garden and resulted only in 1.5% damage compared to over 50% damage of grapes about 75 m away from lamps (Bosch, 1971). According to Yoon and Kim (1977) light traps with ordinary incandescent bulbs were found to attract more moths than traps those with blue yellow light bulbs. Honiball *et al.* (1975) provided notes on the use, installation cost and effectiveness of electric mercury vapour lamps, ordinary electric lamps and paraffin pressure lamps in several peach orchards for the control of fruit piercing moth, *S. partita* in S. Africa.

9.10. *Baiting of the moths*

Susainathan (1924b) recommended baiting of the adult moths by poisoned fruit pieces. Mango fruit pieces were dipped in sodium arsenate or Paris green for an hour and were hung on to pomegranate trees along with un-poisoned pieces. The moths carefully avoided the poison-baits but swarmed on the un-poisoned ones. The reduction of dosage did not had any positive impact. Brushing of plain jaggery on tree trunk was not effective (Susainathan, 1924b). Cherian and Sundaram (1936) suggested the use of plantains (banana) impregnated with a sugar solution of sodium arsenate as bait and were hung along with ripe tomato. Golding (1945) obtained satisfactory control of *Achaea* sp.; *S. chlorea* by exposing moths to poisoned mango slices. Sliced mangoes were soaked for one hour in 1.25% sodium arsenate solution and were hung by twine. Baptist (1944) mixed 3.4 l water, 226 g crude sugar, 1.14 l fruit pulp and 30g lead arsenate and 250 ml of the mixture was kept in wide mouthed bottle. Such 40 traps were provided for one hectare. The solution was changed once I seven days. This method ensured good moth catch. Bajpai (1955) used molasses and vinegar instead of crude sugar and fruit pulp whereas Atwal (1963) used jaggery instead of crude sugar in the above mixture. The number of *E. fullonia*, *E. materna* and *A. janata* killed by poison bait from July to September were 211, 72 and 119, respectively at Nagpur (Bajpai, 1955). Gunn (1932) developed his own baiting technique in south Africa against species of *Achaea* and *Eudocima*. His formula included mixing of 1.8g sodium arsenate and 80 g of demerara sugar in 1,200 ml of water. This formula became famous and known as south African formula. Martinez and Godoy (1981) baited traps (McPhail) with 1, 2.5 and 5% molasses and obtained significant positive correlation between the concentration of molasses and the number of fruit piercing moths caught in Venezuela. Ohmasa *et al.* (1991) isolated sex pheromone from the abdomen tips of female *E. excavata*, which may find use as male attractant of this species in Japan. Out of twelve attractants, pomegranate fruits dipped in jiggery, mango essence and molasses had significantly higher feeding holes by *E. materna* (Jayanthi *et al.*, 2010).

9.11. *Chemical control*

Atwal (1963) recommended spraying fruits with 0.02% endrin whereas Sandhu *et al.* (1980) recommended dusting orange fruits with 2% methyl parathion, which reduced the damage by 50%. Bindra (1957) recommended spraying fruits with 0.25% DDT suspension. Out of several insecticides tested, Deoclean (a Korean product of unspecified composition) resulted in 2% damage, naphthalene (3.6% damage) and thiometon (5.9% damage) whereas demeton resulted in 9.8% damage and a bait spray containing lead arsenate and an attractant named Takju resulted in 10.1% damage and cartap (padan) 14.2% damage (Yoon and Kim, 1977). According to Sandhu *et al.* (1980) a poison bait containing malathion was only partially effective against *E. jullonia* and *E. materna*, while dusting the fruits with 2% methyl parathion reduced the fruit drop by 50%. Mohite *et al.* (1995) found that fenvalerate, cypermethrin, methyl parathion, endosulfan and carbaryl were 238.8, 148.3, 17.9, 8.63 and 2.27 times as toxic as HCH to the 3rd instar larvae of *E. materna*. According to Baghel *et al.* (1987) the descending order of effectiveness of different treatments was covering fruits by *B. frondosa* > covering fruits by paper > poison bait > covering fruits by *Tectona grandis* L. leaves > spraying sevimol 40L at 0.2% > spraying DDT (50WP) at 0.2% > control and the number of marketable orange fruits per tree in above treatments were 146.9, 127.7, 103, 54.3, 33.1, 24.7 and 6.6, respectively.

10. CONCLUSION

The literature on fruit piercing moths points out that the fruit piercing moths belonging to the genera *Eudocima* are distributed throughout India. Pomegranate, orange and guava fruits maturing during Sepember to November suffer maximum damage from the fruit piercing moths. Removal of larval host plants though recommended by the earlier workers, is not practicable as these wild hosts are located in inaccessible places and these hosts find lot of medicinal value. Spraying insecticides on fruits contaminates them and make them unfit for human consumption and also does not kill the moths. Baiting the adult moths, smoking orchards gave partial and temporary control. Providing bright light source in the orchard significantly reduced moths damage on fruits, but economically not viable. Bagging of fruits significantly reduced fruit damage, but deterred the quality of fruits and enhanced fruit rot. Inspite of higher egg and larval parasitisation, the moths still attain damageable populations as they are strong fliers.

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