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Biological suppression of major mealybug species on horticultural crops in India

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ABSTRACT

Mealybugs, known to be 'hard to kill pests', live in protected areas and most stages in their life cycle are covered in a waxy coating. Several insecticides are found ineffective against mealybugs. Fortunately, mealybugs - being sessile insects - are more amenable to biological control. The exotic parasitoid, *Leptomastix dactylopi*i How., was found to be highly effective in suppressing citrus mealybug, *Planococcus citri* (Risso.) permanantly on citrus, sapota, guava, pomegranate and coffee. This is one of the recent successes in classical biological control attempts in India. However, the Australian ladybird beetle, *Cryptolaemus montrouzieri* Muls., often provides spectacular control of heavy infestation of *P. citri* on acid lime, lemon, sweet orange, pummelo, *Crossandra* and custard apple. Though *Anagyrus dactylopii* (How.), is a potential parasitoid of pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green), on grapes, releases of *C. montrouzieri* only help in suppression of the pink hibiscus mealybug on grapes, ber, guava, sapota, custard apple, citrus and hibiscus. The encyrtid parasitoid, *Tetracnemoidea indica* (Ayyar), was able to check the oriental mealybug, *Planococcus lilacinus* (Ckll.) on acid lime and pomegranate. The predators, *C. montrouzieri* and *Spalgis epeus* Westwood, also play a major role in suppression of *P. lilacinus* on guava, ber, sapota and chow-chow. The local parasitoid, *A. dactylopii* was seen to play a major role in suppression of spherical mealybug, *Nipaecoccus viridis* (Maskell) on citrus and jackfruit. Nevertheless, releases of *C. montrouzieri* are found highly effective in controlling *N. viridis* on acid lime and pummelo. Similarly release of *C. montrouzieri* is found to be highly effective in controlling striped mealybug, *Ferrisia virgata* (Ckll.), on guava, tuberose and *Acalypha* in 30-40 days of release. A local parasitoid, *Aenasius advena* Comp., also plays a major role in suppression of *F. virgata* on guava, mango, guava, hibiscus, fig, citrus, etc. Release of the coccinellid predator, *C. montrouzieri*, was found very effective in controlling the mango coccid, *Rastrococcus iceryoides* (Green) on mango and also on the medicinal plant *Decalepis hamiltonii*. The encyrtid, *Praleurocerus viridis* (Agarwal), was found very effective in reducing populations of *R. iceryoides* on guava. *Spalgis epeus* was found to be the predominant predator of the papaya mealybug, *Paracoccus marginatus* Williams and de Granara Willink, but releases of the exotic parasitoid, *Acerophagus papayae* (Noyes & Schauff), only provide excellent control of *P. marginatus* within 3-4 months of release. The second successful classical biological control attempt on mealybugs in India. The brinjal mealybug, *Coccidohystrix insolita* (Green), is known to attack brinjal, *Coleus*, *Hibiscus*, etc. *Cryptolaemus montrouzieri* effectively controlled mealybugs on these three crops in 30-40 days of release. *Verticillium lecanii* Zimm. (Phule bugicide @ 2g/L) is found to be effective in killing the mealybug. Other fungal pathogens, viz., *Beauveria bassiana* (Bals.) Vuill and *Metarhizium anisopliae* (Metch.), are also seen to infect mealybugs in rainy season under humid conditions.

Key words: Mealybug, biocontrol, classical biocontrol, parasitoid, predator

INTRODUCTION

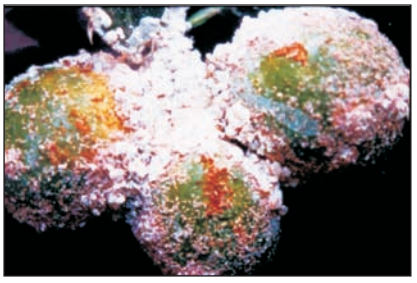
Mealybugs (Pseudococcidie: Homoptera) are highly polyphagous and inflict direct damage to crops by sucking their sap from trunk, cordons, buds, spurs, aerial roots, leaves, shoots, nodes, flower panicles, fruits and roots. Mealybugs have become very serious pests on various crops due to elimination of natural biocontrol agents or due to the pest developing resistance to insecticides due to indiscriminate and frequent application. Mealybugs are generally called 'hard to kill pests'. Perhaps the most important factor is their habitat. Mealybugs live in protected areas such as cracks and crevices of the bark, at the base of leaf petioles, on the underside of leaves and inside the fruit bunch, and most of the stages of this insect are covered with a waxy coating. On several occasions, insecticides do not reach

the target-pest nor are these very effective against mealybug. Luckily, mealybugs (being sessile insects) are more amenable to biological control in horticultural crop ecosystems. Biological suppression of eight major mealybug species attacking various horticultural crops is discussed hereunder.

1. CITRUS MEALYBUG [*Planococcus citri* (Risso.), (*Pseudococcus citri*)]

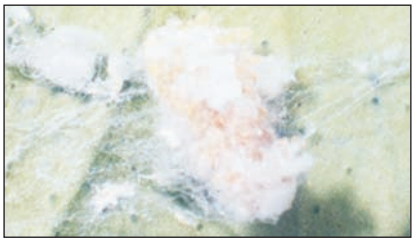
Adult female mealybug has a yellow body partly visible through the dorsal median stripe, and lays about 300 amber coloured eggs. This is a major pest of citrus, grape, pomegranate, ber, custard apple, hibiscus, etc. This mealybug is probably the most cosmopolitan and generally destructive species of the family. There is little valid evidence suggestive of its origin but, by elimination, it is speculated that it may be endemic to China. The host list of *P. citri* is endless as it attacks any flowering crop.

Eggs are laid in groups covered by ovisac wax threads and hatch in 5-8 days. Male citrus mealybugs have four nymphal stages called instars. The first nymphal stage lasts for 6-8 days; the second, 5-8 days; the third 2.5 days and the fourth, 3 days. Approximately four days into the second instar, a black tinge develops around the insect body. Two days later, the nymph starts spinning a cocoon around itself. This cocoon is continuously spun, increasing in density until the winged, adult mealybug is ready to emerge two molts later. Female mealybugs have only three nymphal stages. The first nymphal stage lasts for 6-8days; the second, 5-9 days and the third, 6-9 days. Females lay 200 to 400 eggs, averaging 300 eggs, in a life-time. Life cycle is completed in 30-40 days.



***P. citri* damage**

Adult female



***P. citri* eggs**

Planococcus citri is mobile in the crawler stage, and colonizes in safe sites on trees, under twigs or at the bases of fruit (where navels are deformed), inside big-group fruits, between thick leaves or under leaves on thick twigs. Mealybugs invade tree-surfaces, extract plant sap and excrete honey-dew that provides a medium for growth of the sooty mould. Sooty mould and white wax grow on plants thus reducing photosynthesis, deforming fruits and thereby lowering their price. Insects also release toxins and cause drop of fruits and leaves and result in dried twigs. Nymphs and adult-females extract plant sap and this stops plant growth; leaves become yellow and drop off.

Citrus (sweet orange, acid lime, lemon, pummelo)

The mealybug is known to cause 38% to 65% damage on various citrus species in India. *Planococcus citri* was noticed to be attacked by more than 20 natural enemies in citrus orchards. *Anagyrus* sp., *Blepyrus insularis* (Cam.), *Diversinervus* sp., *Tetrastichus* sp., *Microterys* sp., *Cryptochaetum* sp., *Scymnus coccivora* (Ayyar), *Pullus pallidiocollis* Mst., *Nephus* sp., *Chrysopa* sp., *Micraspas cardoni* (Wse.), *Pseudaspidimerus uttami* Kap., *Cryptolaemus montrouzieri* Muls. and *Spalgis epeus* Westwood were recorded in Kodagu (Anon., 1980). In Assam, *C. montrouzieri* and *Entomophthora fumosa* Speare1922 were observed on *P. citri* (Chowdhury and Majid, 1954). *Coccidoxenoides perminutus* [*C. peregrinus* (Timberlake), Krishnamoorthy and Mani, 1989b], *Mallada boninensis* (Okamoto), *Chrysoperla lacciperda* Kimmins, *Anisochrysa basalis* Walker and *Chrysoperla carnea* (Seph.) (Krishnamoorthy and Mani, 1989a) were found to attack *P. citri* in citrus orchards.

The encyrtid parasitoid, *C. perminutus*, played a dominant role in suppression of *P. citri* on acid lime and lemon (Mani, 1994b). The parasitoid can be multiplied on 5-10 day old laboratory-bred *P. citri*. Several plant products and deltamethrin were found to be safe to *C. perminutus* (Mani and Krishnamoorthy, 2002a).

The exotic parasitoid, *Leptomastix dactylopii* How., was imported from West Indies into India during 1983 for trials against *P. citri* (Nagarkatti *et al*, 1992). It was multiplied on 15-20 day old *P. citri* and *P. lilacinus* reared on pumpkin fruits (Mani, 1995a). *Leptomastix. dactylopii* breeds very well on third instar female mealybug nymphs and on young females. Ripe pumpkins with 15-20 days old mealybugs are held in cages. One to two days old, adult-mealybug infested pumpkins are used for oviposition. The life cycle of the parasitoid is completed in about 15 days. Males develop

slightly faster than females. Only one parasitoid emerges per host. Parasitoids are then collected from the cage using an aspirator and fed on 50% honey solution in clean glass vials. Females are honey-yellow to brownish-yellow in colour with dark brown to blackish markings. They have a small ovipositor. Males are smaller than females and have extensive blackish markings (Krishnamoorthy and Singh, 1987).

C. montrouzieri larva

C. perminutus adult

L. dactylopii adult

Inoculative releases of *L. dactylopii* in citrus orchards gave excellent control of *P. citri*, causing up to 100% parasitism within 3 months of release in Karnataka (Manjunath, 1985b; Krishnamoorthy and Singh, 1987; Nagarkatti *et al*, 1992). *Leptomastix dactylopii*, along with *C. perminutus*, reduced its population from 1342 in February to 15 in May, i.e., in 90 days of the parasitoid activity (Mani, 1994b). Dichlorvos, dicofol, several fungicides and plant products are safe to *L. dactylopii* (Mani *et al*, 1993). *Leptomastix dacylopii* gave good control of *P. citri* on citrus in California, Spain and Italy.

The Australian ladybird beetle, *Cryptolaemus montrouzieri* Mulsant, was first introduced from Australia into India in the year 1898. It was widely used in controlling citrus mealybug. A simple method involving multiplication of the mealybug and *C. montrouzieri* on pumpkin fruit was standardized in India (Chacko *et al*, 1978). Ten beetles to be released per Coorg mandarin tree was recommended in Karnataka. By fifth week of release of the predator, mealybug population was reduced to negligible level. However, release of the predator needs to be repeated whenever the mealybug reappears (Singh, 1978). Threshold temperature for the activity of *C. montrouzieri* is about 20°C. Mani and Krishnamoorthy (2007c) also reported that *C. montrouzieri*, when released @ 2000 adults /ac. against *P. citri*, resulted in decline in mealybug population from 126.64/plant in August, to 0.40/plant in November. Mean 99.68% reduction in mealybug population on acid lime was achieved using the predator within three months of release. *Cryptolaemus montrouzieri* gave partial to complete control of *P. citri* on citrus in Spain, Turkey, Eastern Australia and South Africa.

Planococcus citri was observed on pummelo (*Citrus grandis* Swingle). With release of *C. montrouzieri* @30 larvae/plant on pummelo, the population of *P. citri* declined from 313.84/plant in August, to 2.63/plant in October (Mani and Krishnamoorthy, 2008a).

Guava

Naturally-occurring predators, *S. epeus C. lacciperda* and *C. montrouzieri*, were able to suppress the numbers from 1420 mealybugs per plant in August to 20.4/plant in September, i.e., at 45 days from withdrawal of insecticides (Mani and Krishnamoorthy, 1990b). In another orchard, releases of the exotic parasitoid, *L. dactylopii*, were found to be highly effective against *P. citri*, reducing mealybug population from 1084/plant in May, to 4.36 in August. The local platygasterids *Allotropa citri* Mues. and *C. perminutus* also played an important role in suppression of *P. citri* on guava (Mani, 1994a).

Grape

Planococcus citri was found to cause severe damage in many vineyards resulting in up to 60% loss of fruit bunches in Karnataka and Maharashtra (Mani and Kulkarni, 2007). *Cryptolaemus montrouzieri* was found far superior to chemical control in suppression of mealybug on grapevine. A mean of 0.4% bunch damage was recorded in the bio-control plot compared to 38.4% bunch damage in the plot that followed farmers' practices (Mani and Krishnamoorthy,

***P . citri* on grapes**

P. citri* on *Hibiscus

2008b). Efficacy of *C. montrouzieri* in controlling *P. citri* has been reported in vineyards at Black Sea Coast area and in Turkey.

Inoculative releases of *L. dactylopii* gave good control of *P. citri* on grape in Uzbekistan. Recovery of *L. dacylopii* was made from *P. citri* infesting table-grapes and wine-grapes in Maharashtra and Karnataka.

Ber

Two parasitoids, *C. perminutus* and *Allotropa* sp., and the predator *C. montrouzieri*, were recorded on *P. citri* infesting ber. These three natural-enemies, along with *L. dactylopii*, were able to check the mealybug very effectively from causing further damage/spread (Mani, 1993).

Sapota

The local parasitoid, *C. perminutus*, was able to reduce mealybug population from 156/shoot in January to 0.46/shoot in February, i.e., within 40 days of parasitoid activity. In another orchard, *L. dactylopii* was able to suppress the population from 112 in March to 2.16 in April, i.e., within 30 days of parasitoid activity on *P. citri* (Mani and Krishnamoorthy, 1997a).

Pomegranate

Mealybug is also a major pest of pomegranate (Mani and Krishnamoorthy, 1989e). *Leptomastix dactylopii* and *C. perminutus* were found to be effective in suppressing the mealybug population from 180.3/plant in June to 4.5/plant in August within 30 days of parasitoid activity. *Cacoxenus perspicax* (Knab) was also recorded on *P. citri* (Mani and Krishnamoorthy, 2000).

Custard apple

Planococcus citri is known to occur on custard apple. The predators, chiefly *S. epeus* and *C. montrouzieri*, played an important role in clearing mealybug populations (Mani and Krishnamoorthy, 1989a; Mani and Krishnamoorthy, 2007d). *Leptomastix dactylopii* was recovered in large numbers from *P. citri* infesting custard apple, indicating a good scope for utilizing the parasitoid in custard apple ecosystem (Mani *et a*l, 2007). *Leptomastix dactylopii* was also found to be effective against *P. citri* on custard apple in Queensland, Australia.

***P. citri* on pummelo**

***P. citri* on custard apple**

Crossandra

Releases of *C. montrouzieri* reduced mealybug population from 99.80/plant in October to 1.52/plant in February, i.e., within 90 days of release. *Brumoides suturalis* F. and *Cheilomenes sexmaculata* (F.) were also observed as feeding on *P. citri* although in negligible numbers (Mani and Krishnamoorthy, 2007b).

Coffee

Releases of *C. montrouzieri* were able to clear *P.citri* on coffee in Wynad, Kerala and Coorg, Karnataka (Chacko *et al*, 1978; Singh, 1978). The exotic *L. dactylopii* got established and gave excellent control of *P. citri* on coffee (Manjunath, 1985b; Nagarkatti *et al*, 1993; Reddy and Bhat, 1993).

Hibiscus

Planococcus citri is found to cause very severe damage to *H. rosasinensis*. Releases of *C. montrouzieri* were able to clear *P. citri* on hibiscus.

2. PINK HIBISCUS MEALYBUG [*Maconellicoccus* (*Phenacoccus*) *hirsutus* (Green)]

Adult females are pink and sparsely covered in white wax. Eggs are orange in colour, laid in a loose, cottony, terminal ovisac. It is known to attack grapes, guava, hibiscus, ber, okra, acid lime, phalsa, sapota, pomegranate, custard apple, etc. Females die shortly after depositing eggs. Freshly-laid eggs are orange, and turn pink before hatching. Eggs are found in egg sacs. First instar nymphs (crawlers) of the pink hibiscus mealybug disperse by walking and on the wind. Male mealybugs have four nymphal instar stages while the females have three. Nymphs too can walk considerable distances to find suitable host plants. Their life cycle take about 25-30 days. The reddish-brown adult males are smaller than females and have one pair of wings. Males have two long waxy 'tails'. The pink hibiscus mealybug has a high rate of reproduction (females can deposit upto 600 eggs) and produces upto 15 generations per year. The mealybug feeds on soft tissues of many plant species and injects a toxic saliva that causes curling of leaves. The entire plant may be stunted while shoot tips develop a bushy appearance. Buds may not flower and stems may get twisted. Fruits also may be deformed. The mealybug excretes honeydew

which encourages development of a black sooty-mold. Very high mealybug populations can kill plants. The mealybug is found on stems, leaves, buds, fruits and roots of many plants. On hibiscus, the mealybug usually infests young twigs, causing deformed terminal growth (due to shortening of internodes), deformed leaves and thickened twigs. In grapevines, the mealybug feeds on sprouts that develop after pruning; heavily infested bunches shrivel and drop. Curled leaves mimic viral damage; however, this pest is not known to vector any disease.

Grapevine

Mealybug has become a major pest of grapevine, particularly in peninsular India (Manjunath, 1985a; Mani and Thontadarya, 1987c). Six parasitoids, namely, *Anagyrus dactylopii* (How.), *Allotropa* sp. nr. *japonica* Ashm. *Gyranusoidea mirzai* (Agarwal), *Alamella flava* Agarwal, *Leptopilinia* sp. and *Chartocerus* sp. nr. *walkeri* Hayat, and seven predators, viz., *Scymnus* sp., *S. coccivora, C. montrouzieri Chrysopa* sp., *Spalgis epeus*, *Cacoxenus perspicax* (Knab) and *Triommata coccidivora* (Felt) were recorded. Among these, *A. dactylopii* and *S. coccivora* were seen to be of considerable importance. *Anagyrus dactylopii* caused up to 70% parasitism in nature (Mani *et al*, 1987). Male and female *Anagyrus dactylopii* completed their development in 14.75 and 22 days, respectively, and a progeny of 39.3 was produced (Mani and Thontadarya, 1988d). Third instar nymph and adult female of *M. hirsutus* were found suitable for breeding of *A. dactylopii* (Mani

***M. hirsutus* eggs**

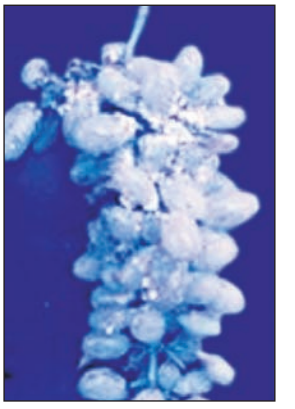
Male mealybug

Female mealybug

and Thontadarya, 1989). A maximum of 182 offspring was produced at 30°C (Mani and Krishnamoorthy, 1992). The parasitoid was found to be least affected by application of dichlorvos, diazinon, phosalone, fish oil rosin soap and commonly used fungicides (Mani and Thontadarya, 1988c). Under field conditions, a positive and significant relationship was found between populations of *A. dactylopii* and *M. hirsutus* (Mani and Thontadarya, 1987b). *Allotropa japonica* bred very well on 15-20 day old *M. hirsutus*. It completed its life cycle in 25.5 days at 25.5°C. Dicofol, copper oxychloride, mancozeb and captofol were less harmful to *A. japonica* (Mani and Krishnamoorthy, 1989c). *Scymnus coccivora* completed its development on *M. hirsutus* in about 20-23 days; adult males and females lived for 60.5 and 68.7 days, respectively. Females produced an average of 46.5 eggs each. A grub of S. *coccivora* consumed 308 eggs or 62 nymphs or 6.55 adult females (Mani and Thontadarya, 1987d). A single larva of *M. boninensis* was found to consume about 240 mealybug nymphs of *M. hirsutus* (Mani and Krishnamoorthy, 1989b).

Shoot damage

Bark damage



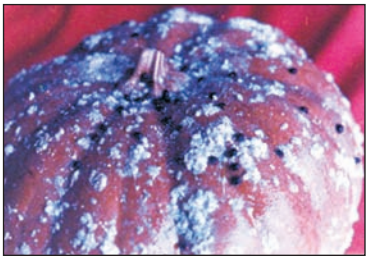
Bunch damage

The coccinellid predator, *C. montrouzieri*, was known to feed on about 1000 eggs or 300-500 mealybug nymphs (Mani and Thontadarya, 1987a). It takes about 30 days to complete its life-cycle. The optimum temperature for development of *C. montrouzieri* maximum was found to be 30°C (Babu, 1986). A simple method of mass culture of *C. montrouzieri* on mealybug infested ripe pumpkin was standardized.

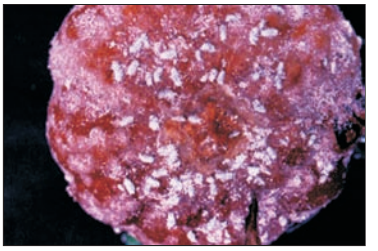
The culture of mealybugs is maintained on ripe pumpkins (*Cucurbita maxima* D.) in a laboratory. Pumpkins with ridges and grooves are selected with a small stalk to enable easy handling. These are cleaned with water to remove dust particles. Systemic fungicides like Bavistin or Benlate @2g/litre of water are swabbed onto the fruits as a prophylactic measure against fungal fruit-rot. Open wounds, if any, are sealed with molten paraffin wax. Ovisacs of the mealybug are then placed on the pumpkin for 48h. Mealybug-infested pumpkin is then transferred to a wooden cage (30 x 30 x 30 cm) with a sliding glass-door on one side and cloth covering on all other sides. In course of time, crawlers that emerge from ovisacs settle on the surface of the pumpkin and develop into fully mature mealybugs. Details of this technique are given by Chacko *et al* (1978) and Singh (1978).

In about 20-25 days after mealybug infestation on the pumpkin, *Cryptolaemus* adults are released into the cage through its sleeve. Adult beetles, besides feeding on

mealybugs, lay eggs singly or in groups near mealybug colonies. Grubs are visible in about a week. Initially, these feed on eggs of the mealybug and on smaller nymphs; later, they feed on all stages of the mealybug. Cannibalism is observed when mealybug population is low. Full grown grubs pupate on the pumpkin, or, anywhere inside the breeding cage. The first beetle emerges in about 30 days from date of exposure of the mealybugs to beetles. Beetles continue to emerge for 5-10 more days. The beetles are collected in glass vials using an aspirator. Each breeding cage yields about 200 beetles. These are fed with honey solution (50%) or honey-agar in the laboratory. In about 10-15 days, when the adult beetles complete their mating and pre-oviposition, these are ready for field-release.



Beetles released for oviposition



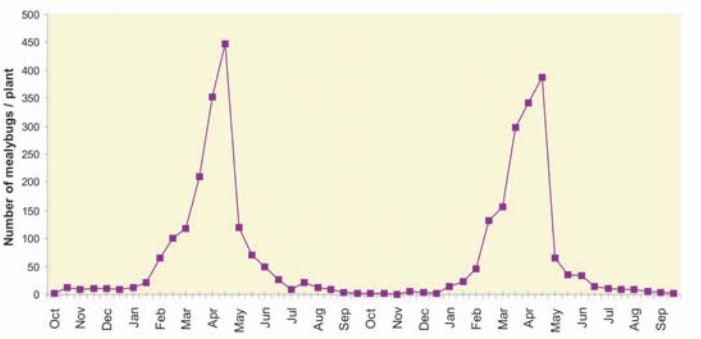
Larvae feeding on mealybugs

***Cryptolaemus* on mealybugs**

Performance of the beetle was evaluated in Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu. A release rate of 2000ac (Ten-day old) adult beetles were recommended for release during the evening time to control grape mealybug. Besides the commonly-used fungicides, dichlorvos, chlorpyriphos and fish oil rosin soap may be used, along with *C. montrouzieri*, in integrated pest management (IPM) programme in vineyards in India (Mani and Thontadarya, 1988a, b; Babu, 1986; Manjunath, 1986). It is advisable to release *C. montrouzieri* preferably in June-August and, if necessary, in mid December-mid January. According to Kamal (1951), complete control of *M. hirsutus* could be achieved in Egypt by introducing *Anagyrus kamali* Moursi from Java. Introduction of *A. kamali* with *C. montrouzieri* resulted in outstanding control of *M. hirsutus* in the Caribbean islands (Kairo *et al*, 2000). Such introductions should also be tested against *M. hirsutus* in India.

Ber

Cryptolaemus montrouzieri is useful for control of *M. hirsutus* on ber. Release of *C. montrouzieri* resulted in reduction in mealybug population from 62.50/plant to 0.85 within 30 days (Mani *et al*, 2007).



Seasonal incidence of grape mealybug

Guava

Local natural-enemy complex was very poor on *M. hirsutus* infesting guava. Releases of *C. montrouzieri* @20/plant were found to be highly satisfactory in suppressing *M. hirsutus* on guava from 1348 in June, to 4.60 in August (Mani and Krishnamoorthy, 2001).

Pomegranate

Mealybug was also recorded as a serious pest for the first time on pomegranate in India (Mani and Krishnamoorthy, 1991b). Releases of the predator, *C. montrouzieri*, were found to be very effective in controlling *M. hirsutus* on pomegranate.

Custard apple

Parasitism did not exceed 5% on mealybugs in custard apple orchards. But, the predators (chiefly *S. epeus* and *C. montrouzieri*) played an important role in clearing mealybug populations (Mani and Krishnamoorthy, 1989a). Releases of *C. montrouzieri* were made @30 larvae/plant twice at 15-day interval. Mealybug population declined from 3507.50/plant in July to 0.00 in September (Mani and Krishnamoorthy, 2007d).

Acid lime

Cryptolaemus montrouzieri @25/plant reduced mealybug population from 39.40/shoot in January to 1.30 in mid-March, i.e., within 50 days of release. *Anagyrus dactylopii* and *T. coccidivora* were recorded in negligible numbers on *M. hirsutus* (Mani and Krishnamoorthy, 1999).

Phalsa

The pink mealybug, *M. hirsutus*, is known to occur on leaves, flowers and fruits. The coccinellid, *C. montrouzieri*, and the lycaenid, *S. epeus*, were known to prey on mealybugs in the field (Mani and Krishnamoorthy, 1996c).

Pink mealybug on pomegranate

Pink mealybug on *ber*

***Cryptolaemus* on pomegranate mealybug**

Hibiscus

Maconellicoccus hirsutus appears in severe form on *Hibiscus rosa-sinensis* L. *Cryptolaemus montrouzieri*, when released @20 grubs/plant, reduced mealybug population from 84.3/plant in March to 0.9/plant in May (Mani and Krishnamoorthy, 2008d).

Sapota

The mealybug, *M. hirsutus*, appeared on sapota in April. Release of *C. montrouzieri* @20/plant resulted in decline of mealybug population from 54.20/plant in April to 1.50/plant on June (Mani and Krishnamoorthy, 2008c).

***Spalgis* on mealybugs**

***Spalgis* larva**

***Spalgis* adult**

***M. hirsutus* on acid lime**

3. ORIENTAL MEALYBUG [*Planococcus lilacinus* (Ckll.)]

Adult females are grayish-pink in color. Females give birth to young ones. It is known to attack cocoa, guava, ber, citrus, black pepper, cashew, pomegranate, guava, coffee, sapota, custard apple, etc. Female insects lay 55-152 eggs in a white, cottony envelop on the stem or on leaf petioles. The eggs hatch within 24 hours. Eggs develop within the female, and females give 'live birth' to the crawler life-stage. The nymphal period of the pest is between 20-25 days. Younger females are maroon in colour. Body-color is visible underneath the waxy covering. In the field, adult females of *P. lilacinus* may be easily distinguished from *P. citri* by the far more globose shape of the former. The mealy wax that covers the body appears in thick, almost segmental, clumps. A central, long strip appears on its back and it has 18 lateral, wax filaments. Legs are present and well developed.

Citrus group

The encyrtid parasitoid, *Tetracnemoidea indica*, was able to check mealybug on acid lime. Due to the activity of *T. indica*, mealybug population reduced from 256.0/plant to 4.50/plant in 55 days on acid lime (Mani, 1995b). Five day old mealybug nymphs were found to be suitable for breeding *T. indica* (Mani and Krishnamoorthy, 1995). The parasitoid could be conserved by application of Fenvalerate (0.01%), neem seed kernel extract (5%) and commonly-used fungicides (Mani and Krishnamoorthy, 1996b).

Guava

Spalgis epeus was the predominant predator on guava, and *C. montrouzieri* supplemented suppression of mealybugs in six months. In addition to

Ants tending to mealybugs

Female mealybug

Tetracnemoidea indica

these, *Brumus suturalis* and *S. coccivora* were also seen to feed on *P. lilacinus* in guava orchards (Mani, 1995b).

Sapota

Cryptolaemus montrouzieri was highly effective in checking the population of *P. lilacinus* (Mani, 1995b).

Pomegranate

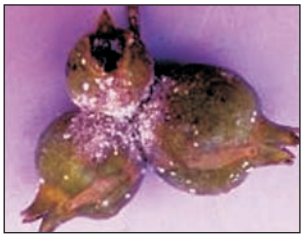
This was a serious pest on pomegranate (Mani and Krishnamoorthy, 1990a). It was predated by *Spalgis epeus, Hyperaspis maindronii* Sic., *Scymnus severini* Weise., *Eublemma* sp., *Leucopis lutecornis* Malloch, and was parasitized by *Anagyrus* sp. (Nair, 1975). *Triommata coccidivora,* S. *epeus, C. montrouzieri, S. coccivora* and *C. perspicax* were reared from *P. lilacinus.* Withdrawal of insecticides in pomegranate resulted in large-scale appearance of both *S. epeus* and *C. montrouzieri.* These predators were responsible for bringing down the mealybug population in four months to negligible numbers (Mani, 1995b). *Tetracnemoidea indica* played a significant role in reducing mealybug population from 180 per plant in June to 4.50 in August, i.e., within 55 days of the parasitoid activity on pomegranate (Mani and Krishnamoorthy, 2000).

Ber

The parasitoid, *Aprostocetus purpureus* (Cam.), and predator, *S. epeus*, were recorded on *P. lilacinus* (Mani, 1995b). A steep decline in the mealybug population from 45.40 to 0.40 was observed within 30days due to predation by *S. epeus* (Mani and Krishnamoorthy, 1996a).

Chow-chow

Fruits of chow-chow were found covered with *Planococcus lilacinus*. Release of *C. montrouzieri* was found to give effective control of *P. lilacinus* on chow-chow (Krishnamoothy and Mani, 1998).



***P. lilacinus* on pomegranate**

***P. lilacinus* on chow chow**

4. SPHERICAL MEALYBUG [*Nipaecoccus viridis* (Maskell)]

It attacks citrus, pomegranate guava, grape, ber, jackfruit, brinjal, etc. Adult females have a purple body, covered by a fluffy ovisac with cottony threads containing purple eggs. It has a body approximately 4mm long x 3mm wide colored black or purple to blue-green, with thick, white or pale-yellow wax. The female produces an ovisac with a wax that is sticky to touch. It lays about 500-800 eggs. Eggs hatch in about 5-10 days into dark-red or purplish nymphs. The nymphs congregate in dense colonies on tender shoots and flower-stalk bases where they acquire a waxy covering, and produce large quantities of honeydew. The sticky, stringly ovisac is well adapted to adhere to feet of birds and, probably, accounts for rapid and widerspread dispersal. Mealybugs reproduce continuously, throughout the year. In high densities, waxy secretions may appear as a continuous layer of wax which obscures individual mealybugs. The wax may turn yellow in older infestations. Specimens do turn black in 70% alcohol.

Citrus group

Anagyrus dactylopii was found parasitizing up to 90% on *Citrus medica* and *C. aurantium* in a field near Aligargh, Uttar Pradesh. The mealybug disappeared within a month of parasiteid activity (Subba Rao *et al*, 1965). Severe infestation of *N. viridis* on citrus was wiped out with liberation of *C. montrouzieri* @10 beetles per tree in Andhra Pradesh (Tirumala Rao and David, 1958). Due to release of *C. montrouzieri*, the population of *N. viridis* declined from 221.3 in March to 1.40/plant in June. The parasitoids, *Anagyrus agraensis*, *A. dactylopii* and *A. mirzai*, also played an important role in suppression of *N. viridis* on acid lime (Mani and Krishnamoorthy, 2002b).

Nipaecoccus viridis is known to attack pummelo (*Citrus grandis* Swingle). *Cryptolaemus montrouzieri* was released @30 larvae/plant in August in a pummelo orchard. The population of *N. viridis* declined from 165.48/plant in August to 0.65/plant in October (Mani and Krishnamoorthy, 2008a).

Mango

Release of *Cryptolaemus* grubs cleared mealybug colonies on mango at Hindupur, Andhra Pradesh (Anon., 1987).

Ber

Eight parasitoids, *Anagyrus agraensis* (Saraswat), *Anagyrus* sp. nr. *almoriensis* (Shaffee *et al*), *A. dactylopii*, *A. mirzai*, *A. flava*, *Gyranusoidea flava* (Shaffee *et al*), *Coccophagus* sp.,

Mealybug on ber

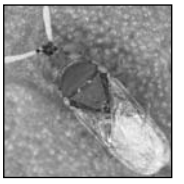
Chartocerus sp., and three predators, *C. perspicax*, *T. coccidivora* and *S. epeus*, were recorded on *N. viridis* infesting ber. Among these, *Anagyrus* spp. and *S. epeus* were seen to be widespread and were frequently collected. Releases of *C. montrouzieri* supplemented local natural-enemies in controlling mealybug on ber (Mani, 1993).

Custard apple

Nipaecoccus viridis is known to occur on custard apple. There was no parasitism on the mealybug in custard

Silken thread from the egg-mass

Female mealybug

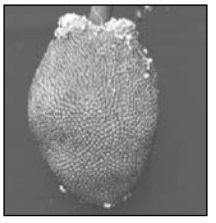


Anagyrus dactylopii

apple orchards. But the predators, chiefly *S. epeus* and *C. montrouzieri*, played an important role in clearing the mealybug population (Mani and Krishnamoorthy, 1989a).

Jackfruit

It is sporadic and severe on jack. The encyrtid *A. dactylopii* and the drosophilid predator *Cacoxenus persipicax* (Knab) effectively reduced the mealybug population from 2.96 to 0.10 within a month (Mani and Krishnamoorthy, 1997b).



Mealybug on jackfruit

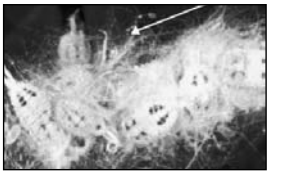
5. STRIPED MEALYBUG [*Ferrisia virgata* (Ckll.)]

It attacks citrus, guava, custard apple, tuberose, acalypha, jackfruit, ixora, *Caesalpinia*, etc. Adult females are grey, with a pair of dorsal stripes on the body and two long tails. The body is covered with long, slender glassy threads. Mealybug eggs hatch immediately after being laid. The entire life cycle takes about 40 days. The female lays 300-400 eggs which hatch in a few hours. Hatchability ranges from 96.2 to 99.1%. and the young nymphs move away quite rapidly. The nymphs are full-grown in about six weeks. The female is distinctive upto 5mm long, with a pair of conspicuous, longitudinal sub-median dark stripes; long glassy wax threads, a pronounced tail about half the length of the body, and a powdery, waxy secretion. The abdomen gently tapers to well-developed anal lobes, each with an apical seta about 280 micrometres long, and a small, elongate, sclerotized area on the ventral surface. The 8-segmented antenna is about 490-560 micrometres long. Legs are well-developed and slender. It feeds on young shoots, berries and leaves. In dry weather, this insect may move down to below the ground and inhabit roots. This mealybug is favoured by dry weather: there are many records referring to heavy attacks following periods of prolonged drought.

Guava

Aenasius advena Comp. and *Blepyrus insularis* (Cam.), *S. coccivora*, *M. boninensis*, *B. suturalis* and *S. epeus*, *C. sexmaculata* were recorded on *F. virgata* (Mani *et al*, 1990; Mani, and Krishnamoorthy, 1989d). *Chrysoperla lacciperda* and *C. carnea* were observed on *F. virgata* in guava orchards (Krishnamoorthy and Mani, 1989a). A single larva of *M. boninensis* was able to prey on about 345 nymphs of *F. virgata* (Mani and

Mealybug on guava



F. virgata

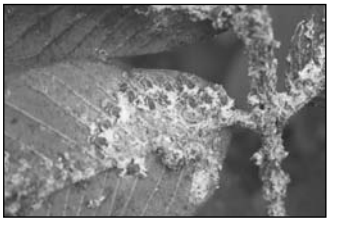
Aenasius advena

Krishnamoorthy, 1990b). *Blepyrus insularis* was reaved on 5-10 old nymphs of *F. virgata* (Mani and Krishnamoorthy, 1991a). The key parasitoid, *A. advena*, could be conserved by application of diazinon, phosalone and dichlorvos (Mani, 1992). *Cryptolaemus montrouzieri* @10 15 adults/tree gave excellent control of *F. virgata*. The population of mealybugs was reduced from 145.3 to 2.8/plant within 40 days of release (Mani *et al*, 1990).

Mango

At times, fruits were found covered with *F. virgata* in Tamil Nadu and Karnataka. Release of *C. montrouzieri* was recommended for suppression of the mealybug.

***Cryptolaemus* clearing mealybugs**



Pupation of *Cryptolaemus* on shoots

Pomegranate

Scymnus coccivora and C. montrouzieri were able to reduce the population of *F. virgata* in Tamil Nadu (Karuppuchamy, 1994).

Custard apple

Ferrisia virgata is known to attack custard apple.

The predators, chiefly *S. epeus* and *C. montrouzieri*, played an important role in clearing mealybug populations (Mani and Krishnamoorthy, 1989a). Releases of Australian ladybird beetle, *C. montrouzieri*, were made @30 larvae/plant twice, at 15-day intervals. The mealybug population declined from 3507.50/plant in July, to 0.00 in September (Mani and Krishnamoorthy, 2007d).

Meaybug on custard apple

***Crypyolaemus* clearing mealybugs**

Pummelo

Ferrisia virgata is known to attack pummelo (*Citrus grandis* Swingle). Release of *C. montrouzieri* @30 larvae/plant reduced mealybug population from 248.85/plant in August, to 7.75/plant in October (Mani and Krishnamoorthy, 2008a).

Tuberose

Following the release of *C. montrouzieri*, mealybug population declined from 190.26/ plant in July to negligible numbers in September (Mani and Krishnamoorthy, 2007a).

***Ferrisia* on tuberose**

Acalypha

Release of *C. montrouzieri* resulted in reduced mealybug population from 247.82 in December to 11.85 in February. The plants were completely cleared of mealybugs within 40 days of release (Mani, 2008).

Ferrisia* on *Acalypha

Poinsettia

The plants were completely cleared of mealybugs with release of *C. montrouzieri*.

Ferrisia* on *Poinsettia

6. MANGO MEALYBUG [*Rastrococcus iceryoides* (Green)]

It attacks mango, sapota, guava, *Hibiscus*, fig, citrus, etc. Adult females are oval, yellowish-cream in colour and covered in lateral waxy processes. Nymphs are brown, but turn white later. Adult females are oviparous and eggs are honey-yellow. Females lay eggs numbering 450-585. Pre-oviposition and oviposition periods are 7-8.5 and 5.7-7.3 days, respectively, and the egg stage lasts for an average of 6.6 days. Female and male nymphs moult 3 and 4 times, respectively. Post-embryonic development lasts for 20.4-31.0 days in females and 18.0-26.0 days in the males. The insects are abundant during April-June. Overwintering takes place in adult females, and the coccid is active from February to October during which period 6-9 generation cycles are completed.

Rastrococcus iceryoides sucks sap from leaves, tender terminal shoots, inflorescences and fruits. The pest also produces honeydew on which sooty mold develops. On heavily infested mango plants, reduced fruit-set was seen and young fruits shed.

Guava

The encyrtid, *Praleurocerus viridis* Agarwal and *S. coccivora*, were found very effective in reducing the population from127 mealybugs/plant to negligible numbers, within a month, due to the activity of natural enemies (Mani and Krishnamoorthy, 1998).

Mango

Several natural enemies were recorded on *R. iceryoides* in UP and Karnataka. *Anagyrus pseudococci* Girault, *Gyranusoidea* sp., *Praleurocerus viridis*, *Allotropa* sp., *Microterys flavus* (Howard), *Dinocarsis* sp., *Promuscidea unfasciaventris* Girault, *Metastenus concinnus* Walker, *Tetrastichus* sp., *Cybocephalus* sp., *S. coccivora*, *Monomorium floricola* (Jerdon), *Coccophagus* sp. and *Proctolaelap*s sp. were recorded from Malihabad. But, *P. unfasciativentris* and *A. pseudococci* were most important (Tandon and Lal, 1978). According to Narasimham and Chacko (1988), the parasitoids *Anagyrus* sp. nr. *dactylopii* (How.), *Anagyrus* sp., *Coccophagus* sp. *C. sexvittatus* Hayat (pseudococci

Female mealybug

***Rastrococcus* egg-mass**

group), *Allotropa* sp, and predators *Leucopis* sp., *C. perspicax*, *S. epeus*. Predatory ants *Camponotus* sp., *Myrmicaria brunnea* Saunders and *Oecophylla smaragdina* (F.) were also known to attack *R. iceroides*. Upto 42% parasitism was observed in nature (Tandon and Lal, 1978). The parasitoid, *Anagyrus pseudococci* Gir., and the predator, *Cacoxenus perspicax* (Knab.), were important in nature.

An individual *C. montrouzieri* consumed about 350 mealybug eggs or 500 nymphs during its larval stage of development. The coccinellid predator, *C. montrouzieri*, was found very effective in controlling *R. iceryoides*. Reduction in fruit damage from 40-50% to 0.00 was observed in different mango varieties (Mani *et al*, 1995). Substantial control of *R. iceryoides* was obtained in the Celebes with *C. montrouzieri*.

Decalepis hamiltonii

This is an important medicinal plant. Release of *C. montrouzieri* reduced mealybug population from 48.75/plant in January to 1.26/plant in March.

7. BRINJAL MEALYBUG

[*Coccidohystrix insolita* (Green)

(=*Phenacoccus insolitus; Centrococcus insolitus*)]

It attacks brinjal, tomato, capsicum, croton, stored potato, etc. Adult females are light yellowish-green in color, with many long, glassy filaments. These are small, oval, soft-bodied insects measuring 3-4mm in length, covered in white, mealy wax. They have reproductive potential of laying 200-300 eggs, majority of which are females, resulting in explosive outbreaks. Eggs incubate beneath their body cavity for about 4-5 days. There are three nymphal instars which last for 22-25 days. Their total lifespan under normal conditions from egg to adult under is 26-30 days.

Both nymphs and adults suck sap from leaves and tender shoots. Heavy clustering of mealy bugs is usually seen under the surface of leaves as a thick mat, with a waxy secretion. They also excrete copious amounts of honeydew on which the sooty mould fungus grows. Affected plants appear sick and black, resulting in reduced fruiting capacity. It is also a notorious pest of stored potato tubers. Stored tubers are found to be infested during July-October, when bud-sprout occurs.

***Rastrococcus* on mango**

Rastrococcus* on *Decalepis hamiltonii

Brinjal

Anisochrysa bonensis (Okaomota), *B. sutarilis*, *Hyperspis maindroni* Sicard *Leptomastix nigrocoxalis* Compere, *L.lyciae* Noyes and Hayat were known to attack *C. insolita.* A single larva of *C. montrouzieri* is known to consume about 1100 nymphs. The mealybug, *C. insolita*, attacking brinjal crop was controlled effectively by the predator *C. montrouzieri* within 20 days of release (Krishnamoorthy and Mani, 1996).

Hibiscus

Mealybug population declined from 145.6/plant in February to 0.6/plant in April 2003. There was 99.6% reduction in the population of *C. insolitus* within 60 days of appearance of the lycaenid predator, *S. epeus* (Mani and Krishnamoorthy, 2008d).

Coleus

Release of *C. montrouzieri* reduced mealybug population within 40 days.

8. PAPAYA MEALYBUG (*Paracoccus marginatus* Williams and Granara de Willink.)

Adult females are light yellowish-white. Eggs are greenish-yellow. Body content: when crushed on white paper, the body is yellow; when preserved in alcohol, it turns black. It attacks papaya, brinjal, tapioca, okra, *Acalypha*, *Anona*, etc. It is native to Mexico, having been first observed there in 1955 and, later, found to spread to the West Indies, Hawaii, Florida, Guam, Palau, Pouerto Rico and Sri Lanka. In India, it was first reported in Tamil Nadu in July 2008 and it spread fast to Andhra Pradesh, Karnataka, Maharashtra and Kerala. It might have been introduced into India from Sri Lanka (Suresh *et al*, 2010).

The adult female deposits about 500 eggs into her ovisac over a period of one to two weeks. Eggs hatch in ten days later and the crawlers, which are mobile, disperse. There are four instar stages in the female and five in the male. The fifth instar male is a pupa in which the nymph undergoes metamorphosis into a winged adult. Mean development time from egg to adult male and female is 28-30 days and 24-26 days, respectively. Longevity of adult

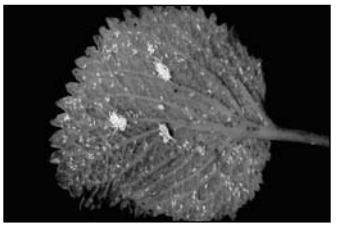
Mealybugs on brinjal fruit

Mealybugs on brinjal leaf

male and female was 2.31 and 21.15 days, respectively. Overall, 53-59% of the adult population was female. Pre-reproductive and reproductive period of the female was 6.29±0.02 and 11.16±0.02 days, respectively.

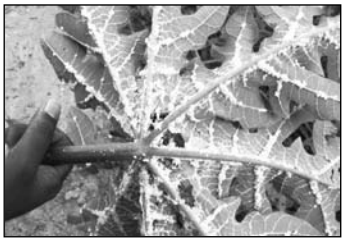
Acerophagus papayae (Noyes and Schauff), *Anagyrus loecki* (Noyes and Menezes), and *Pseudoleptomastix mexicana* (Noyes and Schauff) offered control of papaya mealybug, *P. marginatus* in Puerto Rico, the Dominican Republic, Guam and Sri Lanka. The

Coccidohystrix* on *Hibiscus

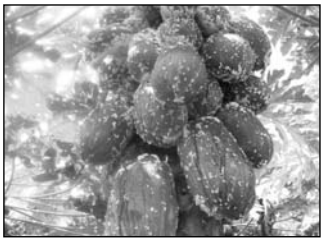


Cryptolaemus* clearing mealybugs on *Coleus

local predator, *S. epeus*, though found in larger numbers, was unable to suppress mealybugs effectively. All the above three parasitoids were imported from Puerto Rico in August 2010 and releases were made in peninsular India.

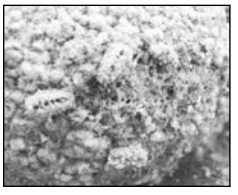


Leaf damage

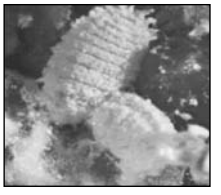


Fruit damage

***Acerophagus papayae*- an exotic parasitoid**



***Spalgis epeus* - an indigenous predator**



Female mealybug

Acerophagus papayae established very well and brought spectacular control of papaya mealybug in Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu and Kerala (Rabindra, 2010; Jonanathan *et al*, 2011; Mundale and Nakat, 2011; Pokharkar *et al*., 2011; Shylesha *et al*, 2011; Krishnamoorthy *et al*, 2011; Kalyanasundaram, *et al*, 2011).

PATHOGENS

Verticillium lecanii Zimm. was isolated from whiteflies and developed as biopsticide and named 'Phule bugicide' at Mahatma Phule Krishi Vidyapeeth (Rahuri, Maharashtra) for control of mealybugs. A rate of 20g formulated material/10 litres of water is recommended to control the mealybugs. Two to three sprays at 15-day intervals in rainy season are needed. Addition of milk powder @5g/10 litre water helps improve control of mealybugs. Foliar sprays of fungal pathogens, viz., *Beauveria bassiana* (Bals.) Vuill and *Metarhzium anisopliae* (Metch.) in rainy season under humid conditions were also found to infect mealybugs (Kulkarni *et al*, 2007).

Liquid formulations A (VGTA50512) and B (VGTA502105) of the entomopathogenic fungus, *Verticillium lecanii* (Zimmermann) Viegas, at 1% concentration of liquid formulation gave highest mortality of 90.5% (Formulation A) and 92.22% (Formulation B) on *M. hirsutus* (Chavan and Kadam, 2010).

FUTURE THRUST

- Inundative releases of indigenous enemies, where large-scale multiplication is feasible, should be attempted for control of mealybugs
- Application of conventional/ broad-spectrum insecticides interferes with activity of naturally-occurring biocontrol agents in horticultural ecosystems. To overcome this, non-conventional chemicals like botanicals, biopesticides, etc. can be applied in mealybug management programmes, without affecting the key, local natural-enemies
- Key natural-enemies can be conserved using safer pesticides. All the commonly-used pesticides should be screened for safety to key parasitoids and predators, and this information should be made available
- Biological control is the backbone of integrated pest management. Proven or promising natural-enemies should be included as a major component in IPM programmes.
- Publicity through various media on the use of biocontrol agents in suppression of mealybugs helps create awareness among farmers

- Research institutes and other government organizations are unable to supply natural enemies to farmers in large numbers due to several limitations. At present, there are very few commercial insectaries in India. Many more large-scale multiplication units need be established in all the states to ensure timely supply of proven natural-enemies to the farmer
- Stringent-quarantine issues are to be addressed at international and national level
- Importation of natural enemies is to be strengthened
- Exploitation of insect pathogens for mealybug management to be explored

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