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Review Article

Recent trends in biological control of scale insects on fruit crops in India

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ABSTRACT: Scale insects are sap feeders, causing threat to the cultivation of several fruit crops. The scale insects can be grouped into two broad categories. The first group belonging to family Diaspidide, comprises many species of armoured scales (hard scales) belonging to the genera. *Aonidiella, Aulacaspis, Pseudaulacaspis, Hemiberlesia, Aspidiotus, Chrysomphalus, Pinnaspis, Parlatoria* etc. The second category belonging to family Coccidae comprises of the soft scales belonging to the genera *Coccus, Puvinaria, Chloropulvinaria, Saisettia, Parasaisettia, Vinsonia, Drephanococcus, Ceroplastes, Ceroplastodes*, etc. Scale insects are highly polyphagous, but certain species cause severe damage to specific fruit crops viz. the red scale, *Aonidiella aurantii* (Maskell) on citrus; latania scale, *Hemieberlesia lataniae* (Sign.) on grapevine.; white scale, *Aulacaspis tubercularis* (Newstead) on mango; green shield scale, *Pulvinaria psidii* (Maskell) on guava, lemon and sapota, *Pulvinaria polygonata* (Ckll.) on mango; green scale *Coccus viridis* (Green) on citrus and sapota and *Drephanococcus chiton* (Green) on ber and guava. Insecticides are not effective due to the presence of protective cover over the scales. On the other hand, scale insects are more amenable for biological control due to their sedentary habit and colonial distribution. Several scale insects are well regulated by the local predators. In nature, green shield scale, *Pulvinaria psidii* (Maskell) is kept under check by the predator, Australian ladybird beetle *Cryptolaemus montouzieri* Mulsant on guava, sapota and lemon. The reduction of the mango green shield scale *Pulvinaria polygonata* was attributed mainly to the action of the predators *C. montrouzieri* and *Spalgis epeus* Westwood. The green scale *Coccus viridis* on acid lime and white scale *Aulacaspis tubercularis* on mango are well regulated by the coccinellids *Chilocorus nigrita* (Fab) and *C. circumdatus* Sch. Local parasitoids are also known to effectively check the populations of the scale insects on different fruit crops. The encyrtid *Anicetus ceylonensis* How and the pteromalid *Cephaleta brunniventris* Motsch are responsible for the suppression of wax scale *Drephanococcus chiton* on ber and guava. The aphelinid parasitoid, *Pteroptrix koebeli* How. plays a major role in the regulation of the mango scale *Aulacaspis tubercularis*. On sapota, the aphelinid parasitoid *Coccophagus* sp. was the dominant natural enemy causing up to 95 % parasitism. *Scutellista cyanea* Motsch. (Pteromalidiae: Hymenoptera) was able to suppress *Parasaissetia nigra* (Nietner) on custard apple and pomegranate. In the absence of effective biocontrol agents in nature, parasitoids and predators have to be released in the field for obtaining an effective and quicker suppression of the scale insects. Release of adult *C. nigirita* was found to be effective in the control of the red scale on citrus in Karnataka, Andhra Pradesh and Punjab. Release of *C. infernalis (C.bijugus)* Mulsant @ 10-20 beetles/tree once in April-May has also been recommended to reduce Sanjose scale. The white halo fungus, *Lecanicillium (Verticillium) lecanii* can be sprayed at 16 x 10^6 spores/ml along with 0.05% of sticking agents in the evening hours at 15 days interval to control the green scale in the hilly areas during cooler months. The biocontrol agents can be integrated with plant origin insecticides as they do not affect the activity of these agents.

KEY WORDS: Biological control, fruit crops, hard scales, predator, parasitoids, scale insects, soft scales

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INTRODUCTION

Scale insects get their name because the females secrete a waxy covering that gives them the appearance of a fish scale. They are tiny insects varying in colour. Scale insects are a diverse group of insects in the order Hemiptera, superfamily coccoidea. Scale insects can be broadly divided into two groups: armored scales (Diapididae) and soft scales (Coccidae). Armoured scales secrete a protective cover over their bodies.The soft scales are usually half round rubbery and are usually larger, lack the protective cover, but protect themselves with waxy secretions. Scale insects are sucking insects laying their the eggs underneath the hard scale covering or in an ovisac covered with filamentous secretion, making difficult to get killed with conventional chemicals (Maniand Krishnamoorthy, 2001). Nymphs and adult female scale insects become immobile /sedentary/sessile. They are easily available /susceptible throughout the year to the attack by the parasitoids and predators. In fact, the first

outstanding biocontrol success was the complete suppression of the cottony cushion scale *Icerya purchasi* Maskell with the predator *Rodolia cardinalis* Mulsant was on citrus fruits ((Bartlett, 1978).

Hard scales (Armoured Scale Insects, Diaspine scales)

Armoured scales are formed from the waxy filaments that the insect secretes as it rotates its body in a circular pattern. Armoured scales are the smallest of scale insects, ranging in size from 1 to 3 mm. The body of the scale insect is protected by a cover (the armour) made from wax secreted by the insect and cast skins (exuviae) of previous growth stages. The exposed body usually is yellow or orange, but may have a pink or red colour to it. This cover also protects the eggs laid by the female. Adult armored scales are usually protected from chemicals because of their protective shell (Rosen, 1990). The hard scales belonging to family Diaspidide, comprises many species belonging to the genera *viz*. *Aonidiella, Aulacaspis, Pseudaulacaspis, Hemiberlesia, Aspidiotus, Chrysomphalus, Pinnaspis, Parlatoria* etc. Among them, Calfornia red scale *Aonidiella aurantii* is found highly destructive to citrus in India causing heavy loss to citrus growers. San Jose scale - *Quadraspidiotus perniciosus* (Comstock) serious pest of many temperate fruits in Jammu & Kashmir, Himachal Pradesh and Uttaranchal. *Aulacaspis tubercularis* and *Aspidiotus destructor* Signoret are well known to cause damage to mango. (Table 1)

Biological control of diaspine/hard scales

San Jose Scale - *Quadraspidiotus perniciosus*

Quadraspidiotus perniciosus (Comstock) is serious pest of many temperate fruits in Jammu & Kashmir, Himachal Pradesh and Uttaranchal. The first signs of infestation include a decline of tree vigor, leaf drop and appearance of sparse yellow foliage, particularly on the terminal growth. Reddish spots on the underside of bark and around scales on leaves or fruit result from feeding of immature stages. In severe cases, the entire surface of bark can become covered with layers of overlapping grayish scales. Cracking and bleeding of limbs occur and heavily injured trees may die**.** The aphelinid parasitoid *Encarsia perniciosi* (Tower) was introduced in 1953 into India (Rao and Rao, 1960). The Russian strain of *E. perniciosi* proved satisfactory in H.P. while Chinese, American and Illinois strains performed much better in U.P. (Sahai and Joshi, 1965). In recent years, the pest has appeared in severe form mainly due to the interference of insecticidal applications. Augmentative release of *E. perniciosi* / *Aphytis* sp. (*proclia* group)/ *Aphytis diaspidis* (How.)@ 2,000 adults / infested tree once in spring is recommended to suppress the scale. Release of *Aphytis* sp. (*proclia* group) had resulted in 60-70% parasitism in Kullu (H.P) (Thakur *et al.*, 1989) and 40.2 % in J&K (Masoodi *et al*., 1989). Coccinellid predators *Chilocorus infernalis* Mulsant and *Pharoscymnus flexibilis* (Mulsant)

Table 1. List of hard scales infesting fruit crops in India

Aonidiella citrina (Coquillett)	Citrus, custard apple, mango, date palm
Aonidiella orientalis (Newstead)	Banana, ber, citrus, guava, jamun, peach, pomegranate, mango
Aspidiotus destructor Signoret	Banana, ber, citrus, guava, jamun, peach, pomegranate, fig, pear, mango, sapota, apple, papaya, grapes
Octaspidiotus tripurensis Takagi	Mango
Aulacaspis tubercularis Newstead	Mango, citrus
Chrysomphalus aonidum (L.) (= *Chrysomphalus ficus* Ashmead)	Citrus, mango, almond, banana, guava, grapes, date palm
Chrysomphalus dictyosperni (Morgan)	Citrus, banana, mango, apple
Hemiberlesia lataniae (Sign.)	Apple, jack fruit, sapota, ber, grapes, plum, peach, citrus, banana, guava, mango
Howardia biclavis (Comstock)	Sapota, peach, apple, ber, citrus, custard apple
Lepidosaphes (=*Corunaspis)* beckii (Newman)	Citrus
*Parlatoria blanchar*di (Targioni Tozzetti)	Date palm
Parlatoria cinerea Hadden	Apple, apricot, citrus, phalsa, jamun, litchi, mango, peach, plum
Parlatoria oleae (Colvée)	Mango, ber, apricot, pomegranate, peach, apple, citrus, fig, grapes, pear, plum, apple
Purgatorial pergandii Comstock	Citrus, guava, mango
Pinnaspis strachani Signoret	Date palm, citrus, banana
Pinnaspis aspidistrae Signoret	Citrus, fig, jack fruit, mango
Pseudaulacaspis rubra (Maskell) (=*Pseudaulacaspis barberi* (Green))	Mango
Pseudaulacaspis pentagona (Targioni)	Apple, cherry, peach, plum, pear
Quadraspidiotus perniciosus (Comstock)	Apple, citrus, cherry, peach, plum, pear, raspberry, strawberry
Chlidaspis asiatica (Archangelskaya)	Apple and plum

were found clearing the scales in Thanedhar areas of H. P. (Rawat *et al*., 1988). Release of *C. infernalis* (*C.bijugus*) Mulsant @ 10-20 beetles/tree once in April-May has also been recommended to reduce the scales (Singh, 2000).

***Aonidiella aurantii* (California Red Scale /Citrus Red Scale)**

Aonidiella aurantii (Maskell) is an armoured scale insect with a circular, brownish-red cover. Scale insects of all ages feed by sucking sap. They are found on all parts of the plant but are most noticeable on the fruit. Heavy infestations may cause discoloration, shoot distortion and leaf drop. The fruit may become pitted and unmarketable. The tree's bark may split and the twigs and branches may die back and this sometimes results in the death of the tree. About 15 natural enemies were known to attack *A. aurantii* in India. *Aphytis fisheri* DeBach and *Aphytis hispanicus* (Mercet) at Gauhati, Assam (DeBach, 1959), *Aphytis* spp., *Coccobius* sp., *Encarsia* sp. and *Pteroptrix koebeli* (Howard) in Karnataka (CIBC, 1984), *Chilocorus nigrita* (Fab.), *Scymnus quadrillum* Motsch. (Pruthi and Mani, 1945), entomopathogenic fungus *Attractium indica* Chona and Munjal, *Chilocorus circumdatus* Sch. and *C. hauseri* Wse. (Rao, 1969) were reported on red scale. According to Krishnamoorthy (1993), *Aphytis melinus* Debach and *A. linganensis* Comp., *A. fisheri* Debach, *Cybocephalus* and *Eryngiopus* sp. were also known to attack the red scale. *A. melinus* when introduced into California from India had resulted in excellent control of the scale in citrus orchards.*C. nigrita* was the most voracious predator of *A. aurantii*. Release of adult beetles was found to be effective in the control of the red scale on citrus in Karnataka, Andhra Pradesh and Punjab (Krishnamoorthy, 1993; Tirumala Rao *et al*., 1954; Batra *et al*., 1987). Neem oil, pongamia oil, dicofol, sulfur, copper oxychloride and maneb were found safer to *A. melinus* and *C. nigrita* (Krishnamoorthy and Rajagopal, 1995).

***Aonidiella orientalis* (Oriental yellow scale)**

The insect damages the plant by sucking sap, weakening it. The physical damage includes discoloration and deformation of leaves. Flowers and fruits fail to develop. When the insects feed on the fruits they are discolored and warped, reducing their value on the market. *Aphytis* sp was collected from *A. orientalis* infesting custard apple and banana but the parasitism did not exceed more than two per cent. The scale insect was found predated by the coccinellid *Scymnus* sp. and the green lacewing *Malllada astur* (Banks) on banana but the former was more abundant than the latter. A fungal pathogen *Cladosporium* sp. was also observed to infect *A. orientalis* to the extent of 20% in February. *Aphytis* sp. was known to parasitise up to 30% on *Aonidiella orientalis* infesting banana (Newstead) (Mani and Krishnamoorthy, 1996a).Oriental yellow scale had appeared in severe form on the fruits of sapota. *C.nigrita* was found actively feeding on the scales and able to clear all the scales in 2005 at IIHR Farm, Bangalore. In U.P., the aphelinid *Ablerus aonidiellae* sp.nr was recorded on *A. orienralis* infesting guava by Hayat (1974). Rajagopal and Krishnamoorthy (1996) indicated the parasitoid *Comperiella bifasciata* Howard and the predator *Chilocorus nigrita* as potential biological control agents. *Encarsia citrina* occurred naturally, producing levels of up to 80% parasitism, and was also therefore important in the biological control of *A. orientalis* (Elder *et al*., 1998).

Aulacaspis tubercularis

The white scale, *Aulacaspis tubercularis* Newstead was first reported on mango in India by Ayyar (1929). The scale infestation was confined to the under surface of mango leaves. Nymphs and female scale insects suck the cell sap resulting in yellow specks on the upper surface of leaves. In fact, the application of insecticides had resulted in marked increase in the population of *A. tubercularis* due to elimination of its natural enemies (Viljoen and Villiers, 1987). A total of ten natural enemies were found attacking *A. tubercularis* infesting mango. Among them, *Pteroptrix koebelei* How (Aphelinidae). was the only parasitoid observed on A. *tubercularis*. Earlier three parasitoids viz., *Aphytis* sp., *Encarsia* sp. and *P. koebelei* were reported on *A. tubercularis* in India (CIBC, 1984)). The predators included *Chilocorus circumdatus* Sch., *Chilocorus nigrita* (Fab.), *Rodolia amabilis* Kapur, *Pseudaspidimerus trinotatus* (Thunberg) Motsch., *Scymnus quadripunctata*, *Ortalia octopunctata* Gorham, *Cybocephalus* sp., *Triommata coccidivora* (Felt) and *Mallada boninensis* (Okamoto) (Mani and Krishnamoorthy, 1998a).

The field study revealed that the population of the scale was 39.50/cm^2 in September'95 which had declined in the subsequent months. The initial sampling itself in September revealed the natural parasitisation (40%) by *P. koebelei* and the predation by local biotic agents. The per cent parasitism went up to 96.61. The activity of the parasitoid was found high in November'95 as 710.75 adults of *P. koebelei* had emerged from the scales infesting a single mango leaf. Among the predators, only *C. nigrita, C. circumdatus, P. trionotatus, S. quadripunctata* were found commonly associated with the mango scale. The population of the mango scale was not significantly affected by the predators and the rainfall. The multiple regression equation fitted with biotic agents and weather parameters to predict the scale population and it is concluded that the decline in the population of *A. tubercularis* was mainly due to the activity of the parasitoid. *P. koebelei* and also the weather

parameters like minimum temperature and humidity (Mani and Krishnamoorthy, 1998a).

Aspidiotus destructor

Aspidiotus destructor Signoret is a highly polyphagous armoured scale and it is known to cause damage to mango. The scale insect is usually found in densely massed colonies on the lower surfaces of leaves, except in extremely heavy infestations where it may be present on both sides. Infestations are typically associated with yellowing of the leaves in areas where the scales are present. The yellowing is caused by the removal of sap by the sucking mouth parts and the toxic effects of the saliva that kills the surrounding tissues at the feeding site. *Aphytis chrysomphali* (Mercet), *Aneristus ceroplastae* How., *Chrysonotomia* sp. *Comperiella bifasciata* How., *Chartocerus* sp. *Thompsonisca desantisiellus* Shafee and *Chilocorus nigrita* Fabr. were recorded in UP. Among them *T. desantiellus* was the most commonly encountered in nature (Tandon and Srivastava, 1980). Predators play a significant part in limiting *A. destructor* populations. *Chilocorus nigrita* could be useful in the suppression of *A. destructor*.

Florida red scale - *Chrysomphalus ficus*

Chrysomphalus ficus **(***C. aonidum*) is a leaf-infesting species, but in high-density infestations it may spread to fruits, stems and trunks, and may cause premature leaf and fruit drop and stem dieback. The scales appear as circular darks pots. An infestation appears as dark-purple to reddish-brown or black spots with paler margins, on both surfaces of shaded leaves of the host plant. Heavy infestations cause yellowing of the leaves, followed by defoliation of part or all of the host. *C. aonidum* prefers shade and is therefore most common in the lower part of the canopy. *Chrysomphalus ficus* Ashmead (= *C. aonidum* L**).** It is of minor importance on citrus in India. About 10 natural enemies were known to attack *C. ficus* in India. *Microterys* sp., *Tetrastichus* sp., *Aphytis* sp., *A. mytilaspidis* (Le Baron), *Coelophora biplagiata* Swartz., *Chilocorus circumdatus*, *C. nigrita, Pharoscymnus horni* and *Nectria* sp. were recorded on *C. ficus* in Karnataka (Singh,1993). *C. nigrita* gave substantial control of the scale in Seychelles (Bennet *et al*., 1976).

Purple scale - *Cornuaspis beckii*

Cornuaspis (= *Lepidosaphes*) *beckii* (Newman) sometimes becomes serious in South India. Scale infestation can be seen by the appearance of the purplish brown scale armour on stems, leaves and fruits of host plants. Nymphs and adults suck sap from the foliage and branches and spread to the fruits, causing disfiguration, which decreases market value. The areas surrounding the scale insects on leaves turn yellow and when severely infested the entire leaf may be discoloured prematurely. Heavy infestation can also lead to leaf fall and leaf and shoot malformation; and in extreme cases, host death. *Microterys* sp., *Adelencyrtus femoralis* Compere and Annecke, *Aphytis* sp., *A. mytilaspidis*, *Tetrastichus* sp., *Coelophora biplagiata*, *Chilocorus circumdatus, C. nigrita, Pharoscymnus horni* and *Nectria* sp. were reported on *C. beckii* (Anon., 1980). In Wynaad (Kerala), it was found infected by entomopathogenic fungus, *Spherostelbe auranticola* (Ramachandran, 1954).

Yellow scale - *Aonidiella citrina*

This species is morphologically close to *Aonidiella aurantii* (Maskell). *A. citrina* is a serious pest, mainly of citrus, causing leaf drop, twig die-back and fruit drop. *Aphytis chrysomphali* (Mercet), *Physcus* sp. nr. *flaviventris* (How.), *Tetrastichus purpureus* Cam. and *Comperiella bifasciata* (How.) from Namkum (Bihar) (Glover, 1935) and *C. bifasciata* from *A. citrina* Coquillett infesting citrus at Bombay and Pune. *Pharoscymnus horni* was considered to be the most promising predator in India (Compere, 1961).

Phenacaspis manni

Heavy infestation of this scale was observed on citrus in Tamil Nadu. *Aphytis* sp. and *Encarsia* sp. were recorded on *P. manni* (Green) (CIBC, 1984).

Pinnaspis strachani

Coccobius albipodus (Agarwal) and *Arrenophagus chionaspidis* Aurivillius were repoted on this scale *Pinnaspis strachani* (Cooley) infesting *Citrus aurantifolia* in Karnataka (CIBC, 1984).

Pinnaspis aspidistrae

In Andhra Pradesh, *Eretmocerus* sp, *Azotus* sp. and *Adelencyrtus* sp. were reared from *Pinnaspis aspidistrae* (Sign.) (Nagalingam, 1980).

Latania scale- *Hemiberlesia lataniae*

Hemiberlesia lataniae (Sign.) is becoming serious on grapevine *Aphytis* sp was found causing 14.6 to 20.6% parasitism during September-March. Release of *Chilocorus nigrita* helped to bring down the scale population on Bangalore blue in Karnataka (Mani, 2002).

Pseudaulacaspis barberii

Aphytis bengalensis Rosen & Debach was recorded on *P. barberii* (Green) infesting mango leaves (Rosen and DeBach, 1986).

Pseudaulacaspis cokerelli

Aphytis sankarani sp nr. *w*as collected from the scale *P. cokerelli* (Cooley) (Rosen and DeBach, 1986).

Aspidiotus orientalis

The scale *Aspidiotus orientalis* (Newst.) was parasitised by *Aphytis chrysomphali* Mercet, *Tetrastichus purpureus* Cam. and *Comperiella bifaciata* How. (Nair, 1975)

Soft Scale Insect species on fruit crops

Soft scales differ from armoured scales in that they do not secrete a waxy covering that is separate from the body. Most soft scales produce a thin, glassy wax that does not obscure the colour or form of the female soft scale. The soft scales unlike hard scales excrete large amounts of honeydew. On this sticky excretion, a sooty mould develops, giving the stems or foliage a blackened appearance. Severe infestations, besides making the plant unattractive, will weaken it considerably even to the point of death. The second category belonging to family coccidae comprises of the soft scales belonging to the genera *Coccus, Puvinaria, Chloropulvinaria, Saisettia, Parasaisettia, Vinsonia, Drephanococcus, Ceroplastes, Ceroplastodes*, etc.

Biological control of soft scales

Coccus viridis

The adult female is shiny pale green with a conspicuous black, irregular U-shaped internal marking that is dorsally visible. The under surface of the leaf is preferred, and adult scales may be found in a line along both sides of the midrib and lateral leaf veins. Often they attack the young shoots. The green scale feeds from the phloem of the host plant and the scale insect excretes honeydew. Usually infestations are accompanied by sooty mold, a black fungus growth, which develops on honeydew excreted by the scale. Accumulations of sooty mold cause the infested plant to be unsightly. Sooty mould blackens the leaf and decreases photosynthesis. On fruit, sooty mold reduces the marketability of the fruit. When large populations are present yellowing, defoliation, reduction in fruit set and loss in plant vigour are caused.

Citrus

The soft green scale *Coccus viridis* (Green) (Homoptera, Coccidae)) has been reported as a pest of citrus (Singh and Rao, 1977; Tandon, 1985). Generally, the management of the green scale is limited to chemical control, but reinfestation of the scale is reported 35 days after insecticidal application (Singh and Rao, 1977). Alternatively, biological control of scales is found effective in the long run. *Microterys* sp., *M. flavus* (Howard), *Anicetus annulatus* Timberlake, *Gyranusa* sp., *Tetrastichus* sp., *Coccophagus* sp. *Coccophagus cowperii* Gir.,*Coccophagus bogoriensis* Kon., *Cheiloneromyia javensis* Gir., *Chilocoru scircumdatus* Sch., *C. nigrita*, *Pharoscymnus horni* Wse., *Cryptolae-*

Table 2. List of soft scales infesting fruit crops in India

Species	Host plants
Ceroplastes floridensis Comstock	Apple, citrus, custard apple, fig, guava, mango, jack fruit, pomegranate, pear, plum
Ceroplastes rubens Maskell	Citrus, fig, jack fruit, mango, pear, date palm
Ceroplastes stellifer (Westwood)	mango
Ceroplastes rusci (Linn.)	Fig
Drepanococcus chiton Green	Ber and guava
Pulvinaria psidii Maskell	Guava, citrus, fig, jack fruit, jamun, litchi, loquat, mango sapota
Chloropulvinaria polygonata Green	Apple, grapes, mango, jamun, peach, citrus
Pulvinaria maxima (Green)	Grapevine, ber, citrus
Coccus acutissimus Green	Banana, ber, jack fruit, mango
Coccus discrepans Green	Banana, ber, citrus, fig, grapes, jamun, mango
Coccus hesperidum Linn	Citrus, papaya, mango
Coccus viridis (Green)	Citrus, sapota, guava, loquat and mango
Eulecanium tiliae (Linnaeus)	Almond, apple, apricot, cherry, loquat, peach, pear, plum
Hemilecanium imbricans (Green)	Mango ,Fig
Parthenolecanium corni (Bouché)	Grapes
Parasaissetia nigra (Nietner)	Citrus, grapevine, guava, litchi
Saissetia coffeae (Walker)	Citrus, guava, fig
Saissetia oleae (Olivier)	Citrus, fig, guava, sapota, mango
Vinsonia stellifera Westwood	Mango, citrus, guava

mus montrouzieri Muls., *Chrysopa* sp., *Verticillium lecanii* (Zimm), *Entomophthora* sp., *Hypocrella olivacea*, *Nectria* sp., *Podonectria* sp., *Fusarium* sp. and *Cladosporium* sp. were recorded from Kodagu (Anon., 1980). Among them, *Aneristus ceroplastae* How. and *Encyrtus lecanorium* Mayr. Was known to cause up to 43% parasitism in the field (Tandon, 1985). Releases of *C. nigrita* helped in bringing down the population of *C. viridis* in citrus orchards (Tirumala Rao *et al*., 1954). The natural enemies were capable of suppressing *C. viridis* in undisturbed ecosystem. In acid lime, three coccinellid predators, *Ch. circumdatus, Ch. nigrita*, *Cr. montrouzieri and* an encyrtid parasitoid, *Encyrtus lecaniorum* Mayr. were observed on *Coccus viridis*. Due to the activity of natural enemies, the population of green scale declined from 300 scales per plant in July to negligible level from December onwards. The mean population of *C. nigrita* ranged from 2.10 to 16.90 per tree with a peak in August, 1994. Congregation of *Chilocorus nigrita* contained 2-6 pupae mainly on the leaf but in the case of *C. circumdatus*, up to 84 larvae were found pupating mainly on the trunk near the basin and sometimes on the ventral surface of the leaf. Both *C. nigrita* and *C. circumdatus* had highly positive and significant correlation with the population of the green scale. The population of *C. montrouzieri* ranged from 2.10 to 4.50. Parasitism by *E. lecaniorum* ranged from 1.38 to 11.60 per cent (Mani and Krishnamoorthy, 1996; 1998b).

The white halo fungus fungus, *Lenticillium* (*Verticilium*, *Cephalosporium*) *lecanii* (Zimmerman) is the most common and apparently causes the highest percentage of mortality. At Kodagu in Karnataka, application of the fungal suspension of *L. lecanii* containing 16 x 10^4 spores/ml sprayed just before the onset of rainy season was found to be effective against *C. viridis* infesting Coorg mandarin (Singh, 1985).

Sapota

Coccus viridis (Green) has recently become a major pest of sapota, *Manilkara zapota* in India (DhraraJothi and Tandon, 1991). Numerous species of predators, parasitoids and pathogens have been reported as natural regulatory factors of *C. viridis* infesting plantation crops and citrus (Narasimham, 1987; Reddy *et al.,* 1997, Mani and Krishnamoorthy, 1997. Mani and Krishnamoorthy, 1998).

Field studies were conducted to determine the impact of natural enemies in the suppression of *C. viridis* on sapota in Karnataka. The green scale population declined from 134.74 in the first week of September to 0.54 by mid November. The population of the coccinellid predator *C.nigrita* ranged from 3.00 to 14.00 with a peak by mid September, while that of *C. montrouziri* from 1.2 to 4.5. The population green scale was positively correlated with the predators. The green scale was completely suppressed with the predators on sapota within three months (Mani and Krishnamoorthy, 1997).

In yet another field study, the population of green scale declined from 30.72 per leaf in May 2004 to 1.62 per leaf in March 2006. Two coccinellid predators *Chilocorus nigrita* (Fab.) and *Cryptolaemus montrouzieri* (Muls.) and one aphelinid parasitoid *Coccophagus* sp. were recorded on *C. viridis*. The parasitoid *Coccophagus* sp. was the dominant natural enemy causing up to 94.67% parasitism. Further, step-wise regression procedure employed to arrive at a multiple regression model showed that about 65.60% of the scale population could be predicted by one factor namely, parasitism by *Coccophagus* sp. it is concluded that the parasitism by *Coccophagus* sp. played a major role in regulating the population of the soft green scale infesting sapota (Mani *et al*.2008).

Green shield scales

Often referred to as mealy scales, they are pale yellowish green insects measuring up to 2.5-3 mm. They cause damage by sucking the sap from leaves, stem and fruits. Heavy clustering of scale insects is usually seen under the lower surface of leaves. The scale insects excrete honeydew on which the fungus sooty mold develops thereby affecting the photosynthesis of the infested plants. Such affected plants appear to be sick and black. In the case of severely affected plants, growth and fruiting capacity are reduced. The green shield scales have high reproductive potential laying 500-700 greenish yellowish eggs in a cottony ovisac. After hatching, the young ones move freely to find a suitable spot on the plant to settle for further development. The young ones are called nymphs which are yellowish green in colour. Adult female scale secretes heavy waxy filaments at its posterior end forming ovisac in which eggs are laid. Eventually the cottony secretion nearby surrounds the scale which dies soon after oviposition and its shrunken body remains loosely attached as a lid on the top of ovisac. Females with ovisacs are often mistaken as mealybugs.

Pulvinaria psidii

Guava

The Green shield scale *Pulvinaria* ((=*Chloropulvinaria*) *psidii* Maskell is maor and regular pest of guava In the case of severely affected plants, growth and fruiting capacity are reduced (Easwaramoorthy and Jayaraj, 1977; Pawar *et al.,* 1984). The green shield scales are very difficult to get controlled with conventional insecticides, since they have mealy covering and the eggs are protected with waxy fila-

ments. *Scymnus coccivora* Ayyar, *Cryptolaemus montrouzieri*, *Chilocorus nigrita*, *Cheilomenes sexmaculat*a (Fab.), *Coccophagus cowperii* Grlt., *C. bogoriensis* (Kow.) and *Aneristus* sp. were known to attack *C. psidii* (Anon., 1979; Puttarudriah and Channa Basavanna, 1957; Manjunath, 1986; Bennet and Hughes, 1959. Mani and Krishnamoorthy, 1990c). Agarwal *et al*. (1984) also reported *Bothriophryne* sp nr. *pulvinariae* Agarwal, Agarwal & Khan and *B*. sp.nr. *tachikawai* Agarwal, Agarwal & Khan from *Chloropulvinaria* sp. infesting guava trees in Rajasthan. Very often the local predators and parasitoids are not sufficient to suppress the population of the green shield scale effectively. The Australian ladybird beetle *C. montrouzieri* was found to be a voracious feeder on the ovisacs of *C. psidii* consuming about 3780 eggs (Mani and Krishnamoorthy, 1990c). The predator can be reared easily on the ripe pumpkins infested with the mealybugs in the laboratory (Chackoo *et al*., 1978). Releasing of *C. montrouzieri* helps to keep the green scales under perfect check.

A field study was conducted to prove its efficacy of releasing *C. montrouzieri* in the suppression of green shield scales. After checking the activity of ants, the predatory beetles were released @ 10 per tree either in the morning on the scale infested plants in the field. The population of the scale insects declined from 145.50/plant in April to 1.20 / plant in October The beetle feeds and breeds very well on the green shield scales and brings down the pest population effectively (Mani and Krishnamoorthy, 1990c). There was positive and significant association between *P. psidii* and *C. montrouzieri* in guava ecosystems (Verghese *et al*., 1998). *Cephalosporium lecanii* Zimm was found pathogenic to *P.psidii* (Easwaramoorthy and Jayaraj, 1977). Complete biological control of *P. psidii* was reported with *Microterys kotinskyi* Fullaway in Bermuda and other countries.

Lemon

Shoots and the leaves of lemon plants (*Citrus limon*L.) were found heavily infested with green shield scales. A mean of 42.50 scale ovisacs were present on a single shoot of 30 cm in length. Release of the Australian ladybird beetle, *Cryptolaemus montrouzieri* @ 30/plant declined from 42.50 in the second week of November to negligible numbers (<1) by the third week of December (Mani and Krishnamoorthy, 1999a)

Sapota

The green shield scale *Pulvinaria psidii* suck the sap from leaves and tender shoots young sapota plants.The green shield scale was controlled by *C. montrouzieri* (Mani and Krishnamoorthy, 1997)

Pulvinaria polygonata

In recent years, scale insect *Pulvinaria (Chloropulvinaria) polygonata* has become serious pest on mango. The nymphs and adults of pest suck the sap of leaves and other tender parts which result in reduction of vigour of plants. Scale also excretes honeydew which facilitates in development of sooty mould on different plant parts.

Aneristus ceroplastae How, *Metaphycus hederaceous* sp. nr. *Tetrastichus* sp., *Anicetus annulatus* Timberlake, *Nicostratus* sp., and *Anagyrus* sp. were recorded from Malihabad (Singh, 1993). *Coccophagus chloropulvinaiae* sp nr (Hayat, 1974), *Scymnus coccivora* Ayyar (Ali 1964), *Nephus regularis* (Sinha and Dinesh, 1984), Coccophagus ceroplastae Howard (Das and Sahoo, A. K.2005 were also reported on *P.polygonata* in India. The parasitoids namely *C. longifaciatus* Timb. *Coccophagus bivittatus* Comp. *C. nigricorpus* sp. nr. *Metaphycus helvolus* sp. nr. and three predators viz. *Cryptolaemus montrouzieri* Muls. *Mallada astur* (Banks) and *Spalgis epeus* Westwood were obsereved on mango green shield scale around Bangalore.(Mani and Krishnamoorthy, 1998c).

The Australian ladybird beetle, *Cryptolaemus montrouzieri* is capable of consuming about 2400 eggs of the mango scale insect *P. polygonata* (Mani and Krishnamoorthy, 1998a). *C. montrouzieri* also feeds on the scales in the absence of egg mass. In the field, ants are commonly associated with the scale insects. They feed on the honeydew excreted by the scales, and ward off local parasitoids and predators of the scale insects. Hence, ants have to be controlled by the destruction of their nests and application of chlorpyriphos (0.05%) to the ant holes. After checking the activity of ants, the predatory beetles are released either in the morning or evening on the scale infested plants in the field. A release rate of 5-10/small plant, 20-30/medium sized tree and 50/large sized tree is recommended for the suppression of the scales. The beetle feeds and breeds very well on the green shield scales and brings down the pest population within 2-3 months.

In a field study on the impact of *C. montrouzieri*, a mean of 128.40 scale insects/ shoot was observed on 16th August 2011.The population of *C. montrouzieri*, ranged from 6.62 to 12.45 per shoot during the study period. The plants were cleared of almost of all the scale insects in the first week of October 2011 as compared to 192.25 scale insects /shoot in the check at same time.. In another field study on the impact of *S.epeus*, a mean of 72.86 scale insects/shoot was observed on 29 th August 2006 along with the appearance of the predator *S. epeus*. The population of

S. epeus ranged from 3.40to 8.45 *S. epeus* /shoot during the study period. The plants were cleared of almost of all the green shield scale insects in the first week of October 2006. There was 97.20%, and 95.27% reduction in the population of *P. polygonata* respectively was recorded within 45 and 35 days of appearance of *C. montrouzieri* and *S. epeus* respectively (Mani and Krishnamoorthy, 2016)

Black/Nigra scale – *Parasaissetia nigra*

Adult females of *Parasaissetia (= Saissetia) nigra* (Nietner) are dark brown to shiny black, elongate-oval, Nymphs are translucent-yellow /yellowish green and flat. The nigra scale feeds from the phloem of the host plant and may be found on leaves or twigs. Damage due to feeding of an individual scale is small. However, when large populations are present, yellowing, defoliation, reduction in fruit set, and a loss in plant vigor may result. Damage is due to secreting large amounts of honeydew which is colonized by sooty mould fungi, covering fruits and leaves by a thick black mass.

Pomegranate

Naturally occurring *Scutellista caerulea* (Fonscolombe) (= *S.cyanea* Mots.) causes heavy parasitism and effectively checks the scale insect in pomegranate orchards in Maharashtra (Jadav and Ajri, 1981)

Custard apple

In Karnataka, Custard apple shoots were found fully covered with *P. nigra* at the IIHR Farm, Bangalore during Jan-March Parasitism by *Scutellista cyanea* Motsch. (Pteromalidiae: Hymenoptera) was 18.50% in January which increased to 42% by March There was no fresh infestation of scales from June ’97 onwards. (Mani and Krishnamoorthy, 1999b).

Wax scale - *Drepanococcus chiton*

Wax adheres tightly to the body of the female scale insect *Drepanococcus* (= *Ceroplastodes*) *chiton* (Green) and cannot be easily separated from it. Most soft scales produce a thin, glassy wax that does not obscure the color or form of the female soft scale. The scale insect infestation is confined to the lower surface of the leaves and shoots of guava plants. They suck the cell sap and excrete honeydew resulting in the development of sooty mold thereby interfering photosynthetic activity of guava plants.

Guava

Five parasitoids *Anicetus ceylonensis* Howard, *Cephaleta brunniventris* Motsch *Diversinervus elegans* Silvestri, *Metaphycus helvolus* (Compere), *Philosindia* sp. nr. *longicornis* Noyes and Hayat and four predators namely *Chilocorus nigrita*, *Cryptolaemus montrouzieri*, *Cheilomenes sexmaculata* and *Scymnus* sp. are found to attack this scale (Mani, 1995). A field study was conducted to determine the impact of natural enemies in the suppression of wax scale on guava. The initial sampling revealed the natural parasitisation and predation of local biotic agents. By middle of November, *A.ceylonensis*, *C. brunniventris* and *C. nigrita* occurred in large numbers. A maximum of 16.30, 80.30 and 23.30 *C. nigrita*, *A.ceylonensis* and *C. brunniventris* were recorded as given in table. The percent parasitism went up to 98.00%. The scale insect was suppressed mainly due to the activity of locally occurring natural enemies. The wax scale did not appear in the subsequent years (Mani, 1995). Dichlorvos (0.10%) and endosulfan (0.07%) and methyl demeton (0.05%) showed the least residual toxicity to *A. ceylonensis* (Mani and Krishnamoorthy, 1997). Dichlorvos 0.10% and deltamethrin 0.005% were found to be safe to *C. brunniventris* (Mani and Krishnamoorthy, 1995).

Ber

The scale insect caused severe damage to ber in Karnataka. Severe infestation was observed on ber in May 1991 at IIHR Farm, Bangalore. Six parasitoids viz. *Anicetus ceylonensis, Diversinervus elegans, Metaphycus helvolus, Philosinida longicornis* and *Cephaleta brunniventri* and four coccinellid predators *Chilocorus nigrita*., *Cryptolaemus montrouzieri, C. sexmaculata* and *Scymnus* sp. were known to attack the scale in the field. Initial sampling in June did not indicated not much activity of natural enemies. The larval stage of predators *Cryptolaemus montrouzieri, C. sexmaculata* and *Scymnus* sp. were found feeding on the crawlers of the wax scale insect but the predatory population remained very low. The primary parasitoids *Anicetus ceylonensis* and *Cephaleta brunniventris* were found emerging in large numbers than the other parasitoids. *A. ceylonensis* was dominant reaching peak population of 47.60 in January 92. *C. brunniventris* was equally important and a maximum of 27.8 adults emerged in November 91.The other parasitoids had emerged in very small numbers .The parasitism by *A. ceylonensis* and *C. brunniventris* had increased from 5.60 in July 91 to 97.56 in January 92. Fresh scale infestation was not observed in the subsequent months in 1992.It is concluded that *A. ceylonensis* and *C. brunniventris* were able to check the scale population very effectively in India (Mani, 1995).

Hemispherical scale - *Saissetia coffeae*

Saissetia coffeae (Walk.) is a minor pest of citrus in India, and about 10 parasitoids and five predators were known to attack the scale. *Aneristus ceroplastae*, *Anysis saissetiae* (Ashm.), *Cardiogaster fusciventris* Motsch, *Coccophagus flavescens* How. and *Encyrtus adustipennis* Motsch were

reported parasitising this species (Pruthi and Mani, 1945). *Microterys* sp., *Anysis* sp., *Coccophagus* sp., *C. cowperii*, *Chilocorus circumdatus*, *C. nigrita*, *Pharoscymnus horni* (Weise), *C. montrouzieri*, *Chrysopa* sp. and *Lecanicilium lecanii* were recorded on *S.coffeae* in Karnataka (Anon., 1980). The encyrtid *Metaphycus helvolus* Cam. gave complete control of the scale in Peru (Beingolea, 1969).

Brown soft scale - *Coccus hesperidum*

Coccus hesperidum Linn. was usually kept under check by natural enemies on citrus in UP in India. *Physeus* sp. n. *oriensis* Hussain & Agarwal was reared from the scale on citrus (Husain and Agarwal, 1982). In March-April 1980, 51.80% of the scales on papaya were found parasitised by *Aneristus ceroplastae* How. (Joshi *et al.,* 1981).

Plum Scales - *Eulecanium tiliae* & *Eulecanium tiliae coryli*

The coccids *Eulecanium tiliae* (L) & *Eulecanium tiliae coryli* (L) infest plum, apricot, almond, cherry, peach, plum and apple in H.P., Kashmir and U.P. The parasitoids *Coccophagus* sp., *Blastothrix sericea* (Dalman) and the fungus *Rhinocladiella* account for 90 % mortality of the scales in H.P. (Sharma and Dogra, 1986).

Hemilecanium imbricans

Hemilecanium imbricans (Green) was initially low during the months of October to December and gradually increased, reached peak at the end of the April-May on mango and fig. Natural enemies like Chrysopid predator, *Mallada desjardinsi* (Navas) (=*Mallada boninensis* (Okamoto)) was recorded on *H. imbricans* from September to February throughout the season. Other predators found were *Chilocorous nigrita* (Fabricius), larvae of *Eublemma amabilis* (Moore) and an unidentified lepidopteran caterpillar (Patil *et al*.2016).

Fig wax scale, *Ceroplastes rusci*

The population intensity of *Ceroplastes rusci* (Linn.) was observed up to 23.33 insects/twig and up to 10.00 insect/leave. The maximum parasitisation by *Tetrastichus ceroplastae* (Gir.) was 67.6 and 71.20% in month of Mar' 2011 and 2012 respectively. While, parasitisation with *Scutellista cyanea* Motsch was find maximum 83.20 and 73.60% in the month of Sep' 2011 and 2012 respectively. These parasites were found to be efficient natural control of *C. rusci* (Kumar, 2013)

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