



# Natural Enemy Fauna of Mealybugs (Hemiptera: Pseudococcidae) Infesting Vegetables in Kerala, India

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**Abstract:** An investigation was carried out at different districts of Kerala to identify the natural enemy fauna associated with the mealybugs during 2017-2020. Twenty species of predators belongs to five families under four orders viz. Coleoptera, Lepidoptera, Diptera and Neuroptera were recorded from mealybugs infesting vegetables in Kerala. The predominant family was coccinellidae with 16 species under six genera and the majority belongs to the genus *Scymnus*. Among the various predators documented, *Cacoxenus* sp. was recorded the first time as a predator of *Pseudococcus jackbeardsleyi* Gimpel and Milller. Eleven hymenopteran parasitoids belonging to five families were documented from mealybugs, of which the majority belongs to the family Encyrtidae. The record of *Aenasius arizonensis* (Girault) on *Ferrisia virgata* (Cockerell), *Blepyrus insularis* (Cameron) on *P. jackbeardsleyi*, *Leptomastix tsukumiensis* Tachikawa on *Coccidohystrix insolita* Green, *Promuscidea unfasciiventris* Girault on *Coccidohystrix insolita* Green and *Paracoccus marginatus* Williams and Granara de Willink were documented for the first time. The study also identified six hyper parasitoids under the family Encyrtidae, of which *Cheiloneurus nankingensis* Li & Xu was recorded for the first time in India.

**Keywords:** Mealybugs, Natural enemies, Hyper parasitoids, Pseudococcidae, Kerala

Mealybugs are highly specialized hemipteran phytophagous insects belonging to the second largest family of Coccoidea having more than 2000 species with wide distribution around the world. About 354 species of mealybugs under 62 genera were recorded from southern Asia, of which 105 species were reported from India (Ben-Dov 2013). The globalization accelerated the international trade of commodities which augmented the dispersal of mealybugs to newer regions. The polyphagous mealybug is a menace owing to its greater propensity to attack new host plants in the invaded regions that ultimately resulted in economic damage to crops (Franco et al 2009). As a result of climate changes, many mealybug species hitherto known as minor pest, attained the status of major pest in agricultural crops. The damage caused by the mealybugs is associated with sap-sucking, honeydew production, injection of toxic saliva and transmission of viral diseases (Gullan and Martin 2003). Heavy infestations often led to defoliation, distortion of the stem, stunting and ultimately the death of the plants (Hodges and Hodges 2004).

Management of mealybug is a tedious task due to the presence of waxy coating over the body, concealed growth habitat and clumped spatial dispersal pattern. The repetitive application of broad-spectrum chemicals led to the elimination of natural control agents, development of resistance and residue problems (Subramanian et al 2021). However, bio

control agents have strong potential for management of mealybug nymphal stages (Waqas et al 2021). Mealybugs are confronted by a diverse array of natural enemies. A total of 118 species of predators and 79 species of parasitoids were recorded from mealybugs, which signified the importance of biocontrol agents in the population regulation of mealybugs around the world (Shylesha and Mani, 2016). The present study was carried out on exploration of natural enemy species composition of mealybugs in Kerala and that would provide a basis for exploitation of these organisms for future augmentative bio control programmes.

## MATERIAL AND METHODS

An exploration of natural enemy fauna of mealybugs infesting vegetable crops in different agro ecological zones of Kerala was undertaken at College of Agriculture, Vellayani during 2017-2021. Detailed investigation across 14 districts of Kerala covering 41 locations were carried out (Table 1) and a location map was created using the software Arc Gis (Fig. 1). During the survey, the adult predators associated with the mealybugs were collected by aspiration, beating or sweeping and killed using ethyl acetate. The specimens were dry preserved in the laboratory and were labeled with details viz., host insect, date of collection, name of the collector, locality and the host plant. The specimens were dried in a hot air oven at 50°C for 5 days and later transferred into an airtight

**Table 1.** GPS locations of the study area

District	Locations	GPS coordinates	
Thiruvananthapuram	Instructional Farm Vellayani	N 8°25'46.6788" E 76° 59'15.02016"	
	Balaramapuram	N 8°25'14.01" E 77° 2'25.68"	
	Thiruvallom	N 8°24'14.87" E 76° 59'28.23"	
	Panagode	N 8°25'22.62" E 76° 58' 17.4252"	
	Amabalathara	N 8°27'08.0" E 76°57'02.2"	
	Karavaram	N 8°45'09.4" E 76°48'52.9"	
	Kulathoor	N 8°32'19.8" E 76°53'07.6"	
	Chenkai	N 8°22'23.2" E 77°06'02.1"	
	Kollam	FSRS, Sadanandapuram	N 8°58'53.9" E 76°48'39.5"
		Poovattor	N 9°03'22.9" E 76°45'02.0"
Ummannoor		N 8°56'02.6" E 76°48'45.1"	
Paravoor		N 8°48'52.6" E 76°40'11.3"	
Perumkulam		N 9°02'32.4" E 76°45'16.9"	
Kadakkal		N 8°49'48.5" E 76°55'12.2"	
Pathanamthitta		Ezhamkulam	N 9°09'10.4" E 76°46'17.6"
	Prakkanam	N 9° 16' 14.88684" E 76° 44'30.62004"	
	Enathu	N 9°05'28.4" E 76°45'16.3"	
Alapuzha	CPCRI, Kayamkulam	N 9°8'51.02" E 76° 30'50.82"	
	Koickal chantha	N 9°11'5" E 76° 33'20.7"	
	ORARS, Onattukkara	N 9°10'33.46" E76°30'59.41"	
Kottayam	RARS, Kumarakom	N 9°37'39.64" E 76° 25'53.2"	
Idukki	CRS, Pampadumpara	N 9°47'56.0" E 77°09'41.5"	
	Prakandam	N 9°47'51.79092" E 77° 8'59.36748"	
	Valiyathovala	N 9°48'8.45028" E 77° 7'57.04824"	
	Mannakkudi	N 9°47'31" E 77° 8'1.58"	
	Anchumukku	N 9°48'10.53504" E 77° 7'35.46552"	
	Munnar	N 10°05'25.7" E 77°03'15.9"	
Ernakulam	KVK, Ernakulam	N 10°02'33.5" E 76°12'24.9"	
Thrissur	COH, Vellanikkara	N 10° 32'43.5" E 76° 17'0.4"	

**Table 1.** GPS locations of the study area

District	Locations	GPS coordinates
Thrissur	KVK, Thrissur	N 10°32'49.3" E 76°16'05.5"
Palakkad	RARS, Pattambi	N 10°48'40.12812" E 76° 11' 25.82916"
	Muthalamada	N 10°38'14.3" E 76°48'02.4"
Malappuram	KVK, Tavanur	N 10°51'12.36348" E 75°59' 13.15032"
	Vattamkulam	N 10°47'24.6" E 76°01'54.2"
Kozhikode	Kavilumpara	N 11°42'13.2" E 75°47'16.1"
Wayanad	RARS, Ambalawayal	N 11°36'59.8" E 76°12'52.2"
	Manjappara	N 11° 36'14.06196" E 76° 12'35.45856"
Kannur	Aandoor	N 11° 35'17.16828" E 76° 1'32.21832"
	PRS, Panniyur	N 12° 4' 47.6202" E 75° 23'41.84016"
Kasargod	RARS, Pilicode	N 12°12'09.7" E 75°09'53.4"
	COA, Padannakkad	N 12°11'41.9" E 75°11'17.4"

insect box. The immature stages of predators were collected along with the host insect and brought to the laboratory for rearing. The emerged adults were killed and dry preserved. Parasitized mealybugs from the field were collected and kept for adult emergence in plastic containers. The emerged parasitoids were preserved in 75 % ethanol for identification purpose. The specimens were also dry preserved and labeled. The associated mealybug specimens were also collected and stored in 75% alcohol for taxonomic identification. Slide mounted adult female specimens were identified by the keys provided by Williams (2004).

## RESULTS AND DISCUSSION

**Diversity of predators recorded from mealybugs infesting vegetables in Kerala:** Twenty species of predators belongs to five families under four orders viz. Coleoptera, Lepidoptera, Diptera and Neuroptera were recorded from mealybugs infesting vegetables in Kerala (Table 2). In the order Coleoptera, Coccinellidae are potential predators of sucking pests and are the most common group widely exploited for biological control programmes around the globe. The present study recorded the family Coccinellidae as the predominant predators of mealybugs in Kerala with 16 species under seven genera. The major genera of coccinellids recorded were *Brumoides*, *Cheilomenes*, *Hyperaspis*, *Pharoscygnus*, *Cryptolaemus*, *Nephus* and *Scymnus*.

Cont...

The genus *Scymnus* was recorded as the most specious group with seven species actively preying on different mealybugs in Kerala. *Scymnus coccivora* Ayyar was prevalent in the vegetable ecosystem preying on *Coccidohystrix insolita* Green. Vidya and Bhaskar (2017) reported that *S. coccivora* was the predominant mealybug

predator with a wide host range of six mealybugs in Kerala. Manjushree et al (2019) also documented *Scymnus* sp. as the dominant predator of *Dysmiococcus brevipes* Cockerell in Kerala. Most of the *Scymnus* species were found preying on *C. insolita* whereas certain species were observed in *Pseudococcus jackbeardsleyi* Gimpel and Miller and

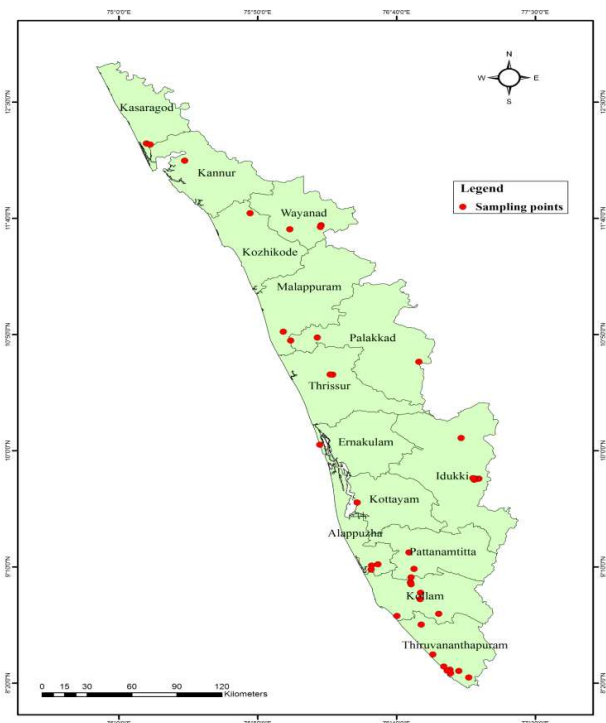
**Table 2.** Predators associated with mealybugs infesting in Kerala

Name of species	Order and family	Prey/associated habit	Associated plants
<i>Brumoides suturalis</i> (Fabricius)	Coleoptera Coccinellidae	<i>Coccidohystrix insolita</i>	<i>Solanum melongena</i>
		<i>Phenacoccus solenopsis</i>	<i>Solanum lycopersicum</i>
<i>Cheilomenes sexmaculata</i> (Fabricius)	Coleoptera Coccinellidae	<i>C. insolita</i>	<i>S. melongena</i>
<i>Cryptolaemus montrouzieri</i> Mulsant	Coleoptera Coccinellidae	<i>C. insolita</i>	<i>S. melongena</i>
		<i>Ferrisia virgata</i>	<i>Colocasia</i> sp. <i>Vigna unguiculata</i> <i>Coffea arabica</i>
<i>Hyperaspis maindroni</i> Sicard	Coleoptera Coccinellidae	<i>C. insolita</i>	<i>S. melongena</i>
<i>Pharoscymnus horni</i> (Wiese)	Coleoptera Coccinellidae	<i>C. insolita</i>	<i>S. melongena</i>
<i>Scymnus coccivora</i> Ayyar	Coleoptera Coccinellidae	<i>C. insolita</i>	<i>S. melongena</i>
<i>Scymnus</i> sp.1	Coleoptera Coccinellidae	<i>C. insolita</i>	<i>S. melongena</i>
<i>Scymnus</i> sp.2	Coleoptera Coccinellidae	<i>C. insolita</i>	<i>S. melongena</i>
<i>Scymnus</i> sp. 3	Coleoptera Coccinellidae	<i>C. insolita</i>	<i>S. melongena</i>
<i>Scymnus</i> sp. 4	Coleoptera Coccinellidae	<i>C. insolita</i>	<i>S. melongena</i>
<i>Scymnus</i> sp. 5	Coleoptera Coccinellidae	<i>Pseudococcus jackbeardsleyi</i>	<i>Codigum varigatum</i>
<i>Scymnus</i> sp. 6	Coleoptera Coccinellidae	<i>F. virgata</i>	<i>C. varigatum</i> <i>Piper longum</i>
<i>Nephus</i> sp.	Coleoptera Coccinellidae	<i>Planococcus</i> sp.	<i>Theobroma cacao</i>
unidentified sp.1	Coleoptera Coccinellidae	<i>F. virgata</i>	<i>Cnidoscopus aconitifolius</i>
unidentified sp. 2	Coleoptera Coccinellidae	<i>C. insolita</i>	<i>S. melongena</i>
unidentified sp. 3	Coleoptera Coccinellidae	<i>C. insolita</i>	<i>S. melongena</i>
<i>Spalgis epius</i> (Westwood)	Lepidoptera Lycaenidae	<i>C. insolita</i>	<i>S. melongena</i>
		<i>Planococcus</i> sp.	<i>T. cacao</i>
		<i>F. virgata</i>	<i>S. melongena</i>
		<i>P. solenopsis</i>	<i>Hibiscus</i> sp.
<i>Diadiplosis</i> sp.	Diptera Cecidomyiidae	<i>Paracoccus marginatus</i>	<i>S. melongena</i>
		<i>P. jackbeardsleyi</i>	<i>S. melongena</i>
<i>Cacoxenus</i> sp.	Diptera Drosophilidae	<i>P. jackbeardsleyi</i>	<i>Cordyline terminalis</i>
<i>Chrysoperla</i> sp.	Neuroptera Chrysopidae	<i>F. virgata</i>	<i>C. aconitifolius</i>
		<i>C. insolita</i>	<i>S. melongena</i>

*Ferrisia virgata* (Cockerell). The mealybug destroyer, *Cryptolaemus montrouzieri* Mulsant, rare in plain areas of Kerala was observed from Balaramapuram of Thiruvananthapuram district which predated on *C. insolita*. *C. montrouzieri* was also recorded as the dominant predator of *F. virgata* in high altitude regions of Kerala. Similar results were corroborated by Vidya (2017).

The ape fly, *Spalgis epius* (Westwood) belongs to the family Lycaenidae (Order: Lepidoptera), a potential predator of mealybug, was recorded from *C. insolita*, *F. virgata*, *Phenacoccus solenopsis* Tinsley, *Paracoccus marginatus* Williams and Granara de Willink and *Planococcus* sp. The larval stages of the lycaenid were observed as voracious feeder of all stages of mealybug. Dinesh and Venkatesha (2011) documented *S. epius* as a dominant predator of *Planococcus lilacinus* (Cockerell) and *F. virgata* whereas Mani et al (2012) reported *S. epius* as a voracious predator of *P. marginatus* in Kerala. Arya (2015) recorded *S. epius* as a potential predator of *C. insolita* in Kerala.

The present study recorded two dipteran predators of family Cecidomyiidae and Drosophilidae from mealybugs of Kerala. The major mealybug predators in the order Diptera are belongs to the family Cecidomyiidae, Drosophilidae and Syrphidae (Shylesha and Mani 2016). The family Cecidomyiidae are well known for phytophagous species but it also consists of several potential predators of mealybugs. However, studies on the life history and taxonomy of these species are meagre which restrain the use of these species in biocontrol programmes (Hayon et al 2016). The predatory gall midge, *Diadiplosis* sp. was documented as a predator of the mealybug, *P. jackbeardsleyi* in Kerala. The larval stages of the gall midge act as active predator of mealybugs preferably feeding on egg and early instar nymphs. The genus *Diadiplosis*, a cosmopolitan genus, commonly distributed in the tropical regions were reported as a predator of several mealybugs and the species *Diadiplosis martinsensis* Culik and Ventura was recorded from *P. jackbeardsleyi* on pineapple and coffee (Culik and Ventura 2013, Urso-Guimaraes et al 2020). The larval stages of the genus *Cacoxenus* belong to the family Drosophilidae was observed on a new mealybug host, *P. jackbeardsleyi* in Kerala. Mani and Shivaraju (2016) reported that drosophilid predators play a supplementary role in the regulation of mealybug population. The genus *Cacoxenus* was previously reported in Kerala as a predator of *D. brevipes* on pineapple (Manjushree et al 2019). The chrysopid predators are voracious feeders of mealybugs and a single species of *Chrysoperla* was recorded as a predator of the mealybug, *F. virgata* and *C. insolita* in Kerala. Adly et al (2016) reported *Chrysoperla carnea* (Steph.) as a predator of *F. virgata*



**Fig. 1.** Study area and locations surveyed for collection of natural enemy fauna in Kerala

infesting Guava in Egypt. The *Chrysoperla zastrowii sillemi* Esben-Peterson recorded a predatory efficiency of 66.87 *F. virgata* nymphs in its entire larval period that highlighted the importance of chrysopids in regulating the mealybug population in an ecosystem (Elango et al 2020).

Among the different mealybug species recorded from Kerala, the highest number of predators were observed in *C. insolita* (13 species) followed by *F. virgata* (5 species). The major predators on *C. insolita* belongs to the family Coccinellidae with 12 species. The relatively high preference exhibited by coccinellids on *C. insolita* may be due to the predator-prey size relationship as most of the coccinellids were very small in size especially the genus *Scymnus* which was a dominant predator on mealybug *C. insolita*. The morphological peculiarities of the mealybug viz., small size and less mobility favored the easy predation on *C. insolita*. Furthermore, most of the coccinellid grubs were observed to be feeding on the eggs in the long ovisac of *C. insolita* that provided protection from harsh external factors. Kitherian et al (2018) also pointed out that predator-prey size ratio and morphological adaptations aids in a higher predation rate of reduviid predators on *P. solenopsis*.

**Diversity of parasitoids of mealybugs:** Mealybugs were parasitized by an array of hymenopteran parasitoids and about 11 species belong to five families were recorded from

Kerala (Table 3). The majority of mealybug parasitoids belongs to the family Encyrtidae followed by Eriaporidae in Kerala. Similar observations were also made by Hayat (2006) and Mani and Shivaraju (2016). The family Encyrtidae contains five species belonging to the subfamily Tetracneminae. Among the encyrtids, the most common genera were *Aenasius* comprised of two species viz., *Aenasius arizonensis* (Girault) parasitizing on *P. solenopsis* and *F. virgata* and *Aenasius advena* Compere parasitizing on *F. virgata*. *A. arizonensis*, an indigenous parasitoid, was recorded as the most successful hymenopteran biocontrol agent of mealybug which recorded 90 per cent parasitism in *P. solenopsis* (Tanwar et al 2011). Bharathi et al (2009) Sudhendu et al. (2010) and Shera et al (2017) also recorded *A. arizonensis* as a specific parasitoid of *P. solenopsis*. The

record of *A. arizonensis* on *F. virgata* was recorded for the first time. Nalini and Manickavasagam (2019) recorded *A. arizonensis* and *A. advena* as dominant parasitoids of *P. solenopsis* and *F. virgata* respectively in Tamil Nadu. Similarly, a high rate of parasitization on *F. virgata* by *A. advena* was noted by Ayyamperumal (2019) and Krishnamoorthy et al (2021).

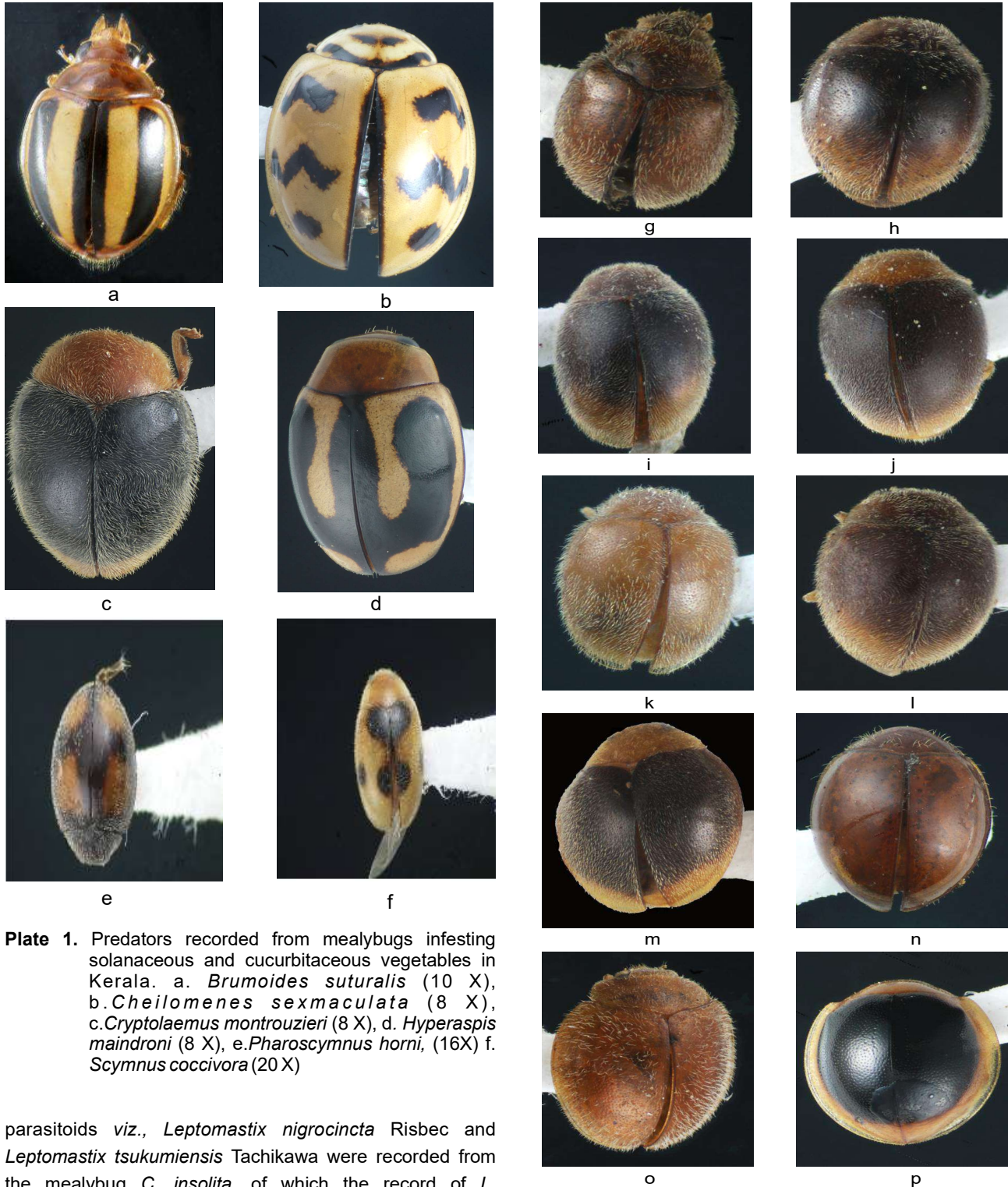
An encyrtid internal parasitoid, *Blepyrus insularis* (Cameron) was recorded from three mealybugs viz., *F. virgata*, *P. solenopsis* and *P. jackbeardsleyi* from Kerala. Nalini and Manickavasagam (2011) recorded *B. insularis* as a parasitoid of *F. virgata* and *P. solenopsis* in Tamil Nadu. Similar observations were also made by Ayyamperumal (2019). The host-parasitoid association of *B. insularis* and *P. jackbeardsleyi* was recorded for the first time. Two encyrtid

**Table 3.** Parasitoids associated with the mealybugs infesting vegetables in Kerala

Species	Family	Host insect	Associated plants
<i>Aenasius arizonensis</i> (Girault)	Encyrtidae: Tetracneminae	<i>F. virgata</i>	<i>Hibiscus rosachinensis</i> <i>S. lycopersicum</i>
		<i>F. virgata</i>	<i>C. aconitifolius</i>
<i>Aenasius advena</i> Compere	Encyrtidae: Tetracneminae	<i>F. virgata</i>	<i>C. aconitifolius</i>
<i>Blepyrus insularis</i> (Cameron)	Encyrtidae : Tetracneminae	<i>F. virgata</i>	<i>S. melongena</i> <i>C. terminalis</i>
		<i>P. solenopsis</i>	<i>Abelmoschus esculentus</i>
		<i>P. jackbeardsleyi</i>	<i>S. lycopersicum</i>
		<i>C. insolita</i>	<i>S. melongena</i>
<i>Leptomastix nigrocincta</i> Risbec	Encyrtidae: Tetracneminae	<i>C. insolita</i>	<i>S. melongena</i>
<i>Leptomastix tsukumiensis</i> Tachikawa	Encyrtidae: Tetracneminae	<i>C. insolita</i>	<i>S. melongena</i>
<i>Promusciae unifasciiventris</i> Girault	Eriaporidae: Eriaporinae	<i>C. insolita</i>	<i>S. melongena</i>
		<i>P. marginatus</i>	<i>S. melongena</i>
		<i>F. virgata</i>	<i>C. aconitifolius</i>
		<i>P. solenopsis</i>	<i>Capsicum annum</i>
<i>Myiocnema comperei</i> Ashmead	Eriaporidae: Euryischinae	<i>P. solenopsis</i>	<i>C. annum</i>
Unidentified	Superfamily Proctotrupeidea	<i>P. jackbeardsleyi</i>	<i>C. terminalis</i>
Unidentified	Superfamily Proctotrupeidea	<i>C. insolita</i>	<i>S. melongena</i>
Unidentified	Aphelinidae	<i>P. jackbeardsleyi</i>	<i>C. terminalis</i>
Unidentified	Pteromalidae	<i>P. solenopsis</i>	<i>C. annum</i>

**Table 4.** Hyper parasitoids associated with the mealybugs infesting vegetables in Kerala

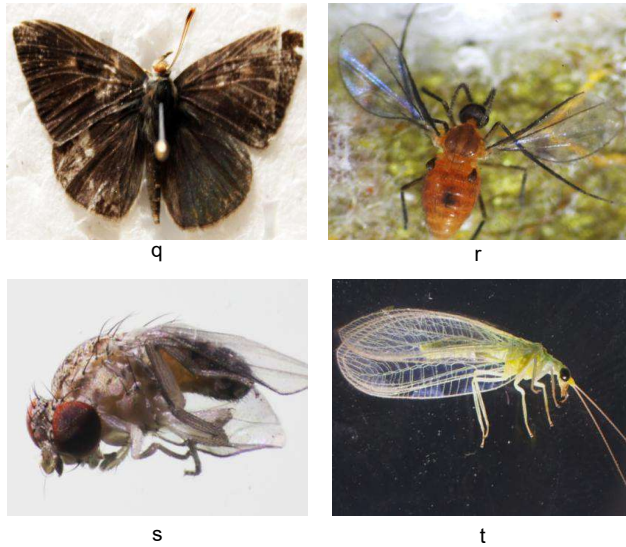
Species	Family	Associated mealybug	Plants surveyed	Location
<i>Cheiloneurus nankingensis</i> Li & Xu	Encyrtidae : Encyrtinae	<i>P. solenopsis</i>	<i>Sesamum indicum</i>	Kayamkulam
<i>Cheiloneurus</i> sp.	Encyrtidae : Encyrtinae	<i>P. solenopsis</i>	<i>Cucurbita pepo</i>	Pattambi
<i>Cheiloneurus</i> sp.	Encyrtidae : Encyrtinae	<i>P. solenopsis</i>	<i>S. indicum</i>	Kayamkulam
<i>Cheiloneurus</i> sp.	Encyrtidae : Encyrtinae	<i>P. solenopsis</i>	<i>Solanum</i> sp.	Vellayani
<i>Prochiloneris pulchellus</i> Silvestri	Encyrtidae : Encyrtinae	<i>C. insolita</i>	<i>S. melongena</i>	Vellayani
<i>Prochiloneris</i> sp.	Encyrtidae : Encyrtinae	<i>P. solenopsis</i>	<i>Euphorbia</i> sp.	Kayamkulam



**Plate 1.** Predators recorded from mealybugs infesting solanaceous and cucurbitaceous vegetables in Kerala. a. *Brumoides suturalis* (10 X), b. *Cheilomenes sexmaculata* (8 X), c. *Cryptolaemus montrouzieri* (8 X), d. *Hyperaspis maindroni* (8 X), e. *Pharoscymnus horni*, (16X) f. *Scymnus coccivora* (20 X)

parasitoids viz., *Leptomastix nigrocincta* Risbec and *Leptomastix tsukumiensis* Tachikawa were recorded from the mealybug *C. insolita*, of which the record of *L. tsukumiensis* on *C. insolita* was documented for the first time in the world. Nalini (2015) and Nalini and Manickavasagam (2011) reported *L. nigrocincta* as a parasitoid of *C. insolita* in Tamil Nadu. The parasitoid, *Promuscidea un fasciiventris* Girault belongs to the family Eriaporidae was observed on mealybugs such as *C. insolita*, *P. marginatus*, *F. virgata* and

**Plate 1.** Predators recorded from mealybugs infesting solanaceous and cucurbitaceous vegetables in Kerala. g. *Scymnus* sp.1 (20X), h. *Scymnus* sp.2 (20X), i. *Scymnus* sp.3 (20X), j. *Scymnus* sp.4 (20X), k. *Scymnus* sp.5 (20X), l. *Scymnus* sp.6 (20X), m. *Nephus* sp. (16 X), n. unidentified sp.1 (16 X), o. unidentified sp. 2 (16 X), p. unidentified sp. 3 (16 X)

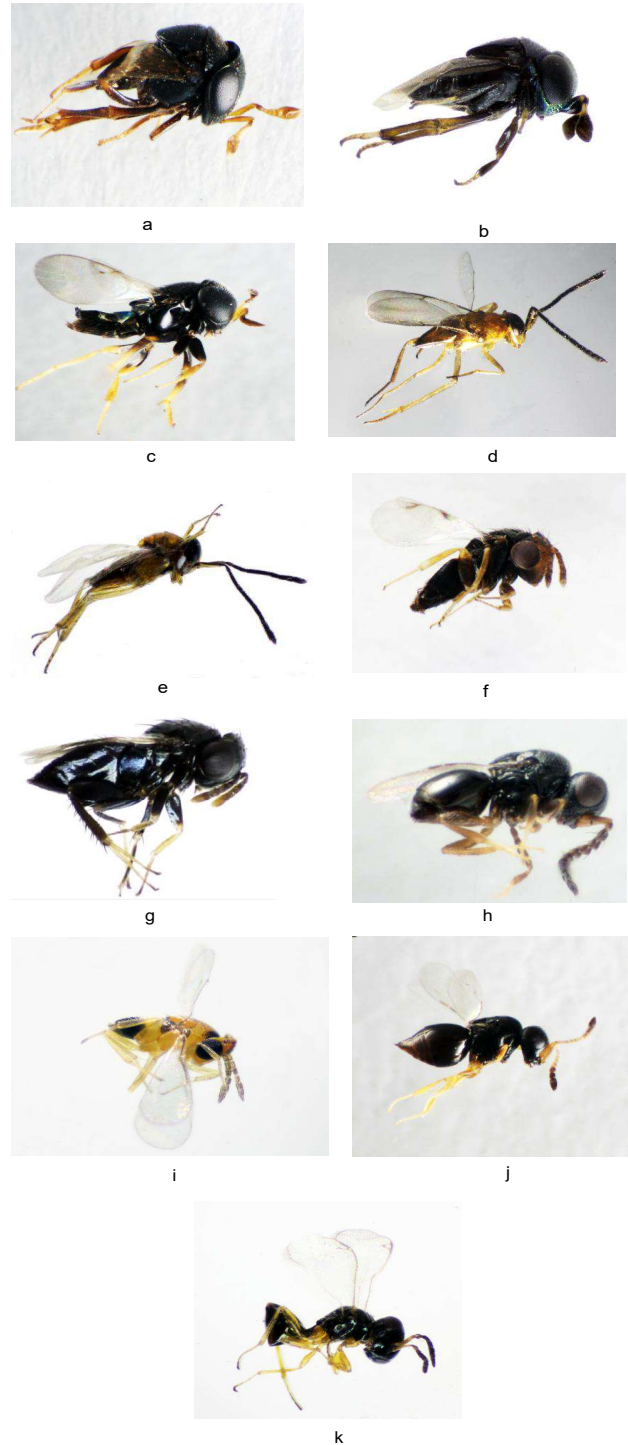


**Plate 1.** Predators recorded from mealybugs infesting solanaceous and cucurbitaceous vegetables in Kerala. q. *Spalgis epius*, r. *Diadiplosis* sp. (20X), s. *Cacoxenus* sp (10X), t. *Chrysoperla* sp. (8X)

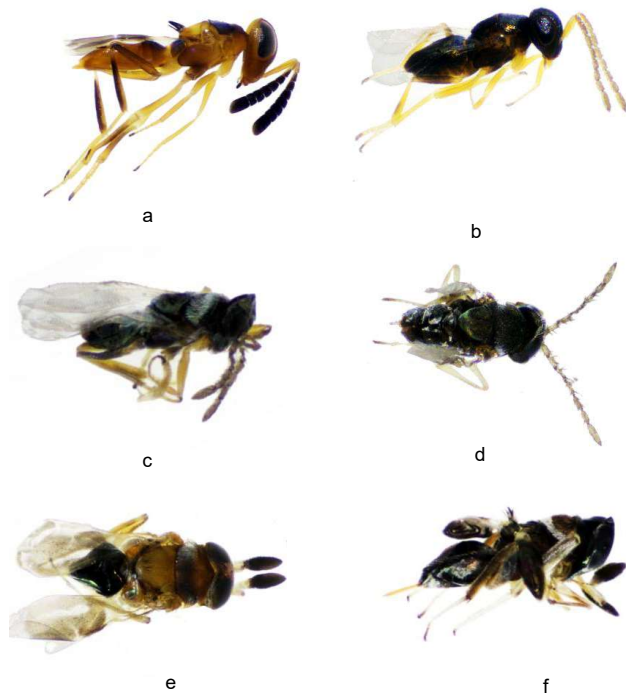
*P. solenopsis* in Kerala. Jhala et al (2009) and Bharathi and Muthukrishnan (2017) documented *P. unfauciiventris* as the primary parasitoid of *P. solenopsis*. However, Ayyamperumal (2019), Torfi et al (2020) and Chen et al (2021) reported *P. unfauciiventris* as a parasitoid of *A. arizonensis* and a hyper parasitoid of *P. solenopsis*. The host-parasitoid associations of *P. unfauciiventris* - *C. insolita* and *P. unfauciiventris*- *P. marginatus* were recorded for the first time in the world. *Myiocnema comperei* Ashmead which belongs to the family Eriaporidae, was also recorded from *P. solenopsis* in Kerala. However, it was recorded as a hyper parasitoid associated with *P. solenopsis* by Ruan et al (2012) and Suroshe et al. (2013) whereas Padmanabhan (2017) and Chen et al (2021) recorded it as a parasitoid of *P. solenopsis* from Kerala and China respectively.

Two species of parasitoids belongs to the superfamily Proctotrupoidea were found to be parasitizing on mealybugs *P. jackbeardsleyi* and *C. insolita* in Kerala. Yasnosh (2016) reported the members of the family Proctotrupoidea from mealybugs, *Pseudococcus* sp. and *Planococcus* sp. Two other parasitoids each from the family Aphelinidae and Pteromalidae parasitizing on *P. jackbeardsleyi* and, *P. solenopsis* were also reported from Kerala during the study. Among the various mealybugs observed in Kerala, *P. solenopsis* was recorded with the maximum number of parasitoids followed by *C. insolita* and *F. virgata*. This may be due to the abundance of these mealybugs in the agroecosystems of Kerala.

**Diversity of hyper parasitoids:** The present study also



**Plate 2.** Parasitoids recorded from mealybugs infesting solanaceous and cucurbitaceous vegetables in Kerala. a. *Aenasius arizonensis* (20X), b. *Aenasius advena* (20X), c. *Blepyrus insularis* (20X), d. *Leptomastix nigrocincta* (16X), e. *Leptomastix tsukumiensis* (16X), f. *Promuscidea unfauciiventris* (20 X), g. *Myiocnema comperei* (20X), h. Superfamily Proctotrupoidea (25X), i. Superfamily Proctotrupoidea (25X), j. Aphelinidae (16X), k. Pteromalidae (25X)



**Plate 3.** Hyper parasitoids recorded from mealybugs infesting solanaceous and cucurbitaceous vegetables in Kerala. a. *Cheiloneurus* sp. (20X), b. *Cheiloneurus* sp. (25X), c. *Cheiloneurus* sp. (32X), d. *Cheiloneurus* sp. (25X), e. *Prochiloneurus pulchellus* (20 X), f. *Prochiloneurus* sp. (20 X)

identified six hyperparasitoids belongs to the family Encyrtidae which comprised of the genera *Cheiloneurus* and *Prochiloneurus* (Table 3). Among these, *Cheiloneurus nankingensis* Li & Xu was reported for the first time in India. The genus *Prochiloneurus* is usually a hyperparasitoid of mealybugs and scale insects via parasitization on primary encyrtid parasitoids (Hayat, 2006). Wang et al (2014) documented *Prochiloneurus* sp. as a parasitoid of *A. arizonensis* in China and Ayyamperumal (2019) recorded *Prochiloneurus* and *Chiloneurus* sp. as hyperparasitoids of *P. solenopsis* and *F. virgata* through *A. arizonensis* in India. The new hyperparasitoids were found as a menace to the natural biological control methods that kept the mealybug population under check.

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