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Contents

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Life cycle of the dung beetle *Onthophagus cervus* (Fabricius, 1798) (Coleoptera: Scarabaeidae: Scarabaeinae) in moist belts of south India

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ABSTRACT: Biology, nesting behaviour, and the factors favouring the high abundance of prominent dung beetle species, *Onthophagus cervus* (Fabricius, 1798) in an open agricultural field in North Kerala were studied. Short life cycle with high fecundity, low egg mortality, shorter larval duration, shorter developmental period, short generation time, female-biased sex ratio, and longer survivability of females were recorded. Female-biased sex ratio in *O. cervus* indicates that mating competition takes place between male offsprings and the high cost of producing males led to their reduction. Broad categorization of *Onthophagus* species is provided based on the comparison of data of brood mass production, fecundity, duration of egg, larval, pupal, adult stages, adult mortality and life span of various *Onthophagus* species. Higher abundance of *O. cervus* in the region is attributed to traits that are characterize of ***r***-selection such as high fecundity, small body size, low egg mortality, shorter larval duration, early onset of maturity, and shorter developmental period. Short generation time which enables attaining maturity earlier together with female biased sex ratio, longer duration of females favouring high egg production and shallow tunnels which enable easy and fast tunnelling process and development in thin soil top soil layer are the other factors that contributed to the higher abundance of *O. cervus*. Present study showed that geographic region wise knowledge on the life history traits of prominent dung beetles are necessary for interpretation of the exact mechanism behind their seasonality and abundance in specific regions and the generated data will be useful for the conservation of species in natural habitats.

KEY WORDS: Onthophagini, fecundity, sex ratio, male and female longevity, nesting behaviour

INTRODUCTION

Scarabaeid dung beetles (Scarabaeidae) belong to three distinct taxonomic groups, Scarabaeinae, Geotrupinae, and Aphodiinae (Baraud, 1985). Within the sub families, Scarabaeinae is the only group that is predominantly coprophagous. They feed on decomposing matter, carrion, decaying fruits, and fungi (Hanski and Cambefort, 1991). Dung beetles are one of the most important invertebrate contributors to dung decomposition in both temperate and tropical agricultural grasslands (Gittings *et al.,* 1994; Davis, 1996a,b; Horgan, 2001; Lee and Wall, 2006; Slade *et al.,* 2011; Kaartinen *et al*., 2013). Dung removal (Slade *et al.,* 2011), nutrient cycling (Menendez *et al.,* 2016; Nervo *et al*., 2017) seed dispersal (Lugon *et al*., 2017), and reduction of greenhouse gas emissions (Piccini *et al*., 2017) are the major ecosystem services provided by dung beetles.

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Analysis of the structure and local distribution of dung beetle assemblages in different biogeographic regions showed that dominant dung beetle species varies among different regions (Nealis, 1977; Doube, 1983; Janzen, 1983; Davis, 1993; Davis, 1998; Davis and Sutton, 1998; Davis *et al*., 2002). *Canthon histrio* Serville, 1828, *Onthophagus hirculus* Billberg, 1815, and *Deltochilum verruciferum* Felshe, 1911 are prominent species in Brazilian dry forest (Novais *et al*., 2016); *Dichotomius amplicollis* Harold, 1869, *Deltochilum gibbosum* (Fabricius, 1775) and *Onthophagus landolti* Harold, 1880 in Mexican dry forest (Andresen 2005, 2008); *O. wallacei* Harold, 1871, *O. fuscostriatus* Boucomont, 1914 in Indonesian forest (Shahabuddin, 2010); *O. vulpus* Harold, 1877, *Sisyphus thoracicus* Sharp, 1875 in a tropical rainforest in Malaysia (Davis, 2000); *Oniticellus pseudoplanatus* Balthasar, 1964 in moist forests of Ivory Coast (Cambefort and Walter, 1991); *Caccobius vulcanus* (Fabricius, 1801), *O. centricornis* Fabricius, 1798, *Tiniocellus spinipes* Roth, 1851, *Caccobius ultor* Sharp, 1875, *O. cervus* (Fabricius, 1798) and *O. dama* (Fabricius, 1798) in the moist belts of south India (Vinod, 2009; Sabu, 2011; Sabu *et al.*, 2011; Simi *et al*., 2012); *Digitonthophagus gazella* (Fabricius, 1787), *O. rectecornutus* Lansberge, 1883, *Copris repertus* Walker, 1858, *C. fricator* (Fabricius, 1787) in Deccan region in south India (Veenakumari and Veeresh, 1994, 1996); *Catharsius pithecius* (Fabricius, 1775) and *Gymnopleurus cyaneus* (Fabricius, 1798) in the agriculture belts in Maharashtra (Patole, 2019) and *Tiniocellus spinipes* Roth, 1851, *Tibiodrepanus sinicus* Harold, 1868, and *Caccobius ultor* Sharp, 1875 in the forests of Haryana in North Western India (Mittal, 2005; Kakkar and Gupta, 2009, Kakkar 2010). However, lack of knowledge on the biology and ecology of prominent dung beetles makes interpretation of the exact mechanism behind their seasonality, abundance and conservation strategies to be adopted in the natual habitats in specific regions impossible (Vinod 2009; Latha, 2011; Nithya, 2012; Sabu, 2012; Sobhana, 2014; Subha, 2017). A quick review revealed that except for the data available on the reproductive biology of *O. hirculus* in Brazil (Gonzalez and Morelli, 1999), *O. landolti* in Mexico (Pérez-Cogollo *et al*., 2015), *O. rectecornutus* Lansberg 1883, *Copris repertus* Walker 1858 and *C. fricator* Fabricius 1787 in south India (Veenakumari and Veeresh, 1994, 1996), reproductive biology of other prominent dung beetles is not available. The present study has been undertaken to understand the life history traits of the prominent dung beetle species, *O. cervus* in the moist belts of south India.

MATERIAL AND METHODS

Adult *O. cervus* beetles were collected using dung baited pitfall traps and hand picking from an open agricultural field at Naduvattam, Malappuram district, Kerala (India) (10^{0}52'55.92"N, 76^{0}0'29.59"E) during June 2016 to December 2017 period. Pitfall traps made of plastic basins, 10 cm in diameter and 15 cm deep with the minimum quantity of water to prevent the drowning of the fallen beetles, were placed in the field during 8:00 am to 12:00 pm. Preliminary verification and separation and sexing of the collected beetles were done by comparing with verified specimens and based on the morphological characters and taxonomic keys in Arrow (1931). Based on morphological characters such as small body size and colour, beetles of uniform age were selected and grouped. Ten mating pairs were selected, each pair was placed in an individual wide mouthed earthen pot with (diameter 51.5 cm, thickness 0.9 cm, and length 14 cm) and filled with finely sieved clay soil collected from the collection site and moistened with water with a depth of 13.5 cm and fresh cow dung on top for food and the construction of brood balls and each pair were provided with fresh cow dung twice a week. Top of the earthen pots was covered with mesh net (mesh size 0.053 µm) to prevent the escape of the beetles and the pots were kept at controlled room conditions (Temperature 23^{0}C-25^{0}C; humidity 75%). Water was sprayed with a mist sprayer on alternate days to prevent desiccation. Daily observations for all life events, such as brood ball formation, egg-laying, egg hatching, duration of the larval and pupal phase, and adult emergence were noted and parallel

laboratory culture was maintained for observing each life cycle stage of the development and also for studying the nest architecture. In order to monitor the life cycle and development of egg, different stages of larval development, pupa and until adult emergence were recorded by making a small opening on each brood ball, which was closed by pasting with a layer of dung and soil after each observation and the brood masses/balls were retained in individual earthen pots arranged with moist soil. Observations were made twice a week until the emergence of new adults. Number, length and width of the brood masses, number of larvae, pupae and adults, and the size of the adults were recorded. Newly emerged beetles were collected, paired and counted and transferred to new individual earthen pot topped with fresh cow dung and were kept until their natural death. Adult longevity (after emergence from their brood ball) is known only in laboratory reared specimens and the survival period was noted for each individual beetle. Experiment set up was kept moist by sprinkling water to prevent desiccation.

Preliminary analysis was done in the field beneath the dung pats to get an idea about the tunnelling behaviour; brood ball construction, nesting preparation, and also open the tunnels by digging in the agriculture field from where the beetle collections were made. For the study of the nest architecture, adult beetles got from the collection site, were placed in plastic pots (15×15×16 cm) which was cut into half lengthwise and re-joined with masking tape to retain their original shape. The re-joined plastic pot was filled with moist soil up to a depth of 12 cm and topped with fresh cow dung droppings. Beetles were transferred to the pre-arranged plastic pot containing soil and cow dung topping. Top of the plastic pot was covered with a mesh net, after introducing the beetles to prevent their escape. The experiment setup was kept moistened by sprinkling water to prevent desiccation. After two weeks, the plastic pot was opened into two halves vertically with care, and the notes were being made on the nest architecture and the length of the tunnel was taken. Photographs were taken using Nikon digital camera D90 and Leica S8APO (Trinocular stereo zoom microscope).

RESULTS

Biology of *Onthophagus cervus*: The life biology involved four stages namely egg, larva, pupa, and adult. Egg stage lasted for 3.60±0.51 days, the larval stage for 16.70 ±1.87 days, the pupal stage for 10.20±1.03 days, and adult stage for 60.17± 2.08 days.

Brood mass and eggs (Fig. 1A-N): Adult beetles constructed brood balls after 12.4±0.69 days. A single mating pair produced 14.10±5.69 brood balls during its period of the life cycle. Oval shaped brood balls have a length of 20.4±0.97 mm, width 32.8±1.62 mm and were coated by a layer of soil and dung (Fig: 1A). The brood masses were formed of dung mass with an egg chamber with the egg glued to the wall of the egg chamber (Fig. 1B). Brood masses were attached to the wall and end of the tunnels. Eggs were elongate oval in appearance and creamy white, during the first two days. Prior to hatching (3rd day), egg became yellowish and the egg shell became transparent (3rd and 4th day) and the larva was clearly visible through the chorion. Egg stage lasted for 3.6±0.51 days. A single mating pair produced 21.7±6.69 surviving eggs during its life time. Low egg mortality (14.57%) was recorded.

Larva: Three larval instars (Fig. 1C, D, E) were recorded. Newly emerged larvae were transparent with the tips of the mandible being dark brown. Larvae were found in a cavity inside a brood ball and they consumed the dung ball from inside. Newly hatched larvae were creamy white fleshy "grubs". All larvae have the characteristic "coprine hump" and the flattened, fleshy-lobed anal segment. The larval period lasted for 16.7±1.87 days. Low larval mortality (16.12%) was recorded. A single mating pair produced 18.2±6.58 surviving larvae.

Pupa: Pupae were present inside the thin walled pupal cell or cocoon constructed by larva inside the brood ball. Inner surface of the pupal cell was smooth and were coated with soft dried dung and soil (Fig. 1F). Newly formed pupae were creamy white, shiny, with four pairs of finger-like processes on the dorso-lateral region of the abdomen and a large, blunt pronotal projection extending over a

posterior portion of the head. Later on, the pupae turned golden brown in colour (Fig. 1G, H). The pupal period lasted for 10.2 ± 1.03 days. Pupal mortality (27.48%) was recorded. A single mating pair produced 13.2±4.88 pupae.

Adult: Teneral period lasted 2.40 ±0.51 days. The teneral adult was light orange-red in colour (Fig: 1, I). Adult emerged by cutting a hole in the brood ball (Fig. 1J). 67.42% of adults emerged (30 females and 10 males) and the sex ratio of 3:1 was observed. Newly formed adults took 1.40±0.52 days for the complete melanisation. On exit from the brood ball, newly emerged beetles constructed the tunnels. Sexual maturity was attained by 11±1.05 days of emergence. Adult male (Fig. 1K) duration of 35.2±8.65 days and female (Fig. 1L) duration of 60.17± 2.08 days were observed. Egg to teneral adults, took 28.2 ±1.03 days. A single mating pair produced 4±2.21 surviving adults during its life time.

Nesting behaviour: Adult beetles (males and females), upon releasing, made vertical (Fig. 1M) and horizontal tunnels (Fig. 1N). Both males and females were involved in tunnel construction and handling of dung. Both vertical and horizontal tunnels were made and were interconnected. Vertical tunnels with a depth of 6.96±1.30 cm and horizontal tunnels were with a length of 2.25±0.59 cm, were observed. Brood masses were present at the bottom of the tunnels. Brood balls were seen in single or in mass.

DISCUSSION

The present study provides data on the reproductive biology and life span of *Onthophagus cervus* and also enabled comparison of data with other *Onthophagus* species. Comparison of data on brood mass production, fecundity, duration of egg, larval, pupal, adult stages, adult mortality and life span of *O. cervus* with other *Onthophagus* species revealed that a broad categorization of *Onthophagus* species based on the life cycle characteristics are possible. Data on the brood mass production of different *Onthophagus s*pecies showed that *Onthophagus* species can be categorized as high and low brood mass producers. *Onthophagus stylocerus* (Samper and Piera*,* 1995); *O. rectecornutus* (Veenakumari and Veeresh, 1996); *O. lentolti* (Pérez-Cogollo *et al.,* 2015); *O. catta* (Gaikwad and Bhawane, 2016)*,* and *O. cervus* comes under the category of high brood mass producers with a brood mass range of 1–40 and *O. hirculus* (Gonzalez and Morelli, 1999); *O. incensus* (Huerta and Garcia, 2013); *O. lecontei* (Arellano *et al.,* 2017) falls under the category of low brood mass producers with a brood mass range of 1–10. Similarly based on the size of brood ball two categories of *Onthophagus* species are recognizable with a large sized brood ball category consisting of, *O. stylocerus* (Samper and Piera*,* 1995); *O. rectecornutus* (Veenkumari and Veeresh, 1996); *O. catta* (Gaikwad ánd Bhawane, 2016) and small brood ball category of *O. medorensis* (Hunter *et al.,* 1991); *O. depressus* (Hunter *et al.,* 1996); *O. hirculus* (Gonzalez and Morelli, 1999); *O. lecontei* (Arellano *et al.,* 2017), and *O. cervus.*

Duration of egg incubation revealed a pattern of longer egg incubation period in *O. medorensis* (Hunter III *et al*., 1991.); *O. stylocerus* (Samper and Piera*,*1995); *O. depressus* (Hunter *et al.,* 1996); *O. rectecornutus* (Veenakumari and Veeresh, 1996); *O. hirculus* (González-Vainer and Morelli, 1999); *O. incensus* (Huerta *et al.,* 2010), *O. cervus,* and short egg incubation period in *O. landolti* (Pérez-Cogollo *et al*., 2015); *O. catta* (Gaikwad and Bhawane, 2016), and in *O. lecontei* (Arellano *et al.,* 2017).

Comparison of larval duration showed that *O. cervus* and *O. rectecornutus* (Veenakumari and Veeresh, 1996) belong to the shorter larval duration category compared to *O. medorensis* (Hunter *et al.,*1991*); O. stylocerus* (Samper and Piera*,* 1995); *O. depressus* (Hunter *et al.,*1996); *O. incensus* (Huerta *et al.,* 2010); *O. landolti* (Pérez-Cogollo *et al*., 2015); *O. catta* (Gaikwad and Bhawane, 2016)*;* and *O. lecontei* (Arellano *et al.,* 2017) with long larval duration period. Comparison of pupal duration among the various *Onthophagus* species show that *O. landolti* (Pérez-Cogollo *et al*., 2015) has short pupal period compared to longer pupal duration in *O. medorensis* (Hunter *et al.,* 1991); *O. stylocerus* (Samper and

Fig. 1A) Brood ball of *Onthophgus cervus,* B) Egg glued to the wall of brood mass, C) First instar larva, D) Second instar larva, E) Third instar larva, F) Pupal cell, G) Pupa - early phase, H) Pupa - late phase, I) Teneral adult, J) Emergence of adult from pupal cell, K) Adult male, L) Adult Female, M& N) Nesting behaviour - vertical & horizontal tunnels.

Piera,1995); *O. depressus* (Hunter *et al.,* 1996); *O. rectecornutus* (Veenakumari and Veeresh, 1996); *O. catta* (Gaikwad and Bhawane, 2016); *O. cervus,* and *O. lecontei* (Arellano *et al.,* 2017). Higher variability in egg hatchability, larval and pupal survivability under uniform conditions in many samples indicate that wider variation exists in the population and the exact reasons are not understood and could be genetical.

Developmental period of *O. cervus* (egg to a teneral adult) and Mexican species *O. landolti* (Pérez-

Table 1. Fecundity, egg mortality, egg hatchability, larval survivability, pupal survivability and adult mortality of *Onthophagus cervus* in the moist belts of south India

Parameters	Mean ±SD	(%)
Fecundity (No of eggs per female)	25.4±6.67	-
Egg hatchability	21.7±6.69	85.43
Egg mortality	3.7±2.31	14.57
Larval survivability	18.2±6.58	83.88
Larval mortality	3.5±1.50	16.12
Pupal survivability	13.2±4.88	72.52
Pupal mortality	5±2.62	27.48
Adult survivability	4±2.21	30.30
Adult mortality	9.2±2.57	69.69

Cogollo *et al.,* 2015) was the shortest among the various *Onthophagus* species. Teneral adult period was shorter in *O. cervus* compared to other *Onthophagus* species. Comparison of adult duration showed that *O. cervus* and *O. medorensis* (Hunter *et al.,* 1991); *O. depressus* (Hunter *et al.,* 1996); *O. landolti* (Pérez-Cogollo *et al*., 2015); *O. lecontei* (Arellano *et al.,* 2017); were species with short adult longevity whereas, *O. stylocerus* (Samper and Piera,1995); *O. rectecornutus* (Veenakumari and Veeresh, 1996); *O. incensus* (Huerta *et al.,* 2010); and *O. catta* (Gaikwad and Bhawane, 2016); were with longer adult duration. Low pupal survivability compared to the high egg hatchability, larval survivability, and adult survivability of *O. cervus* indicated that the pupal phase as the crucial phase in the life cycle of *O. cervus*.

Type 1 pattern of nesting was present in *Onthophagus cervus* with simple, shallow tunnel with bottom containing brood masses and with vertical and horizontal tunnels (Halffter and Edmonds, 1982). Similar type 1 pattern was reported in *O. taurus* (Fabre, 1918); *O. fucatus* (Main, 1922); *O. coenobita* (Burmeister, 1930); *O. catta* (Gaikwad and Bhawane, 2016); and *O. lecontei* (Arellano *et al.,* 2017). Some *Onthophagus* species constructed compound nest (Type 2) with galleries that may have one or more branches, which ended in to brood cells in *O. nuchicornis* and *O. fracticornis* (Burmeister, 1930); *O. medorensis* (Hunter *et al.,* 1991); *O. stylocerus* (Samper and Piera, 1995); *O. rectecornutus* (Veenakumari and Veeresh, 1996); and *O. incensus* (Huerta and Garcia, 2010) .

Among the tunneling species, large species tend to bury their brood balls at a deeper depth and small species at shallower depth which helps to reduce overall competition for nesting space (Hanski, 1991a; Rougon and Rougon, 1991; Hernández *et al.,* 2011).Tunnels were dug roughly perpendicular to the interface between soil and dung, resulting in interference competition for nesting space underneath dung pads, especially in areas where tunnels branch out into nesting chambers (Halffter and Edmonds, 1982; Hanski, 1991b; Anna *et al.,* 2016). Higher longevity of females and sex ratio biased towards females were seen in *O. cervus.* Why females live longer than males are generally unknown, either metabolic differences or differences in patterns of resource allocation between males and females probably account for the gender difference in lifespan (Fox *et al*., 2003). Alternatively, males may allocate a greater proportion of their biomass to the reproduction, or allocate those resources sooner, such that they become resource-stressed at a younger age. Gender-difference in energy expenditure explains at least some of the gender-difference in lifespan. Some of the difference in lifespan and mortality rates between genders is due to faster energy-water loss in males than in females (Fox *et al*., 2003).

Observed sex ratio bias in *O. taurus* females, is caused by the higher mortality of male and suggested that this might be linked to higher demand for nutritional resource during the development of offspring (Clarissa *et al.,* 2010). Differential mortality is common in species like dung beetles with both the sexes having distinct nutritional requirements and energy expenditures as a result of differential mobility and investment in parental care (Veran and Beissinger, 2009). Evaluation of the cost of male production studies with other groups (Jokela *et al*., 1997; Wolinska and Lively, 2008; Anna *et al.,* 2019), have suggested that there is a cost of producing males. Also, as per LMC (local

Table 2. Number and size of brood balls and duration (days) of different life stages of different *Onthophagus* species

Species	Brood ball			Duration (days) of different life stages					
	No.	Length (mm)	Width (mm)	Egg	Larva	Pupa	Teneral adult	Total	Adult longevity
O. cervus (present study)	14.1± 5.69	20.4± 0.97	32.8± 1.62	3.6± 0.51	16.7± 1.87	10.2± 1.03	2.4± 0.51	28.2± 1.03	60.17± 2.08
O. catta (Gaikwad and Bhawane, 2016)	22.5 ± 17.67	27.7± 3.79	5.4 ± 1.49	2.38 ± 0.8	31.5 ± 6.37	13.46 ± 0.8	3.5 ± 0.70	48.33 ± 4.49	66.7± 11.98
O. depressus (Hunter *et al*., 1996)	ND	22 ± 4.24	16 ± 1.41	3.4 ± 1.28	27	12	3	46.5 ± 14.84	50
O. incensus (Huerta *et al*., 2010)	5 ± 5.65	25 ± 7.07	12.5 ± 3.53	4	22	10 ± 2.82	ND	36 ± 2.82	93
O. *landolti* (Perez cogollo *et al.*, 2015)	14.5 ± 13.43	ND	ND	2.2± 0.70	21± 1.41	7 ± 1.41	ND	30	60
O. lecontei (Arellano *et al*., 2017)	3.50 ± 1.74	23.47± 1.52	23.14 ± 0.91	2	22± 1.14	11± 0.87	4± 0.95	39	60 ± 2.3
O. medorensis (Hunter *et al.*, 1991)	ND	10.27± 4.63	ND	4	28	11.5 ± 0.70	4± 1.41	49.5 ± 4.94	53 ± 26.88
O. stylocerus (Samper and Piera, 1995)	19.75 ± 2.16	31.5 ± 9.19	15.5 ± 3.53	7.5 ± 3.53	22.33 ± 3.05	14 ± 4.24	15	60.5 ± 13.43	ND

Author details are provided in parenthesis; ND: no data available

mate competition), female-biased sex ratio is favored if mating competition takes place between male offspring (Hamilton, 1967), whereas an equal sex ratio is expected under random mating (Fisher, 1930). Hence the female-biased sex ratio noticed in *O. cervus* indicate that mating competition takes place between male offspring and the high cost of producing males might have led to the reduction in the ratio of males to females in *O. cervus.*

Traits that are common in an ***r***-selected species such as high fecundity, small body size, low egg mortality, shorter larval duration, early maturity onset, and shorter developmental period (short generation time enables attaining maturity earlier together with female biased sex ratio), longer duration of females (favouring high egg production) and shallow tunnels (which enable easy and fast tunnelling process and development in thin soil top soil layer) contribute to the higher abundance of *O. cervus* and makes it a prominent dung beetle species in the moist belts of south India.

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Biosafety of pesticides and entomopathogens to the anthocorid predator *Blaptostethus pallescens* Poppius (Heteroptera: Anthocoridae)

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ABSTRACT: Laboratory experiments conducted to study the biosafety of insecticides, acaricides and entomopathogens *viz*. imidacloprid, chlorpyriphos, fenazaquin, spiromesifen, azadirachtin, *Beauveria bassiana* and *Lecanicillium lecanii* in different concentrations to *Blaptostethus pallescens,* revealed that imidacloprid and chlorpyriphos were highly toxic with maximum mortality. The acaricides fenazaquin and spiromesifen were less toxic which recorded minimum mortality of predator and more egg laying and hatching. Azadirachtin showed higher oviposition and was on par with spiromesifen. Azadirachtin and acaricides are compatible with *B. pallescens* than entomopathogens. © 2020 Association for Advancement of Entomology

KEYWORDS: Biosafety, insecticides, acaricides, entomopathogens, *Blaptostethus pallescens*

INTRODUCTION

Anthocorid predators are recognized as potential biocontrol agents. They feed on small lepidopteran larvae, small grubs, psocids, mites, thrips, aphids and storage pests and are commonly known as minute flower bugs or minute pirate bugs. Studies carried out so far indicated that anthocorid bug can be used as effective biocontrol agent for controlling the mites (Barber, 1936; Oku and Kobayashi, 1966; Muraleedharan and Ananthakrishnan, 1978). *Blaptostethus pallescens* Poppius (Heteroptera: Anthocoridae) has been reported as a potential predator (Tawfik and El-Sherif, 1969; Tawfik and El-Husseini, 1971; Tawfik *et al*., 1974). *B. pallescens* was reported from Tamil Nadu (Muraleedharan, 1977) and Bangalore (Jalali and Singh, 2002) in vegetable ecosystem. *B. pallescens* has also been recorded from Madagascar (Muraleedharan, 1977) and from warehouses in Egypt, where mites were common (Tawfik and El-Husseini, 1971).

Conservation of natural enemies through selective use of pesticides has been the main criterion for integrated plant protection (Nasreen *et al*., 2005). Naranjo (2001) evaluated the impact of various pesticides on whitefly predators and parasitoids to develop strategies for conversation of natural enemies. The main limiting factor in large scale use of bio pesticides is high toxicity to beneficial insect (Chatterjee and Choudhury, 2003). In view of this,

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adverse effects of some commercial insecticides and entomopathogens were investigated under laboratory condition against anthocorid predator *B. pallescens.*

MATERIAL AND METHODS

Present study was carried out at the Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore (11°0'45" N, 76°55'57"E). Insecticides, Imidacloprid 17.8% SL (Confidor), Chlorpyriphos 20 EC (Chlorocure), Fenazaquin 10 EC (Magister), Spiromesifen 22.9 SC (Oberon) and botanical Azadirachtin 1500ppm (Neem Gold) and entomopathogens *viz*., *Beauveria bassiana* ($1x10^9$cfu/mg) and *Lecanicillium lecanii* ($1x10^8$cfu/mg) were used in the biosafety studies. Mass culturing of *B. pallescens* was carried out by the method followed by Ballal *et al*. (2003). UV irradiated *Corcyra cephalonica* eggs were sprinkled on cotton pad placed at the bottom of the transparent plastic container (500ml). Nymphs were released into the container along with bean pods which supply the required water for the nymphs. Fresh eggs of *Corcyra* were provided on alternate days till the adults emerge. Freshly emerged adults were shifted to plastic containers with green bean pods for oviposition. The pods with the eggs were removed daily and fresh pods were given.

Biosafety of pesticides to nymph of *B. pallescens:*

Mortality: Imidacloprid 17.8 SL, chlorpyriphos 20 EC, fenazaquin 10 EC, spiromesifen 22.9 SC, azadirachtin 0.15% and entomopathogenic fungi *viz*., *B. bassiana* and *L. lecanii* were sprayed in scintillation glass tube at their recommended dosage by crop protection guide, Tamil Nadu Agricultural University. There were eight treatments including untreated control and three replications. The test tubes treated with the above chemicals and entomopathogens were refrigerated overnight. Fourth instar nymphs of *B. pallescens* were released @ 10/tube and allowed to have contact with the chemicals for a period of two hours. After the exposure period of two hours, the nymphs were transferred to the normal container provided with the UV treated Corcyra eggs. The mortality of the nymphs was observed at 24, 48, 72 and 96 hours after exposure.

Oviposition: The effect of treatments on the oviposition of *B. pallescens* was studied under the laboratory conditions. The green French bean pods used as oviposition substrate in mass culturing of *B. pallescens* was treated with various treatment solutions and air dried. The egg laying mated female after 5 days was enclosed in the plastic container along with treated French bean pod. The number of eggs laid on the pod was recorded 24 hours after release.

Hatching of eggs: Newly laid eggs on the ovipositional substrate was treated with the chemical pesticides, entomopathogens and azadirachtin using an atomizer. The treated French bean pods laden with eggs were kept in separate plastic container and observed for the hatching of the eggs. The number of eggs hatched was noted and the percent hatching worked out.

The collected data were transformed through square root transformation and subjected to ANOVA for completely randomized design (CRD) experiments. The mean values of the treatments were compared using Duncan's Multiple Range Test (DMRT) at 5 per cent level of significance in SPSS (Statistical Package for the Social science).

RESULTS AND DISCUSSION

Mortality of fourth instar nymph

Among treatments, the mortality of nymph at 24 hours after treatment (HAT) in chlorpyriphos was maximum (80%) as against the least mortality (10 %) observed in *L. lecanii* at 2g/l of water. Maximum mortality of predator (cent per cent) noted in chlorpyriphos treatment at 72 HAT. Rest of the treatments showed mortality of predator up to 36.67 per cent during the same period of observation. The acaricides fenazaquin and spiromesifen were less toxic to the predator, which showed mortality of 20 and 23.33% at 96 HAT respectively (Table 1).

Table 1. Effect of insecticides and entomopathogens on the fourth instar nymph of *Blaptostethus pallescens*

Treatments	Dose (%)	Mortality*(%)				
		24 HAT	48HAT	72 HAT	96 HAT	Mean
T1- Imidacloprid 17.8 SL	0.0036	26.67 (10.02)b	33.33 (11.27)c	36.67 (11.76)b	36.67 (11.76)b	33.34
T2 - Chlorpyriphos 20 EC	0.0400	80c (16.88)c	96.67 (18.59)d	100 (18.91)c	100 (18.91)c	94.17
T3- Fenazaquin 10 EC	0.0250	13.33 (7.72)ab	16.67 (8.28)bc	16.67 (8.41)ab	20 (8.97)ab	16.67
T4 -Spiromesifen 22.9 SC	0.0183	13.33 (7.29)ab	16.67 (7.98)bc	20 (8.47)ab	23.33 (9.03)ab	18.33
T5-Azadirachtin 1500 ppm	0.0008	23.33 (9.03)b	26.67 (10.02)bc	26.7 (9.61)b	26.7 (9.61)b	25.85
T6- *Lecanicillium lecanii* (1x 10x cfu) 2g/l	0.2	10 (7.04)ab	10 (6.73)ab	13.33 (7.29)ab	13.33 (7.29)ab	11.67
T7- *Beauveria bassiana* (1x 10x cfu) 2g/l	0.2	20 (8.97)b	20 (8.54)bc	20 (8.54)ab	20 (8.54)ab	20.00
T8- Untreated Control	-	0 (4.05)a	0(4.05)a	0(4.05)a	0 (4.05)a	0.00
SE(D)	-	1.98	1.97	2.34	2.41	-
CD	-	4.19	4.18	4.96	5.11	-

*Mean of three observations; HAT – hours after treatment; Values in the parentheses are arc sine transformed values. Means followed by the common letter (s) are not significantly different at P=0.05 level by DMRT

Table 2. Effect of insecticides and entomopathogens on the mortality of adult *Blaptostethus pallescens*

Treatments	Dose (%)	Mortality*(%)				
		24 HAT	48HAT	72 HAT	96 HAT	Mean
T1- Imidacloprid 17.8 SL	0.0036	20.00 (26.57)b	26.67 (31.09)a	33.33 (35.26)b	33.33 (35.26)b	28.33
T2 - Chlorpyriphos 20 EC	0.0400	93.33 (75.04)c	96.67 (79.48)b	100.00 (90.00)c	100.00 (90.00)d	97.50
T3- Fenazaquin 10 EC	0.0250	13.33 (21.42)b	16.67 (24.09)a	20.00 (26.57)ab	20.00 (26.57)ab	17.50
T4 -Spiromesifen 22.9 SC	0.0183	16.67 (24.09)b	16.67 (24.09)a	23.33 (28.88)b	26.67 (31.09)bc	20.83
T5-Azadirachtin 1500 ppm	0.0008	10.00 (18.43)ab	20.00 (26.57)a	30.00 (33.21)b	33.33 (35.26)c	23.33
T6- *Lecanicillium lecanii* (1x 10x cfu) 2g/l	0.20	16.67 (24.09)b	20.00 (26.57)a	26.67 (31.09)b	26.67 (31.09)bc	22.50
T7- *Beauveria bassiana* (1x 109 cfu) 2g/l	0.20	20.00 (26.57)b	23.33 (28.88)a	26.67 (31.09)b	26.67 (31.09)bc	24.17
T8- Untreated Control	-	0.00 (0.00)a	0.00 (0.00)a	0.00 (0.00)a	0.00 (0.00)a	0.00
SE(D)	-	1.55	1.21	1.16	0.94	
CD	-	3.29	2.60	2.45	1.99	

*Mean of three observations; HAT – hours after treatment; Values in the parentheses are arc sine transformed values. Means followed by the common letter (s) are not significantly different at P=0.05 level by DMRT

Mortality of adult

The mortality of adult observed at 24 HAT was maximum (93.33%) in chlorpyriphos 20 EC 0.04% followed by imidacloprid 17.8 SL 0.0036% (20%) and *B. bassiana* 2g/l (20%). The adult predator showed maximum mortality (cent per cent) in chlorpyriphos treatment at 72 HAT. The other treatments, which showed hgher mortality of adult at 96 HAT were imidacloprid 17.8 SL 0.0036% and azadirachtin 1500ppm (33.33%). The acaricides fenazaquin and spiromesifen (0.0183%) tested showed lesser mortality of 20 and 26.67% respectively at 96 HAT (Table 2).

Oviposition

The oviposition of *B. pallescens* on green pods treated with pesticides indicated that imidacloprid treated pods received the lowest number of eggs 0.25 per pod as against 15 eggs/pod in the untreated control at 24 HAR. Imidacloprid treatment (0.25egg/pod) was on par with chlorpyriphos (1.00 egg/pod). Spiromesifen and azadirachtin recorded an oviposition of 10.50 eggs/pod during the same period of observation (Table 3).

Hatching

The effect of the pesticides and entomopathogens on egg hatching of *B. pallescens* revealed that the hatching was relatively higher in acaricides treated eggs (43%) and lowest in chlorpyriphos treated eggs (6.67%). The hatching per cent in *L. lecanii* and *B. bassiana* treated eggs were 20 and 16.67 respectively. The reduction in egg hatching was 90.48 % in chlorpyriphos over the control, while in acaricide treated eggs the reduction over the control was 38.10% (Table 4).

Biosafety studies to insecticides revealed that acaricides *viz,* fenazaquin 5 EC, spiromesifen 22.9 SC and entomopathogen *Lecanicillium lecanii* @ 2g/l recorded the lower mortality and were relatively safer to the nymphs and adults of the predator, whereas chlorpyriphos 20 EC was more toxic followed by imidacloprid. The oviposition substrates treated with imidacloprid 17.8 SL reduced the egg laying up to 98.33% followed by chlorpyriphos 20 EC (93.33%), whereas acaricides

Table 3. Effect of insecticides and entomopathogens on the oviposition (eggs laid on treated green pod 24 HAR) of *Blaptostethus pallescens*

Treatments	Dosage (%)	No. of eggs laid	Reduction over Control (%)
T1- Imidacloprid 17.8 SL	0.0036	0.25 (0.50)d	98.33
T2- Chlorpyriphos 20 EC	0.0400	1.00 (1.00)d	93.33
T3- Fenazaquin 10 EC	0.0250	8.50 (2.92)b	43.33
T4- Spiromesifen 22.9 SC	0.0183	10.50 (3.24)ab	30.00
T5- Azadirachtin 1500 ppm	0.0008	10.50 (3.24)ab	30.00
T6- *Lecanicillium leacnii* (1x 10x cfu) 2g/l	0.2	5.00 (2.24)b	66.67
T7- *Beauveria bassiana* (1x 109 cfu) 2g/l	0.2	4.75 (2.18)b	68.33
T8- Untreated Control	-	15.00 (3.87)a	0.00
SE(d)	-	0.32	-
CD	-	0.66	-

*Mean of three observations; HAT – hours after treatment; Values in the parentheses are arc sine transformed values. Means followed by the common letter (s) are not significantly different at P=0.05 level by DMRT

reduced the egg laying up to 30%. The pungent odour of the chemicals might have deterred the predator from egg laying. In contrast, the chemicals with absence or fewer odours had more egg laying of the predator than the insecticides chlorpyriphos and imidacloprid. Regarding the hatching of the treated eggs, chlorpyriphos showed maximum inhibition (90.48%) followed by imidacloprid. The chemicals imidacloprid and chlorpyriphos being insecticides, exhibited toxicity to eggs of predator as the operculum of this egg was exposed outside the tissue of the pod. The above reason can be attributed to the toxicity of insecticides and safe nature of acaricides to the hatching of predator eggs. The results were similar to the findings of Duso *et al*. (2008) who compared the toxicity of botanicals to predatory mite *Phytoseiulus persimilis* and reported that azadirachtin, pymetrozine and

Table 4. Effect of insecticides and entomopathogens on hatching of *Blaptostethus pallescens*

Treatments	Dose (%)	No.of eggs hatched*	Hatching (%)*	Reduction over Control (%)
T1- Imidacloprid 17.8 SL	0.0036	2.00 (8.97)cd	20.00	71.43
T2- Chlorpyriphos 20 EC	0.0400	0.67 (6.04)d	6.67	90.48
T3- Fenazaquin 10 EC	0.0250	4.33 (12.60)b	43.33	38.10
T4- Spiromesifen 22.9 SC	0.0183	4.33 (12.48)b	43.33	38.10
T5- Azadirachtin 1500 ppm	0.0008	3.67 (11.76)bc	36.67	47.62
T6- *Lecanicillium leacnii* (1x 10x cfu) 2g/l	0.2	2.00 (8.97)c	20.00	71.43
T7- Beauveria bassiana (1x 109 cfu)2g/l	0.2	1.67 (8.41)d	16.67	76.19
T8- Untreated Control	-	7.00 (15.87)a	70.00	0.00
SE(d)	-	1.48	-	-
CD	-	3.14	-	-

*Mean of three observations; HAT – hours after treatment; Values in the parentheses are arc sine transformed values. Means followed by the common letter (s) are not significantly different at P=0.05 level by DMRT

B. bassiana were safer to *P. persimilis*. The findings of Elzen (2001) was also similar to the present study that insecticides like malathion and spinosad were significantly less toxic to male *Geocoris punctipes*. The lethal response of *B. pallescens* to the bioinsecticide azadirachtin and to two synthetic insecticides, chlorpyrifos and deltamethrin revealed that the mild effect of the azadirachtin on the predator (median lethal time of 27 days), relative to deltamethrin and chlorpyrifos (with median lethal time of 25 and 60 min, respectively) (Celestino *et al*., 2014).

The insecticides imidacloprid 17.8 SL 0.0036% and chlorpyriphos 20 EC 0.04% were highly toxic to anthocorid bug which showed maximum mortality, low egg laying and maximum inhibition of egg hatching. The acaricides fenazaquin 10 EC 0.025% and spiromesifen 22.9 SC 0.0183% were found less toxic which recorded minimum mortality of predator and more egg laying and hatching. Hence, the selection of insecticides which are safer to natural enemies are very important as it will increase the effectiveness of biological control and proved to be an eco-friendly insect pest management.

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Eco-friendly management of the pod borers *Maruca vitrata* (Fabricius) and *Lampides boeticus* (L.) of yard long bean under field conditions

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ABSTRACT: Investigations on management of pod borers [*Maruca vitrata* (Fabricius), *Lampides boeticus* (L.)] of yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) under field conditions revealed that Spinosad 45 SC followed by *Bt* formulation 2× 10^8 cfu/ml and *Beauveria bassiana* @ 10^7 spores/ml of water were the most effective treatments in preventing pod borer infestation as well as controlling number of pod borer larvae.

KEY WORDS: *Vigna unguiculata* subsp. *Sesquipedalis, Lampides boeticus*, *Maruca vitrata*), pest management, spinosad, *Bt, Beauveria bassiana*

INTRODUCTION

Vegetable cowpea or yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdcourt) is one of the most important vegetables grown in Kerala. It is cultivated in an area of 7150 hectares in Kerala (GOK, 2017). The most important constraint on the production and productivity of cowpea is the infestation by insects. The profuse vegetative growth of yard long bean attracts a number of insects. The infestation that occurs at the most crucial period of growth stage of the crop causes great economic loss.Among the insect pests of vegetable cowpea, the most destructive are the pod borers *viz.,*spotted pod borer, *Maruca vitrata* (Fabricius) (Lepidoptera: Crambidae) and blue butterfly, *Lampides boeticus* (L.) (Lepidoptera: Lycaenidae). The spotted pod borer,*M. vitrata* is considered as the most devastating pest of yard long bean causing nearly 40 per cent yield loss (Yule and Srinivasan, 2013). About 4-6 flowers are consumed by a single larva of *M. vitrata* (Sharma, 1998). It webs flower buds and flowers together and feeds from within. Moreover, it bores inside the pods and feed on the internal contents. The pod borer, *Lampides boeticus* consumes the flower buds and pods by boring and contaminating them, which causes heavy yield loss (Ganapathy and Durairaj, 2000). The present study aimed at studying the efficacy of different microbial agents, neem

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based and bio rational insecticides against pod borers of yard long bean.

MATERIAL AND METHODS

The research work was carried out in the Instructional Farm of College of Agriculture, Padannakkad from May 2016 to August 2016 and September 2016 to December 2016 in RBD with 9 treatments and 3 replications with twelve plants per treatment. The yard long bean variety 'Lola' released by Kerala Agricultural University (KAU) was selected for conducting the study. The crop was raised on trellis at a spacing of 1.5 x 0.45m. All the planting operations were done based on the Package of Practice recommendations: crops of KAU, 2016. The pure culture of entomopathogenic fungi *Beauveria bassiana*, *Metarhizium anisopliae* and *Lecanicillium lecanii* were brought from National Bureau of Agricultural Insect Resources (NBAIR), Bangalore. The commercial formulation of *Bt* 2 x 10^8 cfu/ml (BT CARE) was purchased from Biopharmacy, Krishibhavan, Nileshwar of Kasargod district. The other treatments *viz.,* azadirachtin 1 per cent (Neemazal-T/S), neem oil, spinosad 45 SC (Tracer 45 SC), malathion (Jaithion 50 EC) were purchased. All the treatments were imposed at fortnightly intervals when borer infestation was first noticed. Observations were recorded at weekly intervals corresponding to standard weeks. There were nine treatments (Table 1). All the treatments except fungal entomopathogens were sprayed by diluting the recommended dose in one litre water and the control plot was treated with water.

Observations included the total number of pod borer larvae per plant and the number of pods damaged out of total number of pods due to infestation. The crop was harvested 60 days after planting. Pooled ANACOVA was carried out to find the treatment mean of pod borers, per cent of infestation during two seasons, kharif and rabi and significance were analysed using DMRT method.

RESULTS AND DISCUSSION

ANOCOVA analysis of pooled mean number of borers between treatments during both seasons (Table 1) showed that on 7DAFS, spinosad and malathion was on par with each other with least number of pod borers and the control, T_9 and *Metarrhizium anisopliae* treated plot recorded the maximum number of pod borers. On 14 DAFS, 7 DASS and 14 DASS, spinosad and malathion was on par with each other and was significantly superior to other treatments including control whereas on 7 DATS, spinosad, malathion, *Bt, Beauveria bassiana* found on par with each other and control plot recorded the maximum number of pod borers. On 14 DATS, spinosad, *Bt, Beauveria bassiana* found on par with each other with minimum number of pod borers. On comparison with kharif and rabi seasons, there was a significant difference between the two seasons in the number of pod borers and was found significantly higher during rabi season.

Pooled ANOCOVA analysis data on mean per cent of pod infestation between the treatments during two seasons were tabulated (Table 2). Data showed that on 7 DAFS, spinosad, *Beauveria bassiana, Bt* and malathion was on par with each other and the control, T_9 and *Metarrhizium anisopliae* treated plot recorded the maximum per cent of pod borer infestation. On 14 DAFS, 7 DASS and 14 DASS spinosad recorded the lowest infestation (8.86, 4.77 and 1.71 per cent respectively) and was significantly superior to other treatments. On 7 DATS and 14 DATS minimum per cent of pod infestation was noticed in spinosad (0.54 and 1.74 per cent respectively). *Bt, Beauveria bassiana* and malathion was on par with spinosad and control plot recorded the maximum per cent of pod damage. On comparing the percentage of pod infestation between seasons, the infestation was on par initially (7 DAFS) and thereafter a significant difference was noticed between the seasons. Pod infestation was lower comparatively during rabi season (Table 2).

From the results obtained, it was concluded that Spinosad 45 SC was effective in reducing the number of pod borer larvae during both kharif and rabi seasons after three consecutive application of treatments (Table 1). The findings of Yadav and Singh (2014) that the larval population of *M. vitrata*

Table 1. Pooled univariate analysis of covariance data on mean number of pod borers during kharif and rabi

Treatments	Days after first/ second/ third spray					
	7DAFS	14DAFS	7DASS	14DASS	7DATS	14DATS
T_1 - *Beauveria bassiana* @ 10^7 spores/ml	2.85^{cd}	2.53^{cd}	2.11^{cd}	1.10^{de}	0.77^{c}	0.44^{cd}
T_2 - *Metarhizium anisopliae* @ 10^7 spores/ml	3.44^{ab}	3.12^{b}	2.94^{b}	2.67^{b}	2.53^{b}	2.80^{b}
T_3 – *Lecanicillium lecanii* @ 10^7 spores/ml	3.13^{bc}	2.76^{c}	2.45^{bc}	1.69^{cd}	1.92^{b}	2.38^{b}
T_4 – *Bt* formulation @ 2× 10^8 cfu/ml @ 1 ml/l	2.96^{c}	2.65^{cd}	2.21^{cd}	1.04^{de}	0.49^{c}	0.20^{d}
T_5 – Neem (Azadirachtin 1%) @ 5ml/l	2.91^{cd}	3.26^{b}	2.84^{b}	2.37^{bc}	2.25^{b}	2.54^{b}
T_6 – Neem oil emulsion 5% @ 50ml/l	3.14^{bc}	3.22^{b}	2.84^{b}	2.42^{bc}	2.37^{b}	2.68^{b}
T_7 – Spinosad 45 SC @ 0.4 ml/l	2.50^{de}	1.97^{e}	1.19^{e}	0.06^{f}	0.04^{c}	0.07^{d}
T_8 – Malathion 50 EC @ 2ml/l	2.36^{e}	2.31^{de}	1.66^{de}	0.74^{ef}	0.55^{c}	0.75^{c}
T_9 – Absolute control	3.72^{a}	3.99^{a}	3.76^{a}	4.09^{a}	4.41^{a}	4.45^{a}
Between seasons						
Kharif	1.68^{b}	1.75^{b}	1.85^{b}	0.48^{b}	0.86^{b}	1.17^{b}
Rabi	4.32^{a}	3.99^{a}	3.04^{a}	3.09^{a}	2.55^{a}	2.46^{a}

Figures denote adjusted treatment means (adjusted for the covariates)
DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

was found to be very low three days after first spray of Spinosad 45 SC in mung bean was in line with the above results. In the present study, though malathion 50 EC showed good control of pod borer larvae at the initial stage, later Spinosad competes with the efficacy of malathion and thus Spinosad is adjudged as the best treatment in reducing larvae of pod borer over other treatments. Sparks *et al.* (2012) explained that Spinosad 45 SC was allowed to use in organic farming as the level of toxicity was less than the treatment with malathion.

The efficacy of Spinosad in pigeon pea was reported by Rao *et al*. (2007) in which it could bring about more than 70 per cent of reduction in population of *M. vitrata.* The present study is in agreement with Kumar and Muthukrishnan (2017) that Spinosad 45 SC assured 76.4 per cent reduction in number of larvae of pod borer, *L. boeticus* in pigeon pea. *Bacillus thuringiensis* formulation 2 × 10^8 cfu/ml showed effectiveness similar to Spinosad 45 SC in controlling the larval population of pod borers during kharif season in the year 2016 (Table 1). Similar findings were made by Sunitha *et al*. (2008) that Spinosad exhibited higher efficacy in lowering the larval population of *M. vitrata* followed by *Bt.* However, the present finding that Spinosad is highly effective against the larvae of pod borers is consistent with the report of Ipsita *et al.* (2014) that there was a greater reduction in the number of pod borer larvae (2.6 per 10 plants) when Spinosad 45 SC was treated. The report of Adsure and Mohite (2015) revealed that Spinosad 45 SC could bring down the larval population to a great extent even after first spray reconfirmed the present study.

Table 2. Pooled analysis of covariance data on mean per cent of pod infestation during kharif and rabi

Treatments	Days after first/ second/ third spray					
	7DAFS	14DAFS	7DASS	14DASS	7DATS	14DATS
T_1 - *Beauveria bassiana* @ 10^7 spores/ml	28.40 (0.56)^{cd}	23.83 (0.54)^{c}	15.55 (0.40)^{d}	10.38 (0.26)^{de}	6.97 (0.19)^{ef}	2.05 (0.13)^{e}
T_2 - *Metarhizium anisopliae* @ 10^7 spores/ml	71.12 (1.05)^{a}	62.18 (0.87)^{a}	57.45 (0.87)^{b}	45.33 (0.78)^{b}	45.82 (0.78)^{b}	40.39 (0.67)^{b}
T_3 – *Lecanicillium lecanii* @ 10^7 spores/ml	45.10 (0.73)^{bc}	34.85 (0.63)^{bc}	38.55 (0.66)^{c}	28.28 (0.54)^{c}	19.88 (0.45)^{d}	26.94 (0.54)^{c}
T_4 – *Bt* formulation @ 2× 10^8 cfu/ml @ 1 ml/l	31.88 (0.60)^{bcd}	24.53 (0.54)^{c}	14.47 (0.39)^{d}	9.23 (0.24)^{e}	5.86 (0.16)^{ef}	0.98 (0.13)^{e}
T_5 – Neem (Azadirachtin 1%) @ 5ml/l	44.82 (0.74)^{bc}	43.49 (0.71)^{b}	37.29 (0.66)^{c}	37.53 (0.66)^{bc}	31.79 (0.61)^{c}	28.08 (0.57)^{c}
T_6 – Neem oil emulsion 5% @ 50ml/l	46.72 (0.75)^{b}	42.31 (0.71)^{b}	38.51 (0.67)^{c}	42.35 (0.72)^{b}	37.43 (0.69)^{bc}	33.52 (0.60)^{bc}
T_7 – Spinosad 45 SC @ 0.4 ml/l	22.24 (0.48)^{d}	8.86 (0.35)^{d}	4.77 (0.19)^{e}	1.71 (0.06)^{f}	0.54 (0.06)^{f}	1.74 (0.15)^{e}
T_8 – Malathion 50 EC @ 2ml/l	35.83 (0.64)^{bcd}	24.36 (0.53)^{c}	20.32 (0.42)^{d}	21.57 (0.37)^{d}	12.38 (0.27)^{e}	9.26 (0.26)^{d}
T_9 – Absolute control	79.31 (1.15)^{a}	75.14 (0.98)^{a}	78.74 (1.14)^{a}	84.03 (1.25)^{a}	83.19 (1.29)^{a}	68.11 (0.95)^{a}
Between seasons						
Kharif	44.07 (0.72)^{a}	40.12 (0.68)^{a}	39.20 (0.66)^{a}	39.89 (0.68)^{a}	31.39 (0.61)^{a}	24.48 (0.49)^{a}
Rabi	46.02 (0.76)^{a}	35.34 (0.62)^{b}	28.72 (0.54)^{b}	22.42 (0.41)^{b}	22.56 (0.39)^{b}	22.43 (0.41)^{b}

Figures in non-parentheses denote adjusted treatment means (adjusted for the covariates)
Figures in parenthesis denotes angular (arc sin) transformed values
DAFS- Days after first spray; DASS- Days after second spray; DATS- Days after third spray.

The mean per cent of pod infestation by pod borer larvae were also found minimum in Spinosad 45 SC treated plot during both seasons, even after two sprays and no damage was seen on pods after third spray (Table 2). The report of Ipsita *et al.* (2014) conveyed that Spinosad 45 SC resulted in only 6.66 per cent of pod infestation compared to control having 27.02 per cent pod damage when sprayed 40 days after sowing endorsed the present study. The effect of the same was again reinforced by the findings of Anitha and Parimala (2014) in which the lowest pod damage of 5.1 per cent was obtained in Spinosad treated plot. The present study and earlier findings ratified the efficacy of Spinosad in reducing the per cent of pod damage in vegetable cowpea.

Bacillus thuringiensis formulation @ 2× 10^8 cfu/ml @ 1 ml/l of water was found to be the next effective treatment after Spinosad in reducing the pod damage during both seasons. After three consecutive sprays at fortnightly intervals, the per cent of pod damage decreased far better in *Bt* treated plot. Similar findings were made by Yadav and Singh (2014) in which Spinosad when applied recorded the lowest pod damage of 3.67 per cent

followed by *Bt* with 4.33 per cent pod damage. The report of Dhaka *et al.* (2011) that Spinosad @ 500 ml/ha exhibited low percentage of pod infestation three days after second spray followed by *Bt* @ 1500 g/ha also substantiated the present study. The efficiency of biorational insecticide, spinosad in controlling insect pests without harming non-target species and its non-toxicity towards humans found to be the best approach among pest management strategies. Through this it is possible to increase good quality produce. Thus spinosad play a promising tool in pest management and are gaining prior importance in the present scenario.

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Biological attributes and qualitative damage of *Oligonychus mangiferus* (Rahman & Sapra) (Acariformes: Tetranychidae) on the medicinal plant *Ichnocarpus frutescens* (L.) W.T. Aiton

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ABSTRACT: *Oligonychus mangiferus* (Rahman & Sapra) was found infesting the medicinal plant, *Ichnocarpus frutescens* L. Its biology and reproduction were studied at four different constant temperature conditions in the laboratory. *O. mangiferus* completed its development faster (7.10 to 8.77 days) at 30° - 32°C. Its egg-laying was highest at 20°C (31.03 eggs/female), but with similar progenial sex ratio (♂:♀) (1:2.68 to 1:2.84) across different temperatures. At 25°C, Mean Generation Time (T) and Doubling Time (DT) were lowest 15.26 days and 8.95 days, respectively, while, Intrinsic Rate of Natural Increase (r_m) was highest (0.085 female off-springs/female/day). Feeding damage by *O. mangiferus* resulted in apparent decline in chlorophyll and flavonoid contents, while alkaloid and terpenoid contents showed increase in mite infested leaves. Observed changes in the quantity of secondary metabolites like alkaloids, flavonoids and terpenoids, subsequent to mite feeding was significant, owing to the medicinal value of the herb. Further investigation on these biochemical changes may throw light on more advantageous medicinal use of *Ichnocarpus* for treating many human disorders.

KEY WORDS: *Oligonychus mangiferus,* medicinal plant, *Ichnocarpus frutescens*, life history, biochemical changes

INTRODUCTION

The spider mite family Tetranychidae comprises of significant number of species known to feed and damage almost all types of economically important cultivated crops (field crops, vegetable crops, fruit crops, ornamental and flower crops) including medicinal and aromatic plants (Gupta and Karmakar, 2010; Vacante, 2015). Quantitative losses due to mite feeding in the yield of food and commercial crops are well documented. Likewise, the mite damage on medicinal plants is expected to inflict variation in terms of its medicinal value. Both in India and outside except that of Ahalya and Mikundan (2009), Saini and Reddy (2013) and Karmakar *et al.* (2014), reports of mites occurring on medicinal plants are either scattered or meagre. Recently, a common medicinal plant *Ichnocarpus*

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frutescens L. (Apocynaceae) was found infested by *Oligonychus mangiferus* (Rahman & Sapra) (Acariformes: Tetranychidae) in the herbal garden of University of Agricultural Sciences campus at Bangalore, with significant damage on the green leaves. *I. frutescens* enjoys good prospects in the Indian medicine for the treatment of fevers, gout, rheumatism, arthritis, epilepsy, venereal diseases, herpes and skin diseases, blood purification, bleeding disorders, diarrhoea and protection of human fetal growth and development, and as cooling attribute (Sini and Malathyn, 2006; Pandurangan *et al.,* 2010; Joshi *et al.,* 2011). Many reports are available on the profile of secondary metabolites in mite-infested crop plants showing resistance or tolerance reaction to mite infestation or damage (Mutturaju, 2013; Rajagopal, 2015). But no systematic study has been attempted to ascertain biochemical changes subsequent to mite infestation or damage in any medicinal plant. Mamun *et al.* (2017) recorded lower amounts of polyphenols and catechins in green leaves of tea infested by *O. mangiferus*, when compared to mite-free fresh leaves. Black tea from severely mite infested leaves had low amounts of theaflavin (0.43%) and caffeine (54.68 ppm), accordingly the tea from mite-infested shoots was graded with inferior grade index of 31.65 to 32.90.

Oligonychus mangiferus is a polyphagous pest with at least 50 host plants (Bolland *et al*., 1998) and the incidence and damage of this mite on *I. frutescens* both in wild and planted situations is reported for the first time in our study. Information on growth, development and reproduction of *O. mangiferus* is available on its major host plants like mango and tea. While biological data of the mite were generated on an important medicinal plant *I. frutescens* for the first time from this study at four different constant temperature (20, 25, 30 and 32°C) and relative humidity (63-85%) conditions in the laboratory. Simultaneously, demography of the mite was also studied considering the significance of life table parameters in determining the population structure and performance of further generations that would ultimately damage the plants and appear as an emerging pest.

MATERIAL AND METHODS

Culturing of mite: The excised leaf disk technique was used for rearing and maintaining mite culture in the laboratory. Initially, *I. frutescens* leaves infested by *O. mangiferus* were brought to the laboratory in polyethylene bags, from which females along with one to two attending males were transferred separately on to 2.5cm X 2.5cm individual leaf disks (by changing at 10-12 days interval) placed on wet cotton wad in 15 inches Petri plates and allowed to colonize for at least 10-15 days and were further used in our studies.

Life history and Life table: The life history of the mite was studied separately at four different constant temperatures of 20±1°C; 75-85% RH, 25.3°C; 67-77% RH, 30±1°C; 64-73% RH & 32±1°C; 62-70% RH and 14h: 10h L: D conditions in a BOD incubator. Initially a cohort of eggs laid on leaf disks was transferred individually using a fine camel hair brush on to 30 separate 1.5 cm × 1.5 cm fresh leaf disks kept on wet sponge placed in 20cm X 15cm polyethylene trays. Development from egg hatching to adult emergence was observed periodically (every 3 to 6 hours) using a stereo-binocular microscope and after transferring hatched larvae on to individual leaf bits separately, duration of each stage of development was recorded. Duration of different developmental stages such as larva, protonymph and deutonymph was computed for male and female separately. Other observations such as longevity and oviposition pattern were also recorded.

To study the reproduction parameters and population characteristics, 30 teleiochrysalis females along with two males (to ensure mating) released separately on individual leaf disc were made used. After the emergence of the female mite reared on individual leaf bit, oviposition pattern (pre-oviposition, oviposition and post-oviposition periods) and daily egg laying were recorded at 24 hours interval, till the female mite stopped laying eggs and died naturally. Since the life span of male was shorter, as and when they were found dead or not seen on the leaf discs, fresh ones were released in the initial period of 10 days. Loss of any female

mite was made-up by replacing with a fresh virgin female/deutonymph or by increasing the number of replications. After recording egg-laying every day, the female mite was carefully transferred on to fresh leaf bit. The eggs laid were reared till adult emergence and sex of the emerging adult mite was recorded. Similarly, reproduction attributes of unmated females were recorded by maintaining female deutonymph separately on individual leaf bits without the release of males to such bits.

Reproduction attributes such as oviposition, fecundity and proportion of male and female off-springs (♂:♀) were recorded and compared across different rearing temperatures. Age specific life table data were computed and demographic characteristics such as, Mean Generation Time (*T)* (average age of parenthood in days), Net Reproduction Rate *(R_o)* (no. of female off-springs/ female/generation as the average number of new born females produced by a female during her entire life time), Finite Rate of Increase (λ) as no. of female off-springs/female/day, Intrinsic Rate of Natural Increase (r_m) (no. of female off-springs/ female/day as the maximal rate of increase by the combination of food, temperature, quality of food, *etc.*) and Doubling Time in days (*DT)* were calculated following the procedure suggested by Birch (1948) and Atwal and Bains (1974) as below;

Net Reproductive Rate, $R_o = \sum l_x m_x$

Mean Generation Time, $T = \frac{\Sigma xlxmx}{Ro}$

Finite Rate of Increase in number, λ =

anti ln $\left[\frac{\log eRo}{T}\right]$

Intrinsic Rate of natural Increase, $r_m = \ln(\lambda)$

Doubling time, $DT = \frac{\ln 2}{r_m}$

Where,

l_x = proportion of females alive at age interval x

m_x = number of female off-springs produced by the surviving female at the age interval x

$l_x m_x$ = product of the proportion of females live at age interval x and the number of female off-springs per original female produced at the age interval x

Duration of different developmental stages and reproduction attributes were expressed as mean ± SE, while data of total development (female and male) were analysed following One-way ANOVA. The standard error of different demographic parameters was estimated by bootstrapping technique and for comparison across different rearing temperature conditions, data were analysed using Tukey's HSD test in the statistical software SPSS 23.

Biochemical analysis: In order to ascertain the qualitative damage to *I. frutescens* plant, biochemical analysis was carried out for only those biochemicals, which are significantly contributing to the medicinal property in the plant. Total chlorophyll content of healthy and mite-infested leaves was estimated following the standard procedure of Arnon (1949) by using one gram of fresh leaf sample incubated overnight in Dimethyl sulfoxide and 80% Acetone mixture in 1:1 ratio, diluting the supernatant extract and recording the absorbance at 645 and 663 nm wavelengths in a Spectrophotometer (Hitachi U-2900).

Healthy and mite infested leaves of *I. frutescens* were shade dried and powdered separately using a Waring blender. Dry leaf powder was used for ethyl acetate extraction in Soxhlet apparatus and evaporated in Rotary flash evaporator. The concentrated extract stored in airtight glass bottles at -20ºC was used for the estimation of total alkaloid content following the procedure of Agarwal and Murali (2010) by Gravimetric method, estimation of total flavonoid content following the method of Samata *et al.* (2012) by absorbance reading at 510 nm in a Spectrophotometer (Hitachi U-2900) and estimation of total terpenoid content (expressed as Ursolic acid) by a High Performance Liquid Chromatograph (Agilent) using methanol - water (95:5) as mobile phase at a flow rate of 1ml/minute and absorbance was measured at 205 nm using the standard ursolic acid calibration curve obtained at the retention time of 8 minutes. Further, the biochemical data from healthy and mite-infested leaves were compared.

RESULTS AND DISCUSSION

Life history

Developmental time of *O. mangiferus* from egg to adult for female was 15.50 days, 12.20 days, 7.10 days and 8.56 days, while it was 14.67 days, 11.99 days, 7.32 days and 8.77 days for male on *I. frutescens* at four temperatures of 20°C, 25°C, 30°C and 32°C, respectively. Developmental time for male was shorter than that of the female at all the rearing temperatures. 30°C was found more suitable for faster mite development and the next best rearing temperature was 32°C (Fig.1).

Reproduction and demography

Age specific fecundity pattern revealed that egg laying by *O. mangigerus* reached peak on 25th, 5th, 18th and 11th day of its emergence over its survival period of 55, 29, 30 and 26 days at 20°C, 25ºC, 30°C and 32º C, respectively (Fig. 2). Each mated female laid as many as 31.03, 21.04, 24.16 and 26.52 eggs over a period of 25.13, 11.52, 10.28 and 10.96 days, respectively, while males lived for a shorter period of 12.75, 8.40, 12.00 and 11.67 days correspondingly. The sex ratio (♂:♀) in the succeeding progeny was 1:2.71, 1:2.84, 1:2.71 and 1:2.68. Virgin females (emerged from female teliochrysalis) maintained separately on individual leaf bits without males laid significantly less number of eggs at 20°C (17.82 eggs) and 32°C (17.55 eggs), but it was highest *i.e*. 36.20 eggs at 30°C. Mated females laid significantly a greater number of eggs at 20°C and 32°C compared to those at 25°C and 30°C (Table 1).

Daily female production by a mated female (rm) was 0.049, 0.085, 0.068 and 0.083 at the rearing temperatures of 20°, 25, 30 and 32°C, respectively. The corresponding Net Reproduction Rate (Ro) was 26.57, 16.29, 17.74 and 18.84 female offsprings/female/generation and the Mean Generation Time (T) were 29.50, 15.26, 19.20 and 16.76 days. Mite's doubling time was relatively shorter at 25°C and 32ºC *i.e.,* 8.95 days and 9.38 days, respectively (Table 2).

Qualitative damage due to mite feeding

O. mangiferus successfully completed life cycle on the medicinal plant, *I. frutescens* at all the test temperatures. The feeding damage of *O. mangiferus* on *I. frutescens* with respect to biochemical constituents was studied. Primary metabolite (chlorophyll) and secondary metabolites (alkaloid, flavonoids, terpenoids) were estimated from both healthy and mite infested /damaged leaves for comparison.

Feeding damage caused due to *O. mangiferus* resulted in 55.88 per cent decline in total chlorophyll content affecting the photosynthetic efficiency of infested leaves and it is obvious that, spider mites will suck away or remove chlorophyll along with the plant sap. Flavonoid content, an important secondary metabolite recorded a decrease of 64.71 per cent in mite infested leaves. But alkaloid and terpenoid contents were found increased in mite infested leaves (Fig. 3).

The herb *I. frutescens* was found infested by *O. mangiferus* as a predominant species and is the first report on this medicinal plant and hence, no earlier report of either biology or demography of the mite on *Ichnocarpus* is available. It is opined that the life table parameters are important indicators of population growth efficiency of a pest species on its host plant (Southwood and Henderson 2000; Islam *et al.,* 2017) and also provide information about survival and multiplication. This is more often useful in the prediction of population size on a host plant, which helps in ascertaining the damage intensity of the mite and growth as well as quality parameters of the medicinal plant.

Total developmental period from egg to adult of *O. mangiferus* on the leaves of *I. frutescens* was 12.20 days at 25ºC, while a study by Abu-shosha *et al.* (2017) recorded a lower total developmental period of 7.51 days on mango leaves. This variation in development is attributed to difference of host plants. Mani *et al.* (2014), who studied the life cycle of the mite on grapevine at 31ºC temperature, recorded a longer total life cycle of 27.3 days, while it has been recorded as a low of 7.10 days at 30ºC rearing temperature in the present study. From this it is evident that *I. frutescens* might be a more preferred host of *O. mangiferus* than grapevine on which the mite took more time to develop and complete its life cycle. Gotoh and Gomi (2003) and

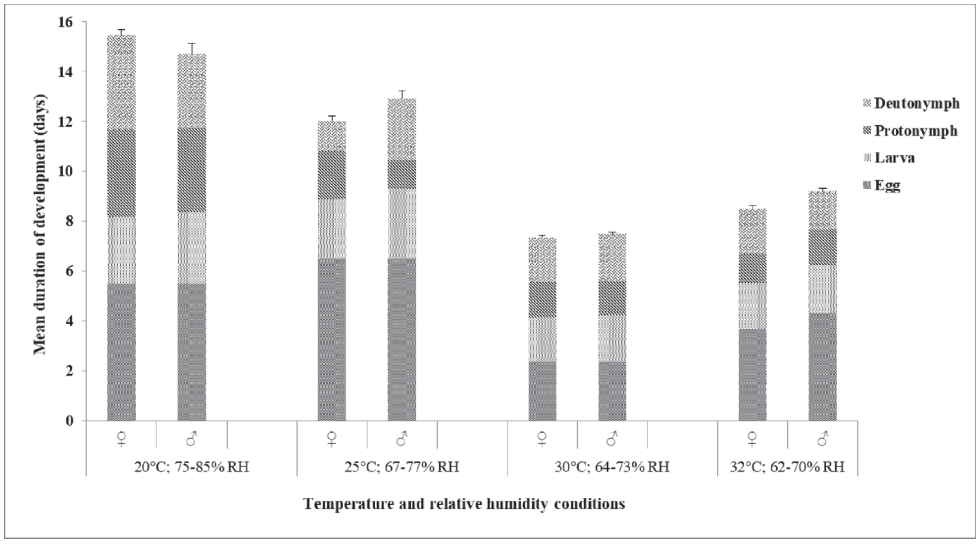

Fig. 1. Development of *Oligonychus mangiferus* on *Ichnocarpus frutescens* at different constant temperature and humidity conditions

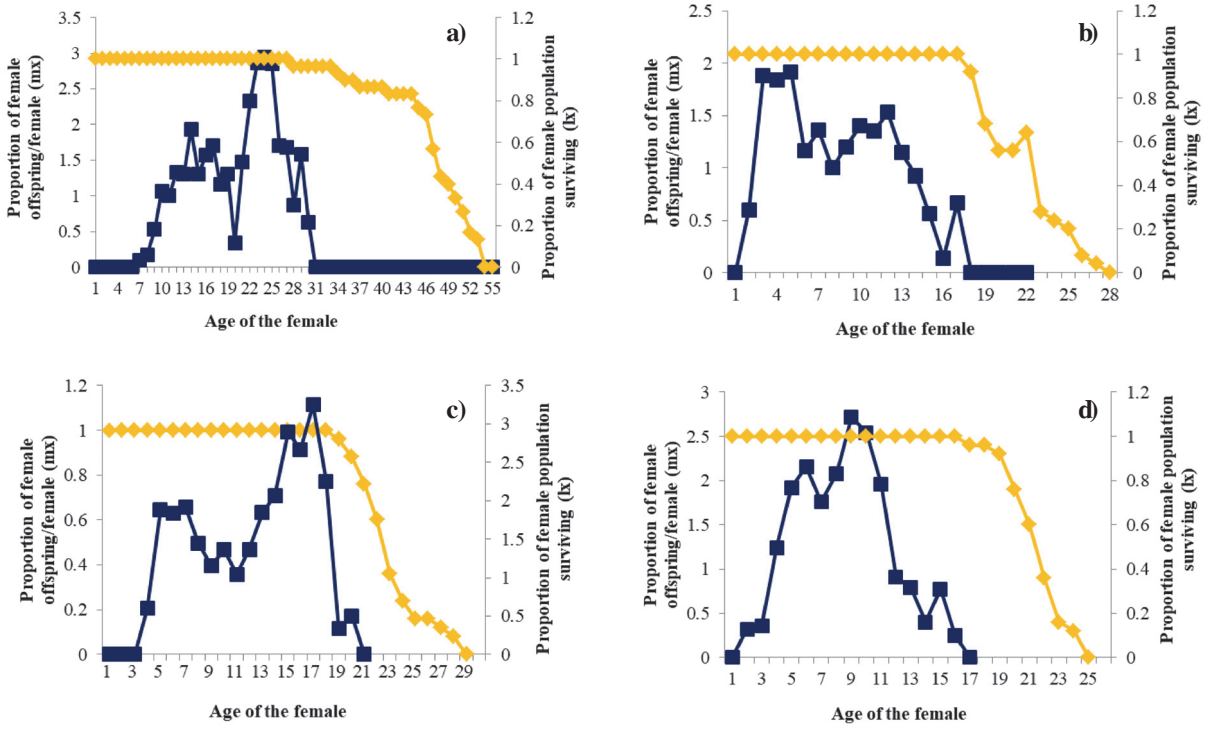

Fig. 2. Age specific survival and fecundity of *Oligonychus mangiferus* on *Ichnocarpus frutescens* at different constant temperature and humidity conditions:

a) 20° C; 75-85% RH, b) 25° C; 67-77% RH, c) 30° C; 64-73% RH and d) 32° C; 62-70% RH

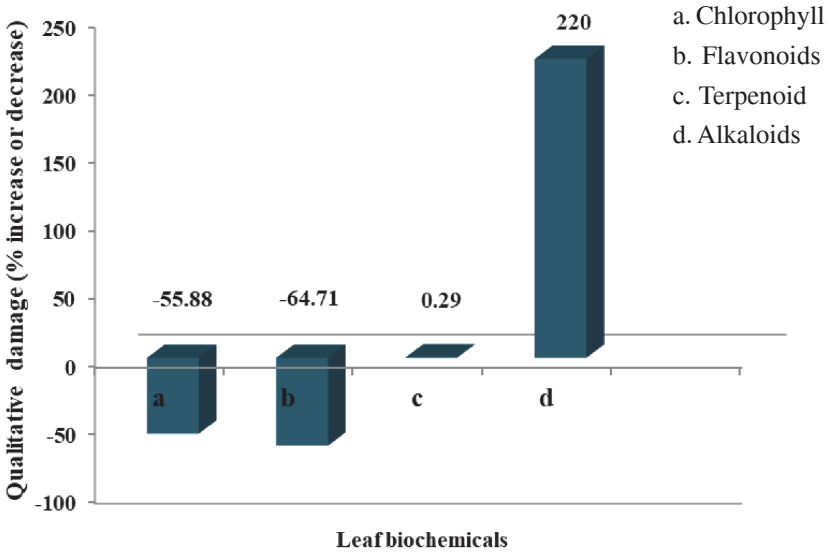

Fig. 3. Biochemical profile of *Ichnocarpus frutescens versus* infestation of *Oligonychus mangiferus*

Table 1. Reproduction of *Oligonychus mangiferus* on *Ichnocarpus frutescens* at different temperature and humidity conditions

Temp. & RH	Pre-oviposition (days)	Oviposition (days)	Post-oviposition (days)	Female longevity (days)	Fecundity (no. of eggs/ female)	Progenial sex ratio (♂:♀)
1 (n=25)	2.90±0.13	25.13±1.50^{b}	4.67±0.33	32.70±1.41^{b}	31.03±1.83^{c}	1:2.71^{a}
2 (n=23)	2.76±0.12	11.52±0.58^{a}	2.92±0.13	17.20±0.54^{a}	21.04±1.15^{a}	1:2.84^{a}
3 (n=25)	2.00±0.13	10.28±0.34^{a}	2.28±0.09	14.56±0.30^{a}	24.16±0.84^{b}	1:2.71^{a}
4 (n=30)	1.61±0.10	10.96±0.40^{a}	1.87±0.14	14.43±0.41^{a}	26.52±0.97^{c}	1:2.68^{a}

n: number of mites observed
1. 20°C; 75-85% 2. 25°C; 67-77% 3. 30°C; 64-73% 4. 32°C; 62-70%
Mean values with same alphabetical superscript within the column are not significantly different as per Tukey's HSD test (p<0.05)

Murungi *et al.* (2010) attributed great variation in development and reproduction of spider mites to the quality of their host plants. Thus, it is inferred that *I. frutescens* would be more preferred by *O. mangiferus* particularly at higher temperatures of 30º to 32ºC, as the mite could complete its development much faster *i.e.,* 7.10 to 8.77 days. Bayu *et al.* (2017) opined that higher rearing temperatures accelerated the biochemical processes of growth and development of two–spotted spider mite, *Tetranychus urticae* Koch.

Our demographic study of *O. mangiferus* is compared with that of Badawi *et al.* (2011) on mango leaves, who recorded the Intrinsic Rate of Natural Increase of the mite as 0.125/female/day at 32ºC, whereas it was 0.083/female/day on a different host *Ichnocarpus* in the present study. The fecundity of 26.52 eggs/female recorded at 32ºC is much lower than that, 46.43 eggs/female recorded by Badawi *et al.* (2011) at the same temperature and this was evidenced from the better reproduction performance of *O. mangiferus* on its original host plant mango. At 25°C rearing temperature, the mite had both Mean Generation Time and Doubling Time as shortest, while its Intrinsic Rate of Natural Increase being highest at this temperature (Table 2).

Table 2. Demography of *Oligonychus mangiferus* on *Ichnocarpus frutescens* at different constant temperature and humidity conditions

Temp. &RH	Mean Generation Time (days)	Doubling Time (days)	Net Repro. Rate (No. of female offsprings/female/ generation)	Gross Repro. Rate (No. of offsprings/ female /generation)	Finite Rate of Increase (No.of female off-springs /female/day)	Intrinsic Rate of Natural Increase (No. of female off-springs/ female/day)
1 (*n=30*)	29.50±0.16[d]	14.49±0.09[d]	26.57±0.11[d]	28.00±0.09[c]	1.051[a]	0.049[a]
2 (*n=25*)	15.26±0.12[a]	8.95±0.09[a]	16.29±0.09[a]	18.61±0.09[a]	1.089[d]	0.085[d]
3 (*n=25*)	19.20±0.12[c]	10.82±0.08[c]	17.74±0.08[b]	28.73±0.11[d]	1.070[b]	0.068[b]
4 (*n=23*)	16.76±0.15[b]	9.38±0.11[b]	18.84±0.11[c]	20.17±0.01[b]	1.0875[c]	0.083[c]

n: number of mites observed

1. 20°C; 75-85% 2. 25°C; 67-77% 3. 30°C; 64-73% 4. 32°C; 62-70%

Mean values with same alphabetical superscript within the column are not significantly different as per Tukey's HSD test (p<0.05)

Apart from the associated host plant, adaptability of the mite to prevalent local climatic conditions would greatly influence the growth, development and multiplication performance of the mite. Even on the same host, rearing of mites at different temperature has varying influence on development and reproduction potential of the mite, which again confirmed by the present study.

Feeding damage by *O. mangiferus* resulted in apparent decline in total chlorophyll and total flavonoid contents. Primary metabolites like chlorophyll have direct influence on plant's photosynthetic efficiency, which is responsible for overall growth and ultimately the medicinal qualities of the plant. In spite of being a secondary metabolite, quantity of flavonoids showed a decline in mite infested plants which should have rather increased. This may be answered by further investigation on the action and role of such biochemicals in the plant system. But alkaloid and terpenoid contents showed increase in mite infested leaves owing to their defensive role. However, observed changes in the quantity of secondary metabolites like alkaloids, flavonoids and terpenoids, subsequent to mite feeding damage may be significant, in view of their definite role in the medicinal value of the herb, therapeutic use and application. The study focused on the importance of feeding damage of mite as a sucking pest on the medicinal quality characteristics of the plant. How these biochemical changes be exploited to the best advantage of medicinal use of *Ichnocarpus,* needs further investigation.

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Checklist of cockroaches (Blattodea) of Kerala, India

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ABSTRACT: Cockroach fauna comprises of 23 valid species under 14 genera. Information on the distribution, synonymy, type locality, type depository are provided. Thirteen species of blattids are added to the fauna of Kerala based on literature survey and study of specimens available in Western Ghat Field Research Centre, Zoological Survey of India, Kozhikode, Kerala. There are four species endemic to Kerala. © 2020 Association for Advancement of Entomology

KEYWORDS: Distribution, taxonomy, species of blattids

INTRODUCTION

The Order Blattodea, includes cockroaches and termites. It comprises of 4641 species of cockroaches under 492 genera in 8 families (Beccaloni, 2014) and 2929 species of termites belonging to 283 genera and 9 families (Krishna *et al.,* 2013). In India, there are 181 species of cockroaches belonging to over 72 genera under 17 subfamilies in 6 families (Gupta and Chandra, 2019). The taxonomic work on Indian blattids still covers only common and easily available species. Despite having rich Indian blattid fauna especially in the forest ecosystem, taxonomy of many families of Blattodea in the country remains in a confused state, as studies on Indian blattids are scanty. From Kerala state, only 10 species of blattids were reported earlier by Gupta and Chandra (2019).

Initially Shelford (1910) described a species *Haanina maindroni* from Kerala, after that Mukherjee and Hazra (1991) recorded some species of cockroaches from Kerala i.e *Haanina patinifera* (Bolívar, 1897); *Rhabdoblatta lineaticollis* (Bolívar, 1897). Roth (1979a) recorded a few more species from Kerala namely *Panesthia monstruosa* Wood-Mason, 1876, *Panesthia morosa* Kirby, 1903 and *Panesthiapara monstruosa* Roth, 1979. Anisyutkin and Yushkova (2017) described three species from Kerala namely, *Morphna indica*, *Rhabdoblattella alexeevi*, *Rhabdoblattella euptera*. Study of specimens in the Western Ghat Field Research Centre, Zoological Survey of India, Kozhikode, Kerala (WGRC) and a detailed literature survey enhanced our knowledge of cockroach fauna of Kerala, adding 13 species now to the list. An updated checklist containing 23 species is enumorated.

MATERIAL AND METHODS

The present study is based on the literature on the cockroaches of Kerala (Shelford, 1910; Mukherjee 1989; Anisyutkin and Yoshkova, 2017; Mukherjee

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and Hazra, 1991; Roth 1979, 1985; Grandcolas, 1993; Beccaloni, 2014) and by the study of specimens present in the National Zoological Collection at Western Ghat Field Research Centre Zoological Survey of India, (WGRC), Kozhikode, Kerala. The classification followed is based on Beccaloni and Eggleton (2013).

Abbreviations used in the text:

TL - Type locality

TD - Type depository. Acronyms for depositories

MNHN - National Museum of Natural History Paris.

CAS - California Academy of Sciences – California

ZMUC - University of Copenhagen Zoological Museum

MHNG - The Natural History Museum of Geneva

MMUM - The Manchester Museum of the University of Manchester, Manchester, United Kingdom

BMNH - (British Museum of Natural History) Natural History Museum, in London.

LSUK - Linnaean Society, London, United Kingdom.

RESULTS AND DISCUSSION

Extensive literature and study of specimens helped in updating the cockroach fauna of Kerala. The updated list and systematic notes on additional 13 species are given (Table 1).

Systematic Account

Order BLATTODEA

Superfamily: BLABEROIDEA Saussure, 1864

Family: BLABERIDAE Saussure, 1864

Subfamily: EPILAMPRINAE Brunner von Wattenwyl, 1865

Tribe ***Morphnini*** McKittrick, 1964

Genus ***Haanina*** Hebard, 1929

1. *Haanina maindroni* (Shelford, 1910)

1910. *Homalopteryx maindroni* Shelford. *Genera Insectorum* 101: 7.

1967. *Haanina maindroni* Princis, *Orthopterorum Catalogus* (11): 644.

TL: India: Puducherry: Mahe (♀)

TD: MNHN

Distribution: India: Puducherry: Mahe

Remarks: Endemic to south India (Kerala).

2. *Haanina patinifera* (Bolívar, 1897)

1987. *Homalopteryx patinifera* Bolívar, *Annls. Soc. Ent. Fr.* 66: 295

1967. *Haanina patinifera* Princis, *Orthopterorum Catalogus* (11): 644.

TL: India: Tamil Nadu: Madurai (♂♀)

TD: MNHN

Distribution: India: Kerala; Tamil Nadu: Madurai; Lakshadweep Island.

Remarks: Endemic to south India.

Genus ***Morphna*** Shelford, 1910

3. *Morphna decolyi* (Bolivar, 1897)

1897. *Molytria decolyi* Bolívar. *Annls. Soc. Ent. Fr.* 66: 294.

1964. *Stridoblatta decolyi* McKittrick. *Cornell Univ. Agric. Exp. Sta. Mem*. 389: 44.

1910. *Homolopteryx decolyi* Shelford, *Genera Insectorum* 101: 7

1967. *Haanina decolyi* Princis, *Orthopterorum Catalogus* (11):644

Table 1. Updated checklist of cockroaches of Kerala

Sl.	Name of the species	References	Remarks
	Order BLATTODEA Brunner von Wattenwyl. 1882		
	Family BLABERIDAE Sassure, 1864		
1.	*Haanina maindroni* (Shelford, 1910)	Shelford (1910)	Endemic to Kerala*
2.	*Haanina patinifera* (Bolívar, 1897)	Mukherjee and Hazra (1991)	Endemic to south India
3.	*Morphna decolyi* (Bolívar, 1897)	Anisyutkin (2014)	Endemic to south India
4.	*Morphna indica* Anisyutkin, 2017	Anisyutkin and Yushkova (2017)	Endemic to Kerala*
5.	*Morphna plana* (Brunner von Wattenwyl, 1865)	Identified specimens from WGRC	Endemic to south Asia**
6.	*Rhabdoblatta lineaticollis* (Bolívar, 1897)	Mukherjee and Hazra, (1991)	Endemic to south India
7.	*Stictolampra plicata* (Navás, 1904)	Mukherjee (1989)	Endemic to India
8.	*Thorax porcellana* (Saussure, 1862)	Roth (1972)	-
9.	*Rhabdoblattella alexeevi* Anisyutkin, 2017	Anisyutkin and Yushkova (2017)	Endemic to Kerala
10.	*Rhabdoblattella euptera* Anisyutkin, 2017	Anisyutkin and Yushkova (2017)	Endemic to Kerala
11.	*Panesthia monstruosa* Wood-Mason, 1876	Roth (1979a)	Endemic to India*
12.	*Panesthia morosa* Kirby, 1903	Roth (1979a)	Endemic to south India*
13.	*Panesthia paramonstruosa* Roth, 1979	Roth (1979a)	Endemic to south India*
14.	*Salganea erythronota* Bolívar, 1897	Roth (1979b)	Endemic to India*
15.	*Salganea indica* Princis, 1953	Identified specimens from WGRC	Endemic to south India**
16.	*Pycnoscelus surinamensis* (Linnaeus, 1758)	Bolivar (1897)	Pest of Agriculture*
17.	*Pycnoscelus indicus* (Fabricius, 1775)	Identified specimens from WGRC	Circumtropical – Pest of Crops**
	Family ECTOBIIDAE Brunner von Wattenwyl, 1865		
18.	*Blattella humbertiana* (Saussure, 1863)	Roth (1985)	-
	Family BLATTIDAE Latreille, 1810		
19.	*Hebardina concinna* (Haan, 1842)	Hebard (1929)	-
20.	*Neostylopyga rhombifolia* (Stoll, 1813)	Identified specimens from WGRC	Circumtropical in Asia**
21.	*Neostylopyga ornata* (Brunner von Wattenwyl, 1865)	Identified specimens from WGRC	Endemic to south India**
22.	*Periplaneta americana* (Linnaeus, 1758)	Identified specimens from WGRC	Cosmopolitan species**
	Family CORYDIIDAE Saussure, 1864		
23.	*Therea petiveriana* (Linnaeus, 1758)	Grandcolas (1993)	Endemic to south India

* Species additional record to Kerala
** Species new record to south India

1971. *Morphna decolyi* Princis, *Orthopterorum Catalogus* (14): 1156-57

TL: Tamil Nadu: Trichy (♀)

TD: MNHN

Distribution: India: Kerala (current record); Tamil Nadu: Tiruchirappalli and Coimbatore.

Remarks: Endemic to South India.

4. *Morphna indica* Anisyutkin, 2017

2017. *Morphna indica* Anisyutkin in Anisyutkin and Yushkova, *Zootaxa* 4236 (1): 56.

Material Examined: 2 , India: Kerala, Chinnar Wild life sanctuary, Churulipetti, 04.iv.2012, coll. Sureshan, Reg.no. ZSI/WGRC/IR INV/ 14732.

TL: India: Kerala (♂)

TD: MHNG

Distribution: India: Kerala: Cardamon Hills.

Remarks: Endemic to Kerala

5. *Morphna plana* (Branner von Wattenwyl,1865)

1865. *Epilampra plana* Brunner von Wattenwyl, *Nouveau Système des Blattaires*: 183.

1897. *Homalopteryx biplagiata* Bolívar. *Annls. Soc. ent. Fr.* 66: 296.

1967. *Morphna plana* Princis. *Orthopterorum Catalogus* (11): 648.

Material Examined: 1♂, India: Kerala, Idukki District, Mathikettan Sholai, 17.ix.2014; 3♂, Idukki district, Eravikulam N.P, 23.ix.2014 coll. Emiliyamma Reg. nos. ZSI/WGRC/IR INV/14735, 14740; 1♂,1♀, Idukki District, Erachippara, 23.ix.2014, coll. Emiliyamma, Reg.no. ZSI/WGRC/ IR INV/ 14824.

TL: Sri Lanka (♂)

TD: MMUM

Distribution: India: Kerala; Tamil Nadu: Tiruchirappalli. **Elsewhere:** Sri Lanka**.**

Remarks: Endemic to south Asia.

Genus ***Rhabdoblatta*** Kirby, 1903

6. *Rhabdoblatta lineaticollis* (Bolívar, 1897)

1897. *Epilampra lineaticollis* Bolívar. *Annls Soc. Ent. Fr.* 66: 298.

1904. *Heterolampra lineaticollis* Kirby, *Syn. Cat. Orthop*: 120.

1967. *Rhabdoblatta lineaticollis* Princis. *Orthopterorum Catalogus* (11): 672.

Material Examined: 1♀, India: Kerala, Idukki district, Mannavan Shola, 06.iv.2012; coll. Sureshan; 1♀, Idukki district, Mathikettan Sholai, 17.ix.2014, coll. Emiliyamma, Reg.nos. ZSI/WGRC/IR INV/ 14733, 14734

TL: India (♂♀)

TD: MNHN

Distribution: India: Kerala (Mukherjee and Hazra, 1991); Tamil Nadu: Trichirappali (Kirby, 1904)

Remarks: Endemic to south India.

Genus ***Stictolampra*** Hanitsch, 1930

7. *Stictolampra plicata* (Navás, 1904)

1904. *Opisthoplatia plicata* Navás. *Bol. Soc. Aragon. Cienc. Nat*. 3: 130.

1910. *Rhicnoda plicata* Shelford. *Genera Insectorum* 101: 9.

1967. *Stictolampra plicata* Princis, *Orthopterorum Catalogus* (11): 683.

TL: India: West Bangal: Kurseong (♀)

TD: Unknown

Distribution: India: Kerala, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Himachal Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Meghalaya, Orissa, Punjab, Sikkim, Tripura, Tamil Nadu, Uttarakhand and West Bengal.

Elsewhere: Borneo; Java; Malayasia (Beccaloni, 2014)

Tribe THORACINI Rehn, 1951

Genus ***Thorax*** Saussure, 1862

8. *Thorax porcellana* (Saussure, 1862)

1862. *Phoraspis* (*Thorax*) *porcellana* Saussure, *Rev. Mag. Zool*. 2(14): 228.

1865. *Paraphoraspis notata* Brunner von Wattenwyl. *Nouveau Système des Blattaires*.: 164.

2014 *Thorax porcellana* Anisyutkin, *Zootaxa* 3847 (3): 321.

TL: India (♂)

TD: MHNG

Distribution: India: Kerala: Trivandrum, Cochin; Tamil Nadu: Coimbatore: Anamalai Hills, Nilgiris and Gudalur (Anisyutkin 2017); Goa; Karnataka: Mysore.

Elsewhere: Sri Lanka and Australia: Victoria (Beccaloni, 2014).

Genus ***Rhabdoblattella*** Anisyutkin, 1999

9. *Rhabdoblattella alexeevi* Anisyutkin, 2017

2017. *Rhabdoblattella alexeevi* Anisyutkin in Anisyutkin and Yushkova, *Zootaxa* 4236 (1): 48.

TL: India: Kerala (♂)

TD: MHNG

Distribution: India: Kerala: Idukki district, Cardamon Hills, Mattupatti near Munnar.

Remarks: Endemic to Kerala.

10. *Rhabdoblattella euptera* Anisyutkin, 2017

2017. *Rhabdoblattella euptera* Anisyutkin in Anisyutkin and Yushkova, *Zootaxa* 4236 (1): 52.

TL: India: Kerala (♂)

TD: MHNG

Distribution: India: Kerala: Idukki district, Cardamon Hills, Valara Falls.

Remarks: Endemic to Kerala.

Subfamily PANESTHIINAE

Genus ***Panesthia*** Serville, 1831

11. *Panesthia monstruosa* Wood-Mason, 1876

1876. *Panesthia monstruosa* Wood-Mason, *Journ. Asiat. Soc., Bengal* 15(2):189.

1897. *Panesthia panteli* Bolívar, *Annls. Soc. Ent. Fr*. 66: 307.

1979. *Panesthia monstruosa* Roth. *Aust. J. Zool., Suppl. Ser.,* 74: 107.

Material Examined: 3 ♂ **India:** Kerala: Idukki Dist. Periyar Tiger Reserve, Eramangalar, 7.ix.2015, coll. Sureshan, Reg.no. ZSI/WGRC/IR INV/ 14822.

TL: South India (♂♀)

TD: Unknown

Distribution: India: Kerala: Chalakudy, *Cochin*; Tamil Nadu: Coimbatore, Coonoor, Nilgiri, Anaikatti, Valparai, Thiruchirapalli, Madurai; West Bengal: Darjling: Kurseong; Sikkim (Roth, 1979).

Remarks: Endemic to India.

12. *Panesthia morosa* Kirby, 1903

1903. *Panesthia morosa* Kirby, *Ann. Mag. nat. Hist*. 7 (11): 412.

1979. *Panesthia morosa* Roth, *Aust. J. Zool., Suppl. Ser.,* 74: 73.

TL: India: Tamil Nadu (♂)

TD: BMNH

Distribution: India: Kerala: Trivandrum; Tamil Nadu: Anaimalai Hills (Roth, 1979).

Remarks: Endemic to south India.

13. *Panesthia paramonstruosa* Roth, 1979

1979. *Panesthia paramonstruosa* Roth, *Aust. J. Zool., Suppl. Ser.,* 74: 109.

Material Examined: 1♂, Eravikulam N.P, Mathikettan Sholai, Idukki District. 10.04.2012 coll. Sureshan, Reg.no. ZSI/WGRC/IR INV/ 14737; 1♂, Idukki District, Eravikulam N.P, Erachipara, 23.09.2014, coll. Emiliyamma, Reg.no. ZSI/ WGRC/IR INV/ 14837 2♀**,** 2 Nymph Kambilipara Shola, Marayoor forest area, Idukki Dist. 20.05.2014. 1 ♂ Kambilipara Shola, Marayoor forest area, Idukki Dist. 23.05.2014, coll. Sureshan, Reg.nos. ZSI/WGRC/IR INV/ 14820,14826

TL: India: Kerala: Munnar (♂)

TD: CAS

Distribution: India: Kerala: Munnar; Tamil Nadu: Anaimalai Hills, Anaikatti.

Remarks: Endemic to south India.

Genus ***Salganea*** Stål, 1877

14. *Salganea erythronota* Bolívar, 1897

1897. *Salganea erythronota* Bolívar, *Annls. Soc. Ent. Fr.* 66: 301.

1979. *Salganea erythronota* Roth. *Australian Journal of Zoology Supp.* 27(69): 94.

Material Examined: 2♀, Mannavan Shola, 06.04.2012, coll. Sureshan, Reg.no. ZSI/WGRC/ IR INV/14736; 1♀, Pambadum Shola N. P Idukki Dist. 26.5.2014, coll. Sureshan, Reg.no. ZSI/ WGRC/IR INV/ 14823; 2 exs. Pullaradi Shola, Mannavan Shola, Idukki Dist. 27.05.2014, coll. Sureshan, Reg.no. ZSI/WGRC/IR INV/ 14819 1♀, Chinna Anamudi, Idukki Dist, 20.09.2014, coll. Emiliyamma, Reg.no. ZSI/WGRC/IR INV/ 14821

TL: India: Tamil Nadu (♀)

TD: MNHN

Distribution: India: Kerala: Munnar; Tamil Nadu: Madurai: Shambaganaur, Trichy, Kodaikanal Hills, Palni Hills; Himalaya (Roth 1979a).

Remarks: Endemic to India.

15. *Salganea indica* Princis, 1953

1953. *Salganea indica* Princis, *Opuscula Entomologica* 18(1): 53.

1979. *Salganea indica* Roth, *Australian Journal of Zoology Supp.* 27(69): 63.

Material Examined: 1♂, 2♀, 9 nymphs, India: Kerala, Kozhikode district, Malabar Wildlife sanctuary, Panikkar Kadavu, 19.03.2012, coll. Sureshan, Reg.no. ZSI/WGRC/IR INV/ 14739. 2♀, 6 nymphs, Kattila Para, Kollam Dist. 21.01.2019, coll. Jafer Palot, Reg.no. ZSI/WGRC/ IR INV/ 14829

TL: India: Tamil Nadu (♀)

TD: MNHM

Distribution: India: Kerala; Tamil Nadu: Anaimalai Hills; Chincona; Karnataka: Mysore (Roth 1979a).

Remarks: Endemic to South India.

Subfamily PERISPHAERINAE Brunner von Wattenwyl, 1865

Genus ***Pseudoglomeris*** Brunner von Wattenwyl, 1893

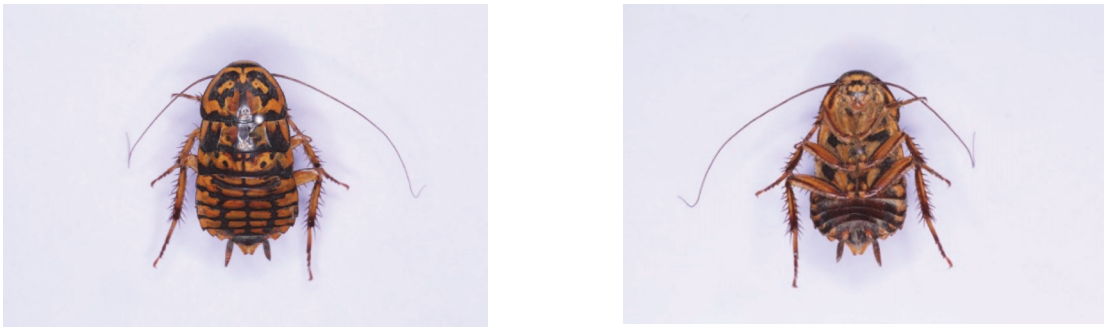
16. *Pseudoglomeris sericea* (Saussure, 1863)

1863. *Perisphaeria sericea* Saussure. *Mém. Soc. Phys. Hist. Nat. Génève* 17:138.

1863. *Perisphaeria emortualis* Saussure. *Mém. Soc. Phys. Hist. Nat. Génève* 17: 138.

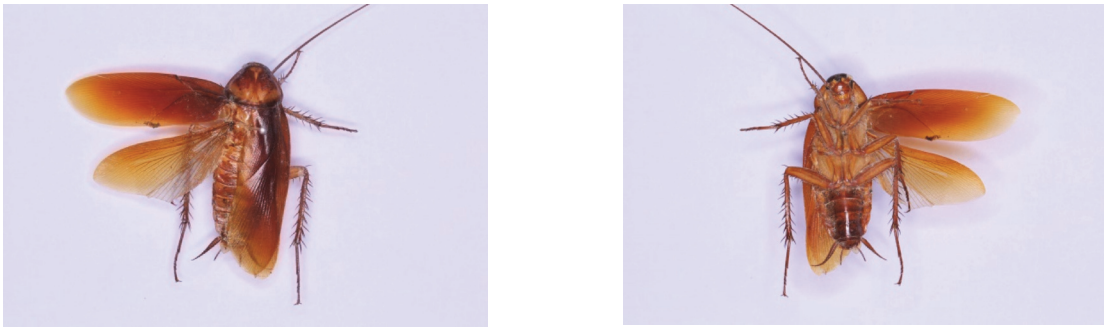
a) Dorsal view b) Ventral view

Fig.1. *Thorax porcellana* (Saussure, 1862)



a) Dorsal view b) Ventral view

Fig.2. *Neostylopyga rhombifolia* (Stoll, 1813)



a) Dorsal view b) Ventral view

Fig. 3. *Periplaneta americana* (Linnaeus, 1758)

a) Dorsal view b) Ventral view

Fig. 4. *Morphna indica* Anisyutkin, 2017

a) Dorsal view b) Ventral view

Fig. 5. *Rhabdoblatta lineaticollis* (Bolívar, 1897)

a) Dorsal view b) Ventral view

Fig.6. *Morphna plana* (Branner Von wattemay, 1865)

a) Dorsal view b) Ventral view

Fig.7. *Salganea erythronota* Bolívar, 1897

a) Dorsal view b) Ventral view

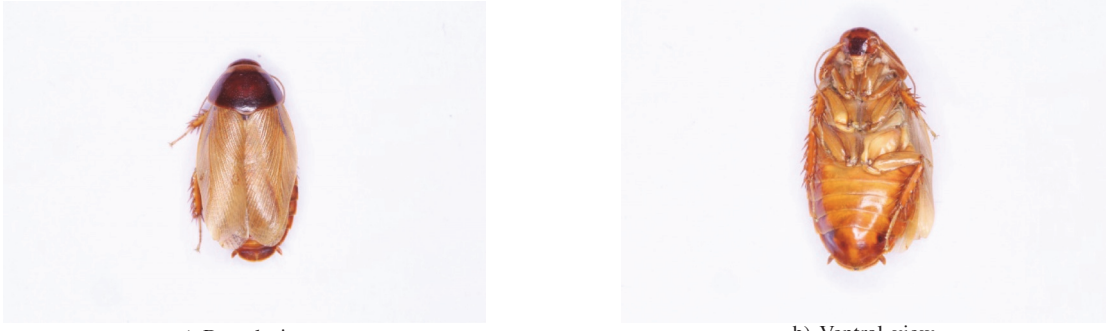
Fig. 8. *Panesthia paramonstruosa* Roth, 1979

a) Dorsal view b) Ventral view

Fig. 9. *Neostylopyga ornata* (Brunner von Wattenwyl, 1865)

a) Dorsal view b) Ventral view

Fig. 10. *Salganea indica* Princis, 1953



a) Dorsal view b) Ventral view

Fig. 11. *Pycnoscelus indicus* (Fabricius, 1775)

1964. *Trichoblatta sericea* Princis. *Orthopterorum Catalogus* (6): 208.

2018. *Pseudoglomeris sericea* (Saussure, 1863) Xin-Ran Li *et.al., Zootaxa* 4410 (2): 259.

TL: India: Tamil Nadu (♂)

TD: Unknown

Distribution: India: Kerala; Tamil Nadu; Puducherry; Andhra Pradesh; Bihar; Gujrat; Karnataka; Maharashtra; Orissa; Sikkim; West Bengal; Arunachal Pradesh; Meghalaya (Mukherjee, 1993).

Remarks: Endemic to India.

Subfamily PYCNOSCELINAE

Genus ***Pycnoscelus*** Scudder, 1862

17. *Pycnoscelus indicus* (Fabricius, 1775)

1775. *Blatta indica* Fabricius, *Syst. Ent*.: 272.

1964. *Pycnoscelus indicus* Princis, *Orthopterorum Catalogus* (6): 270.

Material Examined: 1♀, Pepparai dam, Trivandrum Dist, 13.10.2012, coll.Emiliyamma, Reg.no. ZSI/WGRC/IR INV/ 14827

TL: India

TD: ZMUC

Distribution in India: Kerala

Elsewhere: Sumatra, Thailand, Taiwan, Java, Philippines, USA, Burma, China & Sri Lanka. Circumtropical (Beccaloni, 2014).

Remarks: Agricultural Pest.

Family ECTOBIIDAE Brunner von Wattenwyl, 1865

Subfamily BLATTELLINAE Karny, 1908

Genus: ***Blattella*** Caudell, 1903

18. *Blattella humbertiana* (Saussure, 1863)

1863. *Polyzosteria humbertiana* Saussure, *Mém. Soc. Phys. hist. Nat. Génève*17: 131.

1865. *Phyllodromia cognata* Brunner von Wattenwyl. *Nouveau Système des Blattaires*.: 92.

1871. *Blatta subreticulata* Walker, *Cata. Derm. Coll. Part V. Supp. Cata. Blat.* 23.

1969. *Blattella humbertiana* Princis. *Orthopterorum Catalogus* (13): 842.

TL: Sri Lanka

TD: MHNG

Distribution: India: Kerala; Puducherry: Mahe (Roth,1985); Tamil Nadu; Bombay; Arunachal Pradesh; West Bengal; Andhra Pradesh; Arunachal Pradesh; Delhi; Karnataka; Maharashtra; Manipur; Punjab; Jharkhand; Uttarakhand; Delhi; Meghalaya; Orissa; Rajasthan and Tripura.

Elsewhere: Sri Lanka; Burma; China (Beccaloni, 2014).

Family Blattidae Latreille, 1810

Subfamily BLATTINAE Latreille, 1810

Genus ***Hebardina*** Bei-Bienko, 1938

19. *Hebardina concinna* (Haan, 1842)

1842. *Blatta* (*Periplaneta*) *concinna* Haan, *Verhand. natuurl.* (16) 6: 50.

1873. *Periplaneta borrei* Saussure. *Mem. Soc. Geneve* 23. 113.

1966. *Hebardina concinna* Princis, *Orthopterorum Catalogus* (8): 466.

1999. *Hebardina concinna* Roth, *Oriental Insects*, 33(1): 172.

TL: Indonesia: Java Island (♂♀)

TD: Not Recorded

Distribution: India: Kerala (Mukherjee 1993); Tamil Nadu: Coimbatore: Anamalai Hills, Tiruchirappalli; Uttar Pradesh: Nainital district; Arunachal Pradesh; West Bengal: Howrah, Jalpaiguri and Kolkata.

Elsewhere: Burma; Malaysia (Malacca state); Indonesia (Sumatra); Indonesia (Java Island); Borneo Island (Beccaloni, 2014).

Remarks: Domiciliary pest

Genus *Neostylopyga* Shelford, 1911

20. *Neostylopyga rhombifolia* (Stoll, 1813) (Harlequin Cockroach)

1813. *Blatta rhombifolia* Stoll, *Represent. exact. coloreed'apres nature d. Spectres*: 5.

1966. *Neostylopyga rhombifolia* Princis. *Orthopterorum Catalogus* (8): 534.

Material Examined: 1♀, Kerala, Idukki district, Chinnar Wildlife sanctuary, Vasyapara, coll. Sureshan, 05.v.2012 Reg.no. ZSI/WGRC/IR INV/ 14730.

TL: India: Bombay (♀)

TD: BMNH

Distribution: India: Kerala; Tamil Nadu: Chennai (Madras), Bombay. Meghalaya, Andaman and Nicobar Islands, Andhra Pradesh, Bihar, Madhya Pradesh, Orissa, Uttar Pradesh, and West Bengal; Himachal Pradesh, Circumtropical [Asian origin]. **Elsewhere**: Sri Lanka, Mauritius (East Africa), Borneo; Celebes; Java; Malayasia; Sarawak; Sumatra. America (Beccaloni 2014)

21. ***Neostylopyga ornata*** (Brunner von Wattenwyl, 1865)

1865. *Periplaneta ornata* Brunner von Wattenwyl, *Nouveau Système des Blattaires*.: 225.

1966. *Neostylopyga ornata* Princis. *Orthopterorum Catalogus* (11): 537.

Material Examined: 2 exs. Kerala, Idukki district, Chinnar W.L.S, Surulipatti, 22.05.2014, coll. Sureshan, Reg.no. ZSI/WGRC/IR INV/ 14738.

TL: India (♀)

TD: Unknown

Distribution: India: Kerala; Tamil Nadu: Ramanathapuram: Kilakarai.

Remarks: Endemic to India: Tamil Nadu

Genus ***Periplaneta*** Burmeister, 1838

22. ***Periplaneta americana*** (Linnaeus, 1758)

1758. *Blatta americana* Linnaeus, *Systema naturae 1, ed.* 10, *Holmiae*: 424.

1966. *Periplaneta americana* (Linnaeus, 1758) Princis. *Orthopterorum Catalogus* (8): 405.

Material Examined: 1♂, Kerala, Kozhikode district, Kottooli wetlands, 9.12.2011 Coll. Sureshan, Reg.no. ZSI/WGRC/IR INV/ 14731

TL: America (♂)

TD: LSUK

Distribution: India: Kerala; Tamil Nadu: Thiruchirapalli, Arunachal Pradesh: Papumpare district; West Bengal, Sikkim.

Elsewhere: America and Cosmopolitan [African origin].

Remarks: This is a cosmopolitan species and one of the most important domiciliary cockroach pests.

Superfamily Corydioidea Saussure, 1864

Family Corydiidae Saussure, 1864

Subfamily CORYDIINAE Saussure, 1864

Genus ***Therea*** Billberg, 1820

23. ***Therea petiveriana*** (Linnaeus, 1758)

1758. *Cassida petiveriana* Linnaeus, *Syst. Nat*.: 364.

1767. *Cassida septemguttata* Linnaeus. *Syst. Nat.*: 577.

1963. *Therea petiveriana* Princis. *Orthopterorum Catalogus* (4): 84.

2008. *Therea petriviana* Fritzsche & Zompro. *Arthropoda* 16(4):20.

TL: India (♀)

TD: BMNH

Distribution: India: Kerala; Tamil Nadu: Coimbatore; Puducherry: Mahe.

Remarks: Endemic to India.

Based on a cursory survey of literature and by including the above mentioned 23 species, the checklist of cockroach fauna of Kerala is updated. Among these 10 species were listed earlier by Gupta and Chandra (2019) for Kerala, but their distribution within Kerala state was not mentioned. Study of specimens at WGRC has helped to bridge the gap. This checklist will be beneficial as a baseline data for future studies. Among the 23 species, 15 species are endemic to India in which eight species are endemic to south India and four species endemic to Kerala.

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A study on ectoparasites with special reference to chigger mites on rodents/shrews in scrub typhus endemic areas of Kerala, India

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ABSTRACT: The main goal of this investigation was to record the ectoparasites living on rodents in scrub typhus endemic areas of Kerala state, India. Rodents captured alive using Sherman and wonder traps from four diverse habitations revealed, a total of 59 rodents/shrews constituted by 5 host species from families Muridae and Soricidae. In total, 1135 ectoparasites were collected on these rodents/shrews and were identified representing 23 species from 10 genera in 4 families Trombiculidae, Laelaptidae, Ixodidae and Pulicidae. Dominant insectivore species was *Suncus murinus* (57.6%). 42 (71.2%) rodents and shrews were found to be plagued with at least one of the 23 species of ectoparasite harvested. Mites belonging to the family Trombiculidae were the predominant ectoparasite species collected. Study revealed *Tatera indica* (35.5%) as the primary host harboring the chigger mites. *Xenopsylla cheopis* and *Xenopsylla astia* the flea species important vectors for the transmission of zoonotic diseases such as *Leptotrombidium deliense*, *Schoengastiella ligula* and *Echinolaelaps echidninus* were recorded. Twenty species of mites were reported for the first time in Kerala which add knowledge on the ectoparasites distribution.

KEYWORDS: Muridae, Soricidae, Prostigmata, flea species, zoonotic diseases, vectors

INTRODUCTION

Ectoparasites like mites, fleas, ticks, and lice are hematophagous arthropods regularly found on small mammals like rats, mouse, bandicoots (rodents), and shrew (an insectivore) host. These arthropods live on the body surface of the hosts (Mullen and Durden, 2019) transmitting the arboviral diseases, typhus fevers, plague, tularemia, leptospirosis (Masan and Stanko, 2005), and some parasitic zoonoses like babesiosis to humans and animals (Gratz, 1994; Paramasvaran *et al*., 2009). The ectoparasites of rodents play a vital role in the transmission of vector-borne diseases like scrub typhus and plague. Scrub typhus is an emerging zoonotic disease and the epidemiology of the disease revealed a male predominance with clustering of cases in hilly areas of Kerala (Krishnan *et al*., 2016). Rodents and shrews that live nearby human dwellings are considered synanthropic species, having an important role in the transmission of disease to humans and domestic animals leading to economic losses to agriculture (Brown and Khamphoukeo, 2007).

In rodents and shrews, chigger mites are predominant organisms which are the larval stages of mites belonging to the Trombiculidae family.

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Among the different ectoparasites recovered from the rodents/shrews, chigger mites were the predominant ectoparasites (Sharma, 2014). During the past ten years, more outbreaks of scrub typhus occurred during winter months in northern and central parts (Chakraborty and Sarma, 2017) and also in southern parts of India particularly Kerala and Pondicherry (Stephen *et al*., 2015). The chigger mites transmit scrub typhus and some other zoonoses (Varma, 1969; Wu *et al*., 1996; Lee *et al*., 2009). Several reports of scrub typhus from various parts of India have been published (Mathai *et al*., 2001 and 2003; Somashekar *et al*., 2006; Sharma *et al*., 2005). In India, scrub typhus and other typhus fevers are caused by various ectoparasites commonly found in regions having dense vegetation where this disease was spreading fast (Kumar *et al*., 2014). During the summer and post-monsoon season, the prevalence and diversity of mites and fleas were higher (Sadanandane *et al*., 2016).

Scrub typhus was a major outbreak disease during 2017 in Kerala. Based on our earlier study the prevalence of vector mites was already reported in the scrub typhus affected areas of Krishnagiri district, Tamil Nadu (Philip Samuel *et al*., 2017). A comprehensive survey on the ectoparasites was undertaken in the scrub typhus endemic Thiruvananthapuram, Kerala to determine the information on the different ectoparasites species distribution. The present survey aimed to report the variety of ectoparasites associated with the rodents/ shrews prevalent in the scrub typhus affected areas in Thiruvananthapuram, Kerala.

MATERIAL AND METHODS

Thiruvananthapuram (Latitude 8.524139 and Longitude 76.936638) situated in the Kerala state of India is one of the 14 districts in the Kerala state. The geographical area of this district is 2,192 km^2. The total population as per the 2011 census is 3.3 million. The average annual temperature in Thiruvananthapuram is 26.7^{0}C/80.0^{0}F and the annual rainfall is 1,828 mm/ 72 inches. According to the earlier history of this disease, the maximum number of cases reported in Thiruvanathapuram was selected for this study in consultation with the local health officials. Trapping of rodents was conducted in the four habitats during 2017 to 2018. The habitats include urban area (Kollamthara-Thiruvallam PHC), coastal area (Kidarakuzhi-Vizhinjam PHC), rural area (Pavachakuzhi-Vilavoorkal PHC), and forest area (Panga-Aruvikara PHC) (Fig.1).

Sample collection: All the rodents were captured alive using Sherman traps and wonder traps. In each of the scrub typhus positive selected villages, 50 traps were set outdoors (peri-domestic areas) with scrubby vegetation and rodent burrows. Traps were set in the evening (6.00 pm) and retrieved the next day morning (7.00 am). Rodents were anesthetized for the collection of ectoparasites, (Aplin et al., 2003; Sadanandane *et al*., 2016) transported to the laboratory.

Taxonomic Identification: Identified the rodent species by taxonomical keys (Aphin *et al*., 2003; Dinesan *et al*., 2006; Cunningham and Moors, 1996). Ectoparasites were preserved in 80% ethanol, transferred to clearing agent and mounted in Hoyer's medium, examined under the microscope, and identified up to species level (Fernandes and Kulkarni, 2003; Goff *et al*., 1982; Kerans and Litwak, 1989; Nadchatram and Alexander 1974; Sharif, 1930; Geevargheese and Mishra, 2011). All collected ectoparasite specimens were preserved on microscope slides and deposited in the Mosquito Museum Entomology Laboratory of ICMR-Vector Control Research Centre, Field Station Madurai, Tamil Nadu. This study was approved by the Institutional Animal Ethics Committee (IAEC) of Madurai Medical College, Madurai. The data analysis was performed using SPSS Ver. 15 (Statistics Package for Social Sciences).

RESULTS

A total of 59 rodents/shrews constituted by five host species of rodents/shrews (*Rattus rattus*, *S. murinus*, *T. indica*, *B. bengalensis*, and *M. musculus*) were collected from four diverse habitations. In total, 1135 ectoparasites (chigger mites, ticks, and fleas) were collected from Thiruvananthapuram. These ectoparasites were

Fig.1 Locations where the field works was carried out in Thiruvananthapuram district, Kerala

identified to be 23 species from 10 genera in 4 families.5 rodents/shrews species were entrapped from the coastal areas, 3species were snared from rural areas, 4 species were trapped from urban areas and another 2 species ensnared from forest habitation. *S. murinus* (57.6%) was the dominant insectivore species collected. 42 (71.2%) rodents and shrews were found to be plagued with at least one of the 23 species of ectoparasite harvested. A total of 23 species of different species of ectoparasites comprising five main groups, mites (Mesostigmata), chiggers (Prostigmata), ticks (Acarina), fleas (Siphonaptera) and louse (Phthiraptera) were recovered from rodents and insectivores from all the four varied habitats. Chigger mites 96% (1112) were the predominant ectoparasites found on rodents and insectivores from all the four habitats followed by fleas 2.2% (13) ticks, 0.83% (7) fleas, and 0.83% (3) adult mites (Table 1 and 2). Mites belonging to the family Trombiculidae were the predominant ectoparasites species collected. Our study revealed *T. indica* (35.5%) as the primary host harboring the chigger mites. Ticks linked to the family Ixodidae were harvested mainly from the urban-dwelling insectivores. *X. cheopis* and *X. astia* was the flea species recovered.

There was no significant difference in the distribution pattern of rodents in these localities (F-0.383, df-4, P>0.05). There was also no significant difference in the sex-wise distribution of male and female rodents/shrews in the prevalence of ectoparasites (t- 1.306, df-57, P>0.05). In the insectivores, only *S. murinus* was trapped. But, insectivores were collected more than rodent counterpart. There was a significant difference regarding infestation between rodents and insectivores (t- 2.607, df-57, P<0.05). The distribution of ectoparasites in these four localities showed a significant difference (F-8.662, df-1152, P<0.05). There was no significant difference in the infestation of ectoparasites between male and female hosts trapped (F-0.707, df-1152, P>0.05). There was a significant difference between rodents and insectivores for the presence of ectoparasites (t- 2.607, df-57, P<0.05), and a significant difference was shown in the infestation of ectoparasites in rodents and insectivores (F-25.832, df-1152, P<0.05). Taxonomic checklist of ectoparasites and rodents/shrews are also listed (Table 3 and 4).

DISCUSSION

Many species of mites and ticks harbored by rodents/shrews act as the vectors and thus gained significant medical and veterinary importance (Krantz and Walter, 2009). Scrub typhus is a re-emerging zoonotic disease initially affecting rodents being transmitted to humans through the bite of infected *L. deliense* mites which are found

Table 1. Ectoparasites indices for rodents for four different habitats

Location*	No of traps fixed	No of traps positive	Trap positivity rate	No. of Rodents/ Shrews Collected	No. of rats +ve for chigger mites	Percent positive for Chigger	No. of chigger collected	Chigger Index	No. of rats +ve for fleas	Percent positive for Fleas	No. of fleas collected	Flea Index	No. of rats +ve for ticks	Percent positive for Ticks	No. of ticks collected	Tick Index	No. of rats +ve for Mites	Percent positive for mites	No. of mites collected	Mite Index
Urban	100	12	12.00	13	6	46.2	227	17.46	0	0.0	0	0	0	0.0	0	0.00	0	0.0	0	0.00
Coastal	150	22	14.67	22	14	63.6	346	15.73	1	4.5	3	0.14	1	4.5	8	0.36	3	13.6	3	0.14
Rural	100	16	16.00	16	11	68.8	286	17.88	1	6.3	4	0.25	0	0.0	0	0.00	0	0.0	0	0.00
Forest	100	8	9.00	8	8	100.0	253	31.62	0	0.0	0	0	2	22.2	5	0.56	0	0.0	0	0.00
Total	450	59	13.11	59	40	66.7	1112	18.53	2	3.3	7	0.117	3	5.0	13	0.22	3	5.0	3	0.05

*-Urban-Kollamthara, Thiruvallam, Coastal-Kidarakuzhi, Vizhinjam, Rural-Pavachakuzhi, Vilavoorkal, Forest-Panga, Aruvikara

associated with grassland, bushy areas, gardens, beaches, and forests. Similarly, infected rodents spread many zoonotic diseases indirectly to human beings through the bite of mites, ticks, or fleas. Scrub typhus cases were reported in Kerala from 2000 onwards (Ittyachen, 2009). This study monitored the prevalence of ectoparasites in Thiruvananthapuram, Kerala to unearth the presence of different disease vectors.

Infestation rate for chiggers was 67.8% followed by ticks 3.39%, fleas 3.39% and mites 1.69%. In the present study *T. indica* from urban & coastal areas, *Bandicota bengalensis* from rural areas, and *R. rattus* from forest areas harvested with more ectoparasites while *M. musculus* harbored the lowest number of ectoparasites. The study showed the distribution pattern and density of ectoparasites differed as per the distribution of rodent hosts and locations (Hi *et al*., 1999). All the ectoparasites representing chiggers, fleas, ticks, and mites are available in the coastal area. An ectoparasite prevalence study conducted in Egypt showed more ectoparasites on *R. rattus*, *R. norvegicus* and *Meriones shawi* (Kia *et al*., 2009). *Tatera indica* is a major rodent host on the rice ecosystem, was trapped at urban villages of Thiruvananthapuram, and was found to be a good source for the collection of nine species of chiggers including *Trombicula hypodermata*. *Bandicota bengalensis*, lesser Bandicoot was trapped in less number found only in the coastal area was also a good source for the collection of 9 species of chiggers. All study sites were found positive for *S. murinus* rich in chigger ectoparasites. Vector mite *L. deliense* and plague vector *X. cheopis* were already recorded from Thiruvananthapuram during 2012 (Sharma, 2013).

In the present study, *H. kumari* was recorded in shrews *S. murinus*. An Ixodidae tick species *Hyalomma anatolicum anatolicum* was already recorded in a study conducted on the domestic animals in Kerala along with the same genus *H. marginatam isaaci* and *H. hussaini* on buffalo and cow (Prakasan and Ramani 2007). An Ixodidae tick species *Hyalomma sp*. was reported from Sarpole Zehab, Kwermanshah Province, Iran (Telmmafaarraiy *et al*., 2015). Ixodid ticks are the main parasites of different domestic animals in India. Tick infection on domestic animals is a major problem for its proper development in Kerala. *Hyalomma anatolicum* is a vector for the Crimean-Congo hemorrhagic fever with Nirovirus (Bunyaviridae) as the pathogen. *Hyalomma anatolicum* also transmits protozoa of the genus Theileria (Ghosh and Nagar, 2014). Ticks were mainly collected in coastal and forest sites and all ticks were collected only from *S. murinus*. Contrary to this, no ticks were collected from the other rats in Malaysia (Paramasvaran *et al*., 2009). This is also supporting the presence of ticks in urban rodents which was reported in Malaysia (Audy and Nadchatram, 1957).

There was no flea collected from the urban and forest areas which may not be suitable for the survival of these fleas as already observed in other areas (Geevargheese, 1997). The prevalence of fleas in the coastal and rural villages of Thiruvananthapuram showed a favorable environment

Table 2. Species-wise ectoparasites recovered from field rodents and shrews trapped

Villages	Urban			Coastal				Rural			Forest		Ectoparasites				
Ectoparasites/Hosts	BB	TI	SM	BB	TI	SM	RR	SM	BB	M M	RR	SM	R1	R2	R3	PS	Remarks
Chigger mites																	
Leptotrombidium deliense	●	●	●				●	●	●	●	●	●		●		●	
L. discrepans		●					●									●	New record
L. insigne		●														●	New record
L. spilletii		●														●	New record
L. kulkarni		●														●	New record
L. delimushi	●															●	New record
L. fulmentum									●							●	New record
L. rajesthanense									●							●	New record
Leptotrombidium sp		●							●							●	
Schoengastiella pracipua	●															●	New record
S. ligula		●									●					●	New record
S. ralagea				●					●			●				●	New record
S. helata					●				●							●	New record
S. bengalensis									●							●	New record
Schoengastiella.sp									●							●	
Herpetacarus schlugeri	●			●		●		●	●			●				●	New record
Microtrombicula kanjutekrii		●			●											●	New record
M. khurdagencosa					●											●	New record
Neotrombicula fujigmo	●															●	New record
N. microti					●											●	New record
Neotrombicula sp.		●														●	
Trombicula hypodermata	●				●						●					●	New record
Walchia rustica									●							●	New record
Mites																	
Echinolaelaps echidninus						●										●	New record
Ticks																	
Hyalomma kumari						●						●	●			●	
Fleas																	
Xenopsylla cheopis				●										●	●	●	
X. astia										●					●	●	

SM-*Suncus murinus*, RR-*Rattus rattus*, MM-*Mus musculus*, TI-*Tatera indica*, BB -*Bandicota bengalensis,*R1-(Geevarghese *et al*., 1997), R2-(Sharma, 2013), R3-(Sharif, 1930). PS - Present survey

Table 3. Taxonomic checklist of ectoparasites collected from the rodents/shrews

Family/ Subfamily	Tribe	Genus	Subgenus	Species
Trombiculidae Ewing, 1929/ Trombiculinae Ewing, 1929b	Trombiculini Vercammen-Grandjean, 1960	*Leptotrombidium* Nagayo et al., 1916	*Leptotrombidium* Nagayo et al., 1916	*deliense* (Walch, 1922) *insigne* Stan Fernandes & Kulkarni, 2003 *delimushi*Vercammen-Grandjean & Langston, 1976 *discrepans* Fernandes, 1988. *fulmentum*Vercammen-Grandjean & Langston, 1976 *kulkarnii*Vercammen-Grandjean & Langston, 1976 *spilletti* Mitchell & Nadchatram,1966
			Ericotrombidium Vercammen-Grandjean & Andre, 1966	*rajasthanense,* Stan fernandes and Kulkarni, 2003
		Trombicula Berlese,1905		*hypoderma*, Nadchatram and Traub, 1966
	Schoengastiini Vercammen-Grandjean, 1960	*Neotrombicula* Hirst, 1925		*fujigmo* (Philip and Fuller), 1950
				microti (Ewing) 1928
		Microtrombicula Ewing, 1950	*Microtrombicula* Traub & Nadchatram, 1966a	*kajutekrii* (Joshee, 1964) *khurdagencosa* Fernandes, 1988
		Herpetacarus Vercammen-Grandjean, 1960	*Herpetacarus* Vercammen-Grandjean, 1960	*schlugeri*(Radford), 1953
	Gahrliepiini Nadchatram & Dohany, 1974	*Schoengastiella* Hirst,1915		*bengalensis* Hirst, 1915 *helata* (Traub and Evans), 1954 *ligula* Radford, 1946b *praecipua* Nadchatram and Fernandes, 1989 *ralagea* Fernandes, 1988
		Walchia Ewing, 1931		*rustica* (Gater 1932)

present for its survival. Generally, fleas are collected from *R. rattus* and *R. norvegicus* as already reported from Angola (Linardi *et al*., 1994). In Indonesia, *X. cheopis* was the most common on *R. rattus* (Durden and Page, 2008). In Iran, the fleas catch was related to the availability of *R. norvegicus* (Kia *et al*., 2009). In the present study, *X. cheopis* was collected only in *B. bengalen-*

Table 4. Taxonomic checklist of rodents/shrews collected

Family	Subfamily	Genus	Species
Rodents - Muridae Illiger, 1811	Gerbillinae Gray, 1825	*Tatera* Lataste, 1882	*indica* Hardwicke, 1807
	Murinae Illiger, 1811	*Mus* Clerck, 1757	*musculus* Linnaaeus, 1758
		Bandicota Gray, 1873	*bengalensis* Gray, 1835
		Rattus Fischer de Waldheim, 1803	*rattus* (Linnaeus, 1758)
Shrew - Soricidae Fischer, 1814	Soricinae Fischer von Waldheim, 1817	*Suncus* Ehrenberg, 1832	*murinus* (Linnaeus, 1766)

sis from coastal area and *X. astia* in *M. musculus* recorded from rural areas. Fleas were collected from *R. norvegicus*, *R. rattus,* and Hamster in Bandar Abbas, Southern Iran (Kia *et al*., 2009). No lice were collected in the Thiruvananthapuram area from the rodents collected from the areas. The available rodents from these places, considered as infected, were *M. musculus* spreading 14 different diseases, *R. rattus* spreading 13 different diseases and *T. indica* spreading 4 different diseases and *S. murinus* spreading one disease (Rabiee *et al*., 2018; Hi *et al*., 1999). *B. bengalensis* can also cause a range of diseases and cause very similar concerns as the other commensal rats. *Rattus rattus* (common house rat) cause the spread of diseases like plague, typhus & leptospirosis and is a serious pest in Kerala (Dinesan *et al*., 2006).

In this study, medically important ectoparasites like *L. deliense* (scrub typhus vector), *S. ligula* (Scrub typhus vector) Tilak *et al*., 2011), *E. echidninus* (induce cross-reactivity with other allergic mites (WHO, 1986; Kia *et al*., 2009), *X. cheopis*, and *X. astia* (plague vectors) (Shashi *et al*., 2013) were recorded which showed the potential risk for the transmission of zoonotic diseases. Thiruvananthapuram climatic condition favored the development of the ectoparasites and different species of rodents/shrews (Saxena 1989; Kumar *et al*., 2004). The proliferation of these acarine vectors will increase the contact between human and rodents which in turn promote the transmission of various acari-borne zoonotic diseases and enhance the disease burden.

This study reports nineteen species of chigger mites and one species of adult mite for the first time report in Kerala. All of the surveyed areas are receptive to the high risk of transmission of scrub typhus. Rodent/shrew, chigger vector mite, and flea control are also to be undertaken to prevent the further spread of the diseases by these vectors. Information, education, and communication (IEC) awareness campaigns are to be taken up to sensitize the public about these diseases. Different risk factors like epidemiological, behavioral, and environmental risk factors about these areas are to be identified and appropriate measures are to be taken up to sensitize the public. In the coastal area rodents/shrews had a higher ectoparasitic infestation. The current knowledge on ectoparasites load on rodents in Kerala brings forth the main reason for the sudden resurgence of the scrub typhus cases in many places. Monitoring of rodent population and their ectoparasites brings forth important data to facilitate arthropod-borne disease control strategies by the public health authorities.

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Efficacy of new insecticides against okra shoot and fruit borer, *Earias vitella* (Fb.) (Lepidoptera: Noctuidae)

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ABSTRACT: A field study conducted to evaluate the efficacy of new molecules against okra shoot and fruit borer, *Earias vitella* (Fb.) during rabi and summer season revealed that Chlorantraniliprole 8.8% + Thiamethoxam17.5% SC @ 0.7 ml/l significantly reduced the percentage of shoot and fruit damage. No shoot and fruit infestation was recorded at seven and fourteen days after treatment. It was on par with the standard check Chlorantraniliprole 18.5 SC @ 0.3 ml/l followed by Novaluron 10 EC @ 2 ml/l and Lamdacyhalothrin 4.6% + Chlorantraniliprole 9.3% ZC. Chlorantraniliprole 8.8% + Thiamethoxam17.5% SC treated plots recorded highest total yield of 469.86 and 594.31 g/plant respectively. Maximum marketable yield was also recorded from Chlorantraniliprole 8.8% + Thiamethoxam17.5% SC treated plots respectively. Chlorantraniliprole 8.8% + Thiamethoxam17.5% SC also showed high benefit-cost ratio of 2.42 and 3.12 during rabi and summer season respectively.

KEY WORDS: *Earias vitella,* management, Chlorantraniliprole 8.8%+ Thiamethoxam17.5% SC, Novaluron

INTRODUCTION

Okra (*Abelmoschus esculentus* L.) is one of the most important vegetable crop grown throughout the world for its edible green fruits. India ranks first in the world with a production of 6095 MT and an area of 509.02 ha with a productivity of 12.0 MT/ha. In Kerala okra is grown in an area of 2.48 ha with a production of 34.65 MT and productivity of 13.96 MT/ha (Anonymous, 2018). A number of insect pests attack the crop reducing the production and productivity. In which the important and the destructive pest is okra shoot and fruit borer, *Earias vitella* (Fb.) (Lepidoptera: Noctuidae). The infested shoots droop, wither and dry up and larvae bore into the fruits and bore holes are plugged with excreta. Infested fruits become deformed and unfit for consumption. It causes 5.33 to 75.75 percent fruit loss in the field (Pareek and Bhargava, 2003). Though different non-chemical and chemical methods are developed under the IPM strategy, these pests are still in the fields and making the cultivation difficult for farmers. The shoot and fruit borer also developed resistance against the conventional insecticides making it difficult to control (Kranthi *et al*., 2002). Combination of two chemicals with different mode of action is the new strategy to reduce the development of resistance among insects (Kumar *et al*., 2010). New molecules are more tissue-specific and undergo rapid degradation; leaving very less amount of residues in the environment hence reduces

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environment pollution and safe to non target organisms. Pesticide mixtures have broad spectrum of activity, multiple target sites with synergistic action, reduces the number of spray hence reduces the cost, saving time and safe to farmer's health (Anjabapu, 2018). Keeping in this backdrop, this study has been undertaken to evaluate the efficacy of new insecticides against okra shoot and fruit borer *Earias vitella.*

MATERIAL AND METHODS

A field study was carried out in RARS Pilicode sub centre, Karuvachery in two seasons during rabi season (September to December 2018) and summer season (January to April 2019). The experimental material selected for the study was okra, variety Varsha Uphar. The experiment was laid out in Randomized Block Design with 8 treatments (Table 1) and 3 replications. Treatments were applied one at vegetative stage and one at reproductive stage after the incidence of pest. Damage symptoms were recorded at 7 and 14 days after spraying. Observations were taken from six plants and its average was taken. A pre-count was also recorded one day before spraying. The data recorded from field experiment was tabulated and statistical analysis was performed using analysis of variance (ANOVA). Web Agri Stat Package (WASP) was used to compare the significance of each treatment.

RESULTS AND DISCUSSION

Okra shoot damage during rabi season

Seven days after first spray, no shoot damage was observed in T_1 and T_6 as against maximum shoot damage of 77.77 per cent in untreated control. Less shoot damage was noticed in plots treated with T_5 (9.65 per cent) and T_2 (22.04 per cent). T_7, T_3 and T_4 recorded significantly high shoot damage of 61.75 per cent, 51.21 per cent and 35.35 per cent shoot damage respectively. Fourteen days after spraying there was an increase in the shoot damage in T_8 (82.05 per cent) followed by T_7 (63.01 per cent) and T_3 (52.24 per cent). No shoot damage was noticed in plots treated with T_1 and T_6. Less damage was recorded in T_5 (4.11 per cent) followed by T_2 (7.39 per cent). T_4 was significantly different from other treatments with 31.80 per cent shoot damage. Similar trend was observed seven days after second spraying, no shoot damage was noticed in T_1 which was on par with T_6. Maximum shoot damage was recorded in T_8 (83.55 per cent), followed by T_7 (63.81 per cent), T_3 (52.88 per cent) and T_4 (33.76 per cent). Less shoot damage was observed in T_5 (17.26 per cent) followed by T_2 (17.26 per cent). After fourteen days, shoot damage was reduced in T_5 (3.25 per cent), T_2 (7.99 per cent), T_4 (27.60 per cent) and T_3 (47.86 per cent). Highest shoot damage was observed in T_8 (84.64 per cent) followed by T_7 (64.19 per cent) (Table 1).

Okra shoot damage during summer season:

Seven days after treatment no shoot damage was reported in T_1 and it was on par with T_6 as against maximum damage was observed in T_8 (81.56 per cent). T_7 (58.89 per cent), T_3 (49.87 per cent) and T_4 (40.45 per cent) showed significantly high shoot damage. T_5 and T_2 recorded less shoot damage of 21.61 per cent and 24.48 per cent respectively. After fourteen days no shoot damage was observed in T_1 and T_6. There was a gradual increase in the shoot damage in T_8 (83.29 per cent) and T_7 (59.01 per cent). T_3 and T_4 recorded significantly higher shoot damage of 49.10 and 37.81 per cent respectively. T_5 and T_2 reduced the damage to 17.19 and 19.28 per cent respectively. Seven days after spraying T_1 and T_6 were on par with each other with no shoot damage. Maximum shoot damage was observed in T_8 (77.54 per cent). T_7 and T_3 recorded 46.98 and 38.24 per cent shoot damage respectively. Less damage was reported in T_5 (8.00 per cent) and T_2 (16.78 per cent). The same trend was followed after fourteen days of spraying. Shoot damage was reduced to 6.62, 14.06, 20.45 and 37.96 per cent in T_5, T_2, T_4 and T_3 respectively. They are significantly different from each other. The highest shoot damage was record in T_8 (74.79 per cent) and T_7 was significantly different from T_8 with 47.33 per cent shoot damage (Table 1).

Table 1. Percentage of shoot damaged by *Earias vitella* in okra treated with different insecticides during rabi season (September to December 2018) and summer season (January to April 2019)

Treatments	Shoot damaged in rabi season (%)					Shoot damaged in summer season (%)				
		First spray		Second spray			First spray		Second spray	
	1 DBT	7 DAT	14 DAT	7 DAT	14 DAT	1 DBT	7 DAT	14 DAT	7 DAT	14 DAT
T_1 - Chlorantraniliprole 8.8% + Thiamethoxam 17.5% SC	68.40	0.00 (0.59)	0.00 (0.59)	0.00 (0.59)	0.00 (0.59)	75.2	0.00 (0.59)	0.00 (0.59)	0.00 (0.59)	0.00 (0.59)
T_2 -Lambda cyhalothrin 4.6% + Chlorantraniliprole 9.3% ZC	65.50	22.04 (27.93)	7.39 (15.55)	17.26 (24.37)	7.99 (16.37)	71.66	24.48 (29.62)	19.28 (25.94)	16.78 (24.17)	14.06 (22.00)
T_3 - Thiamethoxam 12.6% + Lambda cyhalothrin 9.5% ZC	64.72	51.21 (45.69)	52.24 (46.28)	52.88 (46.66)	47.86 (43.77)	60.16	49.87 (44.92)	49.10 (44.48)	38.24 (38.19)	37.96 (38.03)
T_4 - Flubendiamide 19.92% w/w + Thiacloprid 19.92% w/w	67.52	35.35 (36.45)	31.80 (34.31)	33.76 (35.52)	27.60 (31.69)	78.15	40.45 (39.48)	37.81 (37.94)	22.83 (28.53)	20.45 (26.88)
T_5 - Novaluron 10 EC	67.18	9.65 (17.98)	4.11 (11.53)	9.34 (17.59)	3.25 (10.29)	73.5	21.61 (27.64)	17.19 (24.49)	8.00 (16.37)	6.62 (14.85)
T_6 - Chlorantraniliprole 18.5 SC (check)	64.26	0.00 (0.59)	0.00 (0.59)	0.00 (0.59)	0.00 (0.59)	67.18	0.00 (0.59)	0.00 (0.59)	0.00 (0.59)	0.00 (0.59)
T_7 - Thiamethoxam 25 WG (check)	60.78	61.75 (51.81)	63.01 (52.56)	63.81 (53.05)	64.19 (53.28)	63.09	58.89 (50.15)	59.01 (50.19)	46.98 (43.27)	47.33 (43.48)
T_8 - Absolute control	70.16	77.77 (61.97)	82.05 (64.97)	83.55 (66.18)	84.64 (67.11)	78.29	81.56 (64.17)	83.29 (65.97)	77.54 (62.02)	74.79 (59.98)
C.D.(0.05%)		3.70	3.52	4.52	3.95		4.21	3.02	4.28	3.27

Figures in parentheses are arc sine transformed values. DAT- Days after treatment, DBT- Day before treatment

Okra fruit damage during rabi season:

Seven days after second spray no fruit infestation was recorded from T_1 and T_6, they were statistically on par followed by T_5 (7.91 per cent). T_8 (89.03 per cent) recorded highest fruit infestation followed by T_7 (67.98 per cent) and T_3 (51.49 per cent). T_2 and T_4 recorded 13.79 and 30.98 per cent damage respectively. Data recorded after fourteen days of treatment revealed that no fruit infestation was recorded from T_1 and T_6 and an increase in the fruit infestation was noticed in T_8 (91.16 per cent). Reduction in the fruit infestation was observed in T_5 (3.04 per cent), T_2 (8.38 per cent), T_4 (27.45 per cent) and T_3 (48.72 per cent). Only a slight decrease was noticed in T_7 (67.49 per cent) (Table 2).

Okra fruit damage during summer season:

Seven days after treatment T_1 and T_6 showed non-significant difference with no fruit infestation. Second lowest infestation was observed in T_2 having 13.70 per cent fruit infestation. It was found on par with T_5 (15.35 per cent). T_8 (85.47 per cent) showed maximum per cent fruit infestation followed by T_7 (63.81 per cent) and T_3 (52.88 per cent). Fourteen days after spraying, all treatments reduced fruit infestation except T_8 (87.41 per cent) and T_3 (39.09 per cent). No fruit infestation was recorded in T_1 and T_6. T_5 recorded less fruit damage (8.86 per cent) which was found on par with T_2 having 9.34 percent fruit damage. Fruit infestation was also reduced in T_4 (21.10 per cent) and T_7 (58.53 per cent) (Table 2).

Table 2. Percentage of fruits damaged by *Earias vitella* in okra treated with different insecticides during rabi season (September to December 2018) and summer season (January to April 2019)

Treatments	Percentage of fruits damaged (mean of 18 plants)					
	Rabi season			Summer season		
	1 DBT	7 DAT	14 DAT	1 DBT	7 DAT	14 DAT
T_1 - Chlorantraniliprole 8.8% + Thiamethoxam 17.5% SC	70.87	0.00 (0.59)	0.00 (0.59)	73.02	0.00 (0.59)	0.00 (0.59)
T_2 -Lambda cyhalothrin 4.6% + Chlorantraniliprole 9.3% ZC	65.27	13.79 (21.73)	8.38 (16.78)	75.28	13.70 (21.70)	9.34 (17.78)
T_3 - Thiamethoxam 12.6% + Lambda cyhalothrin 9.5% ZC	60.21	51.49 (45.86)	48.72 (44.27)	67.18	39.75 (39.02)	39.09 (38.70)
T_4 -Flubendiamide 19.92% w/w + Thiacloprid 19.92% w/w	74.56	30.98 (33.82)	27.45 (31.54)	63.09	31.52 (33.98)	21.10 (26.96)
T_5 - Novaluron 10 EC	69.42	7.91 (16.30)	3.04 (10.01)	74.52	15.35 (23.00)	8.86 (17.29)
T_6 - Chlorantraniliprole 18.5 SC (check)	65.97	0.00 (0.59)	0.00 (0.59)	71.66	0.00 (0.59)	0.00 (0.59)
T_7 - Thiamethoxam 25 WG (check)	68.80	67.98 (55.56)	67.49 (55.26)	68.72	59.18 (50.32)	58.53 (49.91)
T_8 - Absolute control	75.89	89.03 (70.78)	91.16 (72.87)	79.5	85.47 (67.63)	87.41 (69.29)
C.D.(0.05%)		2.99	3.49		4.99	4.65

Figures in parentheses are arc sine transformed values. DAT- Days after treatment, DBT- Day before treatment

Chlorantraniliprole 8.8 per cent + Thiamethoxam 17.5 per cent SC treated plots recorded high net returns during both rabi (Rs.192330.54/ha) and summer season (Rs. 28788592/ha). It was followed by Chlorantraniliprole 18.5 SC (16408705 and 56758322 Rs./ha during rabi and summer season respectively). Similar findings were reported by Anjabapu (2018). In the present study the highest benefit-cost ratio was obtained from Chlorantraniliprole 8.8 per cent + Thiamethoxam 17.5 per cent SC treated plots and it was 2.42 and 3.12 during rabi and summer season respectively. The report of Rambhau (2018) showed that Chlorantraniliprole 8.8 per cent + Thiamethoxam 17.5 per cent SC recorded highest benefit-cost ratio of 3.72, which supports the present study (Table 3).

Results obtained from the study concluded that Chlorantraniliprole 8.8 per cent + Thiamethoxam 17.5 per cent SC @ 0.7 ml/l of water was very effective against okra shoot and fruit borer larvae during both rabi and summer. The efficacy of the same in tomato was reported by Kuhar *et al*. (2011) in which Chlorantraniliprole 8.8 per cent + Thiamethoxam17.5 per cent SC @ 7 oz/acre significantly reduced fruit damage in tomato. The present study was in line with Hossain (2015) who reported that pod borer infestation was lowest in plots treated with Voliam flexi 300 SC @ 0.5 ml/l. In the present investigation next best treatments were Novaluron 10 EC and Lamdacyhalothrin 4.6 per cent + Chlorantraniliprole 9.3 per cent ZC (Ampligo).

Reddy *et al.* (2018) evaluated the persistence and dissipation of combination insecticides in cowpea, concluded that in the combination of Chlorantraniliprole 8.8 per cent + Thiamethoxam 17.5 per cent SC, single insecticides were dissipated

Table 3. Economics of different insecticides during rabi season and summer season

Treatments	Rabi season			Summer season		
	Gross income (Rs./ha)	Net income (Rs./ha)	B : C ratio	Gross income (Rs./ha)	Net income (Rs./ha)	B : C ratio
T1 - Chlorantraniliprole 8.8% + Thiamethoxam 17.5% SC	328051.52	192330.54	2.42	423606.9	287885.92	3.12
T2 - Lambda cyhalothrin 4.6%+ Chlorantraniliprole 9.3% ZC	273740.00	137844.02	2.01	341658.9	205762.92	2.51
T3 - Thiamethoxam 12.6% + Lambda cyhalothrin 9.5% ZC	140548.00	5970.77	1.04	175970.2	41392.97	1.31
T4 - Flubendiamide 19.92% w/w + Thiacloprid 19.92% w/w	194636.80	58320.82	1.43	246236.8	109920.82	1.81
T5 - Novaluron 10 EC	278044.20	139748.22	2.01	333999.7	195703.72	2.41
T6 - Chlorantraniliprole 18.5 SC (check)	300733.03	164087.05	2.20	404229.2	267583.22	2.90
T7 - Thiamethoxam 25 WG (check)	153533.20	18897.22	1.14	215229.4	80593.42	1.59
T8 - Absolute control	78985.10	-54810.88	0.59	103081.4	-30714.58	0.77

to Below Quantification Level (BQL) on 10th day. As a single insecticide Chlorantraniliprole dissipated at 7th and Thiamethoxam at 5th day. They also conducted the risk assessment revealed that Theortical Maximum Residual Concentration (TMRC) of the mixtures on cowpea pods were below Maximum Permissible Intake (MPI) at 2hrs after spraying.

In this mixture Chlorantraniliprole is a ryanodine receptor modulator, which interrupts the calcium ion balance and disrupts proper muscle function in insects. It is highly specific to insect ryanodine receptors. Thus it is safe to natural enemies and mammals. Voliam flexi is a combination insecticide (Chlorantraniliprole 8.8 per cent + Thiamethoxam 17.5 per cent SC) which is effective against borers and sucking pest. So it eliminates the cost of other insecticides and also reduces the cost of spraying. This compensates the high cost of Chlorantraniliprole 8.8 per cent + Thiamethoxam 17.5 per cent SC. This is also supported by findings of Sangamithra *et al.,* (2018) that the combination insecticides with different modes of action and target group is effective against pest infestation and also reduces the number of insecticide spraying and they fit very well in the IPM strategies.

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First record of four whiteflies (Hemiptera: Aleyrodidae) and their natural enemies in Lakshadweep Islands, India

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ABSTRACT: Four whitefly species including three invasive whitefly species *viz.,* rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Alyrodidae) on 10 host plants; Bondars nesting whitefly, *Paraleurodes bondari* Peracchi on seven host plants, woolly whitefly, *Aleurothrixus floccosus* (Maskell) on guava and *Bemisia euphorbiae* (David & Subramaniam) on two plants were reported for the first time in Lakshadweep. Parasitoid, *Encarsia guadeloupae* Viggiani (Hymenoptera: Aphelinidae) and predators *viz., Pseudomallada* (=*Dichochrysa*) *astur* (Neuroptera: Chrysopidae) and *Cybocephalus indicus* (Coleoptera: Nitidulidae) were found associated with these whiteflies. Distribution of whiteflies along with their host plants and natural enemies in Lakshadweep Islands are given.

KEYWORDS: Invasive, whiteflies, Lakshadweep, coconut, guava, natural enemies

INTRODUCTION

Lakshadweep is India's smallest Union Territory located in the Arabian sea comprises of 36 tiny coral islands, 12 atolls, three reefs, five submerged banks and ten inhabited islands (8° and 120-300' North latitude). Agriculture and fisheries are the most widely prevalent economic activity in the territory for their livelihood. Almost all the households have own small or marginal pieces of agricultural land. Although coconut is the main crop in all the islands, banana, guava, papaya, sapota, several vegetables cultivated as intercrop with coconut and ornamental plants are also widely cultivated and grown as landscape and sea erosion plants. Islands of Lakshadweep are rich in biodiversity including insects. Ghosh (1991) documented about 79 species of insects under order of Coleoptera, Dermaptera, Dictyoptera, Diptera, Lepidoptera, Mantodea, and Orthoptera which feed on different crop plants. Rhinoceros beetle, *Oryctes rhinoceros* L, black headed caterpillar, *Opisina arenosella* Walker, mealybugs, *Pseudococcus* spp. coconut eriophid mite, *Aceria guerreronis* Keifer have been reported as pest of coconut whereas scales, whitefly, serpentine leaf minors, aphids, fruit borer and fruit flies which affect the intercrops (Anonymous, 2012).

Significant contribution on the whitefly fauna of Lakshadweep was made by Ramani (2000) who reported the occurrence of spiralling whitefly, *Aleurodicus dispersus* Russell in 27 islands. Dubey *et al.* (2004) documented the occurrence of 12 whitefly species belonging 11 genera in Lakshadweep. *Bemisia tabaci*, *Dialeuropora*

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decempuncta and *A. dispersus* were found on 4, 3 and 2 host plants, respectively, representing 9 families. Among host plants, *Thespesia populnea* harboured 4 whitefly species (*Aleuroclava complex*, *A. dispersus*, *Aleurolobus marlatti* and *B. tabaci*). The present survey is under taken on the whiteflies infesting coconut and other crop plants in the Island along with their natural enemy's complex.

A survey was conducted in various islands *viz.,*Kavaratti, Amini, Minicoy, Androtт and Keltan of Lakshadweep to investigate the occurrence, intensity of infestation, host plants, distribution and natural enemies of whiteflies during March, 2020. The intensity of damage was assessed randomly on five plants in each location on economically important host plants. Host plant leaves infested with immature stages and puparium in paper envelopes and adults whiteflies in 70% ethanol were collected as described by Dubey and David (2012) along with relevant collection data for further identification and documentation. Part of collected of host plant leaves/parts infested with immature stages and puparium were placed in rearing jar (21×10 cm) for the emergence of parasitoids. The emerging parasitoids were collected using aspirator and preserved in vials containing 70% ethanol for further identification.

Permanent mounts of the puparium were prepared as suggested by Martin (1987) and best mounts were obtained from puparial cases from which adults have emerged. Total of about 49 specimens were mounted representing four species and voucher specimens were deposited in ICAR-NBAIR museum. Identification of the whitefly species and their natural enemies were confirmed by morphological means. Assessment of natural parasitism (%) was determined based on the number of puparium parasitized as against un-parasitized pupae in the host leaves. The host plants were identified with the help of plant taxonomists.

Four species of whiteflies, two species each representing the subfamily Aleurodicinae and Aleyrodidae were recorded from Lakshadweep Islands. This include three invasive *viz.,* rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin; Bondar nesting whitefly, *Paraleurodes bondari* Peracchi and woolly whitefly, *Aleurothrixus floccosus* (Maskell) and one native species *Bemisia euphorbiae* on two host plants. All the four species were reported for the first time in Lakshadweep islands.

1. Rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin, 2004

Distribution: It is believed to have originated from Central America and its incidence is limited to Belize, Mexico, Guatemala and Florida in Central and North America. In India, it was recorded on coconut and on many other crop plants during 2016 at Pollachi, Tamil Nadu (Sundararaj and Selvaraj, 2017). The pest further rapidly spreads to Karnataka, Kerala, Andhra Pradesh, Telangana, Goa, Assam, West Bengal, Maharashtra, Gujarat and Meghalaya (Sumalatha *et al*., 2020). The infestation of this whitefly is noticed in Lakshadweep Islands, Amini, Kavaratti, Minicoy, Androtт and Keltan island.

Host plants: Coconut, *Cocos nucifera* (Arecaceae), Indian almond, *Terminalia catappa* (Combretaceae), guava, *Psidium guajava* (Myrtaceae), banana, *Musa* spp. (Musaceae), rose apple, *Syzygium jambos* (Myrtaceae), noni, *Morinda citrifolia,* all spices, *Pimenta dioica* (Myrtaceae), ficus, *Ficus* spp. (Moraceae), sapota, *Manilkara zapota* (Sapotaceae) and portia tree, *Thespesia populnea* (Malvaceae). A total of 20 pupal cases on 10 slides were prepared to determined occurrence of this pest on these host plants.

Rugose spiralling whitefly is a highly polyphagous pest reported to feeds on about 120 plant species including economically important cultivated crops and palms. In India, it was found to feed on about 40 host plants especially coconut, banana, mango, sapota, guava, cashew, ramphal, oil palm, maize, Indian almond, water apple, jack fruit and many other ornamental plants like bottle palm, Indian shot, false bird of paradise and butterfly palm (Selvaraj *et al*., 2017; Selvaraj *et al.,* 2019).

2. Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi, 1971

Distribution: *P. bondari* is a native of Neotropical region and it was first described on citrus from Brazil in 1971 (Peracchi, 1971). It was also been reported from Belize, Puerto Rico, Madeira, Comoros, Mauritius, Taiwan, Hawaii and Florida in the USA (Stocks, 2012). In India, its first incidence was reported on coconut palms from Kerala during 2018 (Josephrajkumar *et al.,* 2019), Karnataka and the Andaman and Nicobar Islands (Vidya *et al.,* 2019). Present study confirms the occurrence of this pest in Lakshadweep islands.

Host plants: Coconut, guava, banana, noni, ficus, portia tree and unidentified plant. A total of 14 pupal cases on slides were prepared to determined occurrence of this pest on these host plants. *P. bondari* is polyphagous in nature and has more than 25 susceptible host plants. In India, it is found to feeds on coconut, banana, guava, citrus sp. avocado, cassava, custard apple and ornamental ficus (Vidya *et al.,* 2019).

3. Woolly whitefly, *Aleurothrixus floccosus* (Maskell), 1896

Distribution: *A. floccosus* was first described from Jamaica in 1896 (Martin and Mound, 2007) and native to the Neotropical region wherever citrus is grown (Malumphy *et al*., 2015). In India, its occurrence was first reported on guava (*Psidium guajava*) in Kozhikode, Kerala (Sundararaj *et al.,* 2020). Subsequently, it was found in Ramanagara, Bengaluru Rural, Bengaluru Urban Mysore and Mandya districts of Karnataka and Coimbatore, Salem and Dharmapuri districts of Tamil Nadu on guava (Unpublished data). The infestation of this whitefly was noticed on guava in three islands of Lakshadweep *viz.,* Kavaratti, Keltan and Amini.

Host plants: It was found infesting guava, *A. floccosus* is polyphagous**,** reported to feed on 20 plant families, and exhibits a strong preference for citrus (Malumphy *et al.,* 2015) but so far in India, it was found to feed only on guava. A total of 5 pupal cases on slides were examined to confirm the occurrence of this pest on guava.

***4. Bemisia euphorbiae* David & Subramaniam, 1976**

Distribution: David and Subramaniam (1976) described this whitefly on *Euphorbia prostrata* from Madurai, Tamil Nadu. Jeritta and David (1986) reported it on *Phyllanthus fratemus* and *P. maderaspatensis* in Tamil Nadu. Mani and Krishnamoorthy (1995) recorded this whitefly on *P. acidus* in Bangalore, Karnataka. The occurrence of *B. euphorbiae* was also reported on Chekurmanis, *Sauropus androgynus* (George and David, 2010),

Host plants: In Lakshadweep it was found infesting Indian gooseberry *P. acidus* and *P. niruri* (Phyllanthaceae). Ten pupal cases on slides were examined to confirm the occurrence of this pest on these plants.

Co-existence: All three invasive species recorded in the survey are believed Neotropical origin and have host preference towards many economically important crop plants including coconut, banana and guava. The co-occurring of these whiteflies was commonly observed in the same palms and even in the same colony indicates probably the pests would have invaded simultaneously into India. *A. rugioperculatus* co-exists with *A. dispersus* and *P. bondari* on coconut palms whereas *A. floccosus* co-occurred with *P. bondari, A. dispersus* and *A. rugoperculatus* on guava. Similarly, *P. bondari* was coexist with *A. rugioperculatus* on other host plants. This co-existence and mutual survival of these species is could be due to the marked time partitioning of the resources in their niche for their growth and survival.

Natural enemies: The surveys also revealed the presence of several natural enemies associated with these whiteflies in Lakshadweep. Aphelinid parasitoid, *Encarsia guadeloupae* on *A. rugioperculatus* and predators *viz., Pseudomallada* (=*Dichochrysa*) *astur* and *Cybocephalus indicus* were observed to be feeding on *A. rugioperculatus, A. floccosus* and *Bemisia euphorbiae*. The natural parasitism of *E. guadeloupae* was observed to the extent of 24-46% on *A. rugioperculatus*.

Exotic non-native invasive whiteflies in India cause direct and indirect yield losses in agriculture, horticulture and forestry crop plants. In the present study, it was found breeding of four more whitefly species in the Lakshadweep islands in addition to earlier report 12 species. Considering the small but unexplored area of Lakshadweep, the present contribution is emphasis the need for further extensive and intensive study of whitefly species occurring in the Lakshadweep. It is believed, these invasive whitefly species might be moved from main land of India through the transportation of crop plants/seedling. Domestic quarantine may be strengthened to prevent the un-deliberate introduction of invasive species into islands. Further, awareness may be created among the island resident and tourist to stop the unwanted introduction of pest from mainland. Prevention is the most economic option and they can be managed strategically through timely implementation of classical biocontrol programme. Further, augmentation and conservation of potential natural enemies is necessary to reduce below the damaging level. Hence it is of utmost importance that effective measures for the prevention of this alien species are to be taken on a long-term basis.

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Social tolerance of spider *Stegodyphus sarasinorum* Karsch (1891) between their colonies under controlled and field conditions

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ABSTRACT: Investigation on social interaction between the individuals of *Stegodyphus sarasinorum* of two different colonies and their cooperation in prey capture showed that members of different colony were socially accepted by both adults and juveniles. The study also revealed that this species prey upon rice ear bugs and cercopids which form major pests in paddy fields and banana plantation respectively.

KEY WORDS: Social organization, social interaction, *Stegodyphus sarasinorum*, rice ear bugs, cercopids, paddy fields, banana plantation

Social organization and maintenance of group living is exhibited by a few species of spiders which has evolutionary significances in reducing risk of predation. *Stegodyphus sarasinorum* Karsch (1891) belonging to family Eresidae is one such group that lives in large colonies as social spiders. Largely, females are inhabited in *Stegodyphus* colony than males. Female spiders display collective behavior in prey capture, web maintenance and brood care, while adult males rarely take part in these tasks in *S. sarasinorum*, as in other species of social spiders (Lubin and Bilde, 2007). Not just the colony association but also the complex nest which provides protection from outside environmental influences and their predators is an important factor facilitating social behaviour. This kind of a communal living categorizes them under social species. Groups of spiders can capture larger prey than can solitary individuals of the same species (Burgess, 1976; Ward, 1986), and the thicker, larger web of social spiders aids in the capture of large prey (Jackson, 1979). Collective predation and communal feeding reveals the interaction between the members of their colony. Organisms foraging in groups experience increased foraging efficiency in comparison to solitary foragers by capturing large or greater numbers of prey, reducing the likelihood of prey escape, hunting risk and lower variability in prey capture (Rypstra, 1989). The present study was conducted to analyze whether individuals of different colonies can perform similar behaviour when maintained in controlled and field conditions. The study was conducted in Department of Zoology University of Kerala, Kariavattom, Thiruvananthapuram, Kerala (8.5678 °N, 76.8908°E). The duration of the study was from February 2020 to July 2020.

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Collection

Webs having colonies of *S. sarasinorum* were collected from three different plants, *Citrus limon, Polyalthia longifolia,* and *Celosia cristata.* In the laboratory, the spiders were taken out from the web using brush and fine forceps without injury and collected in a bottle to count the number of individuals in a colony.

Experimental set up in laboratory

Spiders were introduced in three cages of surface area 1.08m^2 each covered with a white net cloth.

Cage I- Seven adult females marked with non-toxic acrylic paint from a colony.

Cage II- Eleven adult females of from one colony and one female from another colony (marked with non-toxic paint).

Cage III- Fifty five spiderlings of one colony and one adult female of another colony.

Before commencement of the experiment the colonies in the cages were allowed to build their nests. The spider colonies under observation of this experimental setup were fed with insects such as rice ear bugs (*Leptocorisa oratoria*), Cercopid (*Phymatostetha deschampsi*) and housefly (*Musca domestica*) which are collected using a sweeping net. The prey was introduced using forceps into the cage through a small opening made on the white net cloth covering the cage. The opening was plugged with a cork after introducing the prey. The insect was allowed to get trapped on the web by gently placing them on it. Each prey was introduced alternatively i.e. one day only one type of prey was provided to each cage as their feed. The consumption rate of the spiders is given in Table 1.

Experimental set up in field

Colonies of *S. sarasinorum* was observed near the paddy field constructed on electric posts in Edthuva, Kuttanad, Kerala. The paddy field is surrounded with banana plantation on one side. Two small webs from the above mentioned colonies were allowed to grow on an artificial frame made of bamboo sticks and was placed at a corner of this paddy field in such a way that the frame is situated between the paddy and the banana plantation. Overnight construction of the web was observed in both the experimental setups. Images of the experimental setup are illustrated in Figs. 1, 2, 3, 4, 5 and 6.

Laboratory Experimental set up

When a prey was introduced in the cage, only few of the spiders get attracted initially by the vibration of the insect. Later a large number of spiders crowd together over the prey and drag it into the retreat. It was observed that in Cage **I,** out of the seven adult female spiders, two attacked the prey and the struggle between the spider and the prey caused vibration which was detected by the rest of the spiders. It was also noted that the females preparing for laying egg sacs did not participate in prey capturing, instead the prey was dragged towards them by the other members this spider colony. In Cage II, adult females were reported to capture the introduced prey as mentioned above in Cage I. Adult female from a different colony was equally involved while feeding the prey. No sign of aggressiveness or competition were observed between the individuals of this experimental group.

Table 1. Prey consumption rate of *S. sarasinorum* in experimental rearing

Sl. no.	Experimental set up no. (Cage)	Type of prey	Consumption rate (per cage/ day)		
			Feb-March	April-May	June-July
1.	I, II and III	Housefly	3/3	4/ 4	4/5
2.	I, II and III	Cercopid	3/3	4/4	4/5
3.	I, II and III	Rice ear bug	3/3	3/4	3/5

Plate 1

Fig. 1. *S. sarasinorum* colony for laboratory rearing

Fig. 2. Laboratory experimental set up (Cage)

Fig. 3. Field experimental set up with one colony

Fig. 4. Field experimental set up with two colonies

Fig. 5. Field experimental set up with three colonies

Fig. 6. Field experimental set up (side view)

Spiderlings collected from one colony and an adult female from another colony was also under observation in Cage III**.** Maternal care by this female spider was shown to the spiderlings by attacking the prey and then letting the young ones to feed on it.

Field experimental set up

Both the colonies constructed their webs on the wooden frame. In the subsequent month another colony was built by these spiders. By the end of July three colonies (Fig. 5) were observed on the frame. The web was decorated with the exuviae of these spiders and remains of different insects like dragonfly, rice ear bug, cercopid, beetles, and bugs.

From the study we infer that the Indian social spider *S. sarasinorum* exhibit high level of colony coherence. They maintain an amiable environment with other colony members. They are also believed to feed communally even though all the members do not participate in prey capture (Bradoo 1980). It was examined from both the experimental setup in laboratory and field that these species can feed on different types of insects because all the three insects introduced in the cage were consumed. And they have the capability to attack the pests of rice crop (rice ear bug) and banana plantation (cercopid). The study reveals the feeding activity of the predators instead of their preference to a particular prey. It is shown that these conspecific individuals which prefer to form open societies are freely exchangeable between colonies as stated by Seibt and Wickler (1988). *S. sarasinorum* can help the farmers to get rid of insect pests to a greater extent if sufficient numbers of colonies are reintroduced in the agro ecosystem.

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Outbreak and life cycle of the hook tip moth, *Deroca inconclusa* (Walker,1856) (Lepidoptera: Drepanidae) on Himalayan Dogwood, *Cornus capitata* Wall. ex Roxb. (Cornaceae) in Garhwal region of Western Himalaya, India

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ABSTRACT: During the course of survey carried out in Chakrata hills (Chakrata Forest Division, Dehradun district, Uttarakhand (Western Himalaya), sporadic infestation by the hook tip moth, *Deroca inconclusa* (Walker,1856) (Lepidoptera: Drepanidae : Drepaninae) was recorded on *Cornus capitata* Wall. ex Roxb. trees in Chakrata Reserve Forest at several locations. Outbreak of the hook tip moth is being reported for the first time from this region along with its life history on *C. capitata* from the Garhwal region of the Western Himalaya.

KEY WORDS: Antioxidant, tannin, astringent, Moru oak, Ban oak, eggs, larva, pupa

Himalayan Dogwood, *Cornus capitata* Wall. ex Roxb. (Cornaceae) tree is commonly known as 'Bhamora' in Uttarakhand, India and is native to the low-elevation woodlands of the Himalaya in India, Nepal, Bhutan and adjoining countries of SE Asia: Myanmar, Laos, Vietnam and China. It is often grown as an ornamental tree in gardens, valued especially for its summer flowering and late autumn fruits. It has naturalized in parts of Australia and New Zealand. This evergreen tree grows to 12m in height and width and is naturally found in forests and shrubberies between 1200 m and 3000 m altitude along the edges and gaps in oak-mixed forests in the Western Himalayas (Joshi *et al.,* 2018). It is common in secondary forest especially ban-oak-rhododendron from 1500-2400m (Upreti *et al*., 2010). Flowering occurs in May-July and fruiting takes place in August-November. The ripe fruits are reddish, fleshy and edible (Fig.1). *C. capitata* fruit has high nutritional and low anti-nutritional content as well as considerable antioxidant and antimicrobial activity with possible nutritional and health implications (Mishra *et al*., 2017). The bark is used medicinally and is source of tannin which is used as an astringent (http://temperate.theferns. info/plant/Cornus+capitata). The young twigs are also used as fodder locally. The dry wood is used mainly as fuel and for making tools (http://anilkthakur.blogspot.com/2014/09/himalayan-strawberry-tree-cornus.html).

During the course of surveys carried out in Chakrata hills (Chakrata Forest Division, Dehradun district, Uttarakhand) (Western Himalaya), sporadic infestation by the hook tip moth, *Deroca*

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Table 1. Life cycle of hook tip moth, *Deroca inconclusa* (Walker,1856) on *Cornus capitata* Wall. ex Roxb. (Cornaceae) during July-August 2020 in Chakrata Forest Division (2100m), Dehradun District, Uttarakhand, India

Life history stages	Duration (days)	Morphological features and habits
Eggs	4-5 days	Eggs are laid in clusters of 80-220 on the abaxial side of leaf. Eggs are 0.5 mm in length, oval in shape, pale yellow when laid; chorion is smooth and has red colour patch in between and turns dark yellow before hatching. (Fig 7 a-b).
Larva		
1st instar larva	3-4 days	Length: 1.5-02mm; head is black along with setae on it and body is pale green; larva has grey markings behind the head on the thorax region and covered with setae all over the body. Feeding takes place by scratching and skeletonizing the upper leaf surface. Several larvae may feed together on a single leaf (Fig.8 a&b).
2nd instar larva	4-5 days	Length : 04-06mm; black head . Two black bands run parallel on the entire dorso-ventral surface. The colour of the dorsal surface between the two parallel lines changes from pale green to grey in the second instar. The last abdominal segment is tailed with numerous setae. Feeding takes place on the leaf tip and margins (Fig.8c).
3rd instar larva	4-5 days	Length: 08-09 mm; The colour of the dorsal surface between the two parallel black lines changes from grey to pale green in the third instar. The abdominal segments now become more distinct and the head capsule turns pale green with black dots on the head region and two black bands running parallel on the dorso-ventral surface of the body. The tail in the last abdominal segment increases in size with numerous black setae on it. The third instar feeds mainly on the leaf margins (Fig8 d).
4th instar larva	5-6 days	Length: 10-12 mm; Larva is now more elongated, pale green having black dots speckled all over the head region. The tail on the last abdominal segment becomes more pointed bearing numerous spine like setae. The larva in this stage feeds more vigorously mainly on the leaf margins and central axis and may consume the entire leaf. (Fig.8e).
5th instar larva	4-5 days	Length: 12-14 mm; Full grown larva is pale green with setae all over the body; abdominal segments are distinct and has two black bands running parallel on the dorso-ventral surface of the body; head possesses setae and black lines on the sides. There are 3 pairs of thoracic legs and 4 pairs of abdominal prologs which are yellowish brown. The larva now consumes the entire leaf and can move on to other leaves on the same branch for feeding. Just before pupation it stops feeding and fixes itself on the tip or the base of the leaf near the mid rib where it pupates (Fig. 8f & Fig.9 a-f).
Larval Period	20-25 days	Length: 1.5-14 mm (July-August).
Pre- Pupa & Pupa	3-4 days	Pre-pupa: Length 07 mm. ; Before pupation the larva shrinks in size and become stouter in shape and looses the legs and attached itself to the stalk or midrib of the eaten leaf before transforming into pupa (Fig.10). Pupa: Length: 09 mm; Creamish-white with brown markings on it. Has fine hair like setae present on the abdominal region. Cremaster has series of spines. The pupa is generally concealed in dry or curled leaf surface, hanging on the tree itself (Fig.11. a-d).
Adult (Moth)	2-5 Days	Wing Span: 40 mm (Fig19-22). Moths are medium sized, translucent, white having chequered white and black markings all along the margins of both the wings. On the forewing there are two oval grayish spots between the cell and the apex, four spots close to the apex and grayish markings in between the cell and the costa (Fig.12a&b).
Total	**27-34 days**	**July-August**

inconclusa (Walker,1856) (Ditrysia: Drepanoidea : Drepanidae : Drepaninae) was recorded on *C. capitata* trees in Chakrata Reserve Forest at several locations (30°43"28'.9 N and 77°51"39'.7E between 2079-2264 m) comprising of forest sub-types 12/C1b Moru oak Forest & 12/C1a Ban oak Forest (Champion and Seth,1968) on 13-17 July, 2020 (21-27 °C and 60-85% RH-day time). The

Fig.1a. *Cornus capitata* fruiting during rainy season 19.vii.2020

Fig. 1b. Ripened fruits during autumn (14.x.2020) in Chakrata Forest Division, Uttarakhand, India

(a)

(b)

Fig. 2 a & b Complete defoliation of *Cornus capitata* trees during rainy season in Chakrata Forest Division Uttarakhand, India (17.vii.2020)

(a)

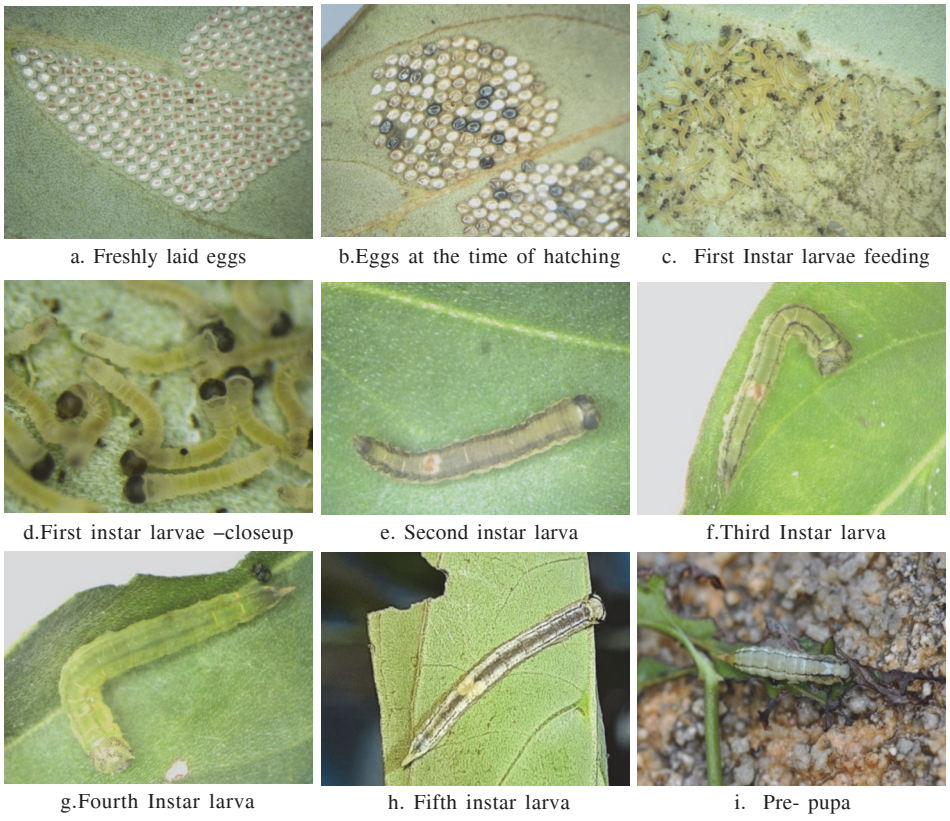
(b)

(c)

(d)

Fig. 3 a-d. Pattern of defoliation by hook tip moth, *Deroca inconclusa* (Walker,1856) on *Cornus capitata* foliage and pupae attached to eaten leaf of *Cornus capitata*

Fig 4: Freshly emerged hook tip moth, *Deroca inconclusa* (Walker,1856) and individuals perched on *Coriaria nepalensis.*



a. Freshly laid eggs b.Eggs at the time of hatching c. First Instar larvae feeding

d.First instar larvae –closeup e. Second instar larva f.Third Instar larva

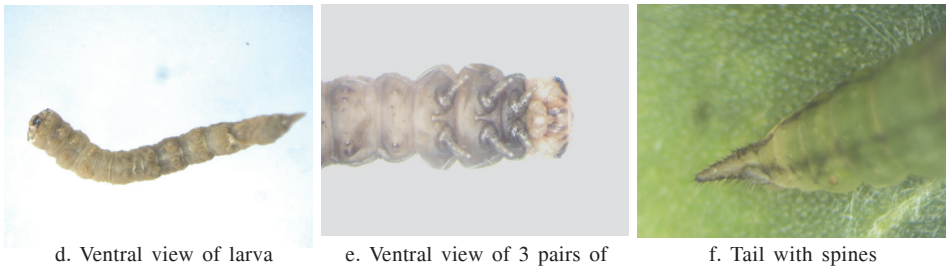
g.Fourth Instar larva h. Fifth instar larva i. Pre- pupa

Fig. 5 a-i: Eggs and larval stages of hook tip moth, *Deroca inconclusa* (Walker,1856) on *cornus capitata*

infestation took the shape of an outbreak spreading all over Chakrata Forest Division during August (17-27 August 2020; 18-29°C and 74-90% RH - day time). The infestation started with the onset of rainy season spread over the entire Garhwal region i.e. Chakrata Forest Division , Mussoorie Forest Division (30°45"58.9 N and 77°12"21.5E; 2120 m; 02.ix.2020; 21°C and 90% RH-day time) and near Suwakholi and Buranskhanda Tehri Garhwal, Uttarakhand (30°27"21'.3 N and 78°08"90'.4E; 2168m; 02.ix.2020; 20°C and 87% RH-day time) which continued during the entire rainy season and lasted till the post monsoon season (Sept 2020). Most of the affected trees had practically no green foliage and presented a leafless, dry brownish appearance (Fig. 2 a, b).

The infestation by young larvae starts from the tip of the branches with initiation of feeding on the terminal leaves. Initially the tip of the leaf is

a. Larva dorsal view b. Close up of head of larva c. Lateral view of larva



d. Ventral view of larva e. Ventral view of 3 pairs of thoracic legs and mandibles f. Tail with spines

Fig. 6 a-f: Mophological features of 5th Instar larva of hook tip moth, *Deroca inconclusa*

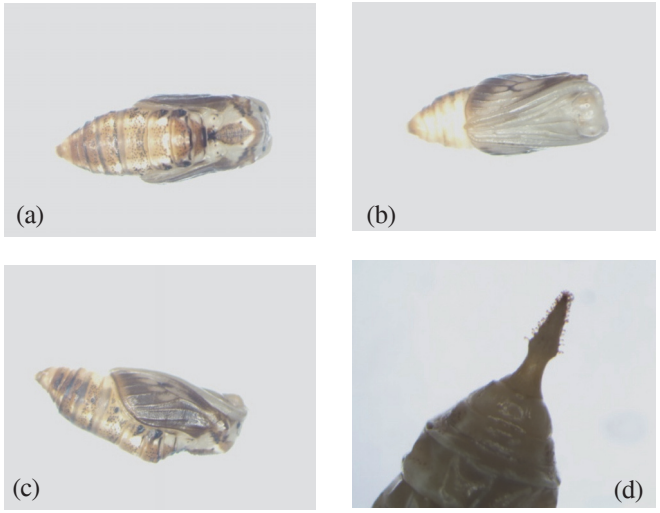


Fig. 7: a-d.: Pupa of hook tip moth, *Deroca inconclusa*:
a- Dorsal view, b- Ventral view, c-lateral view, d- Spines on the cremaster

devoured by the growing larva which slowly feeds on the entire leaf downwards towards the stalk but leaving the mid rib intact (Fig. 3 a-c) after which, it moves to another leaf. One larva feeds on an average 1-2 leaves and on completion of the larval stage, it pupates on the leaf. Up to 3 pupae may be present on a single leaf (Fig.4). Thus, at on instance there may me many pupae on the same branch of the same generation. Emergence of moth takes place on the tree itself from the hanging pupae and many individuals can be noticed emerging from the pupae simultaneously (Fig. 5). Emergence was observed during the day time with adults resting on the branches of the tree or on bushes and small nearby trees such as *Coriaria nepalensis*. They fly around and mate during dusk and night (Fig. 6).

The holotype of *D. i. inconclusa* (Walker, 1856) was redescribed from Musoorie, Garhwal, Uttarakhand itself by Watson (1957) and specimens of this moth have been collected during May-July between 1868-1914 at ~2100m. Mathur and Singh (1956) have previously reported the larva of *D. inconclusa* defoliating *C. capitata*, from Gwaldam

a- Male moth

b- Female moth

Fig. 8 a-b: Adult of hook tip moth, *Deroca inconclusa:* a- Male, b- Female

in Almora, Kumaon, Uttarakhand based on 2 specimens collected by J.C.M.Gardner on 16.vi.1937 (National Forest Insect Collection, Forest Research Institute, Dehradun- Accession No. 16618). However, its life cycle has not been studied so far.

Hook tip moth, *D. inconclusa* has distribution in the Himalayan region of northern India through Nepal, Myanmar, China extending up to Taiwan, Korea, Japan in far East (Hampson, 1892; Watson, 1957). Another sub species of *D. inconclusa phasma* Butler, 1878 found in Japan and Korea is known to feed on Japanese Dogwood (Yamabushi), *Cornus kousa* F.buerger ex Hance (Cornaceae) in Japan (Digital Moths of Asia). The current findings are significant as it reports for the first time an outbreak the hook tip moth, *D. inconclusa* (Drepanidae) on Himalayan Dogwood, *C. capitata* (Cornaceae) from the Garhwal region of the Western Himalaya.

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BOOK REVIEW

Butterfly Gardening – Theory and Practices

By **George Mathew and Elizabeth George**

Here is a book on butterfly gardening by an author whose commitment to the subject is unique. Dr. George Mathew is a Forest Entomologist, with basic specialization in insect taxonomy, and particular knowledge of the groups, moths, butterflies, and beetles. In the 1990's, as part of his investigations on insect biodiversity, he experimented with setting up a butterfly garden in a patch of degraded natural forest, in the Kerala Forest Research Institute (KFRI) campus at Peechi, with limited resources. Initial success and the lessons learnt from careful observations led him to continue these studies and soon the KFRI butterfly garden became a favourite spot for visitors to the institute, particularly, school children. Demands were made to the Institute to help establish butterfly gardens in schools, colleges and other public places and Dr. Mathew's services were made available. He studied various aspects related to setting up butterfly gardens and in the following years several successful butterfly gardens were set up in public places in Kerala and elsewhere, under his guidance. These include gardens at KFRI campuses at Peechi and Nilambur; Higher Secondary Schools at Thrissur and Elanthikkara (Paravoor); Army Head Quarters at Pangode, Thiruvananthapuram; Orange County Resorts, Kabany; Vandaloor Zoo; Indira Gandhi Atomic Research Centre, Kalpakkam; Indian Oil Corporation, Pongam; Tropical Butterfly Conservatory, Trichy; and Butterfly Conservatory at Reng Reng in Sikkim. The success of these gardens is due to the imaginative planning and scientific management of the gardens under the guidelines set by Dr. Mathew, who may be called the Father of Butterfly Gardens in India. In recognition of his contributions to biodiversity conservation, he has been selected as 'Green Hero of Conservation' by CNN – IBN in 2008.

Butterfly gardening is a process in which the butterfly fauna of a specific area is conserved and enriched by introduction of suitable butterfly host plants and habitat improvement. This is an in situ Conservation cum educational programme. In contrast to this is the ex situ Conservation programme or Butterfly Farming, which must be resorted to when the natural populations of the butterflies in an area have disappeared due to habitat degradation. Here the method adopted is captive breeding of butterflies and reintroducing them in recreated habitats. In situ and ex situ Conservation programmes (Outdoor Conservatory or Butterfly Gardening and Indoor Conservatory or Butterfly Farming, respectively) call for entirely different approaches.

The book deals comprehensively with all these aspects. The setting up and running of a Butterfly Garden or Farm call for integration of knowledge not only on butterflies and plants but also from art, science, technology, and management, at large, and the authors have done full justice to that. In this task, Dr. Mathew is joined by his co-author, Dr. Elizabeth George, who holds a doctorate degree in horticulture, and who is also his daughter, although he does not mention it in the book.

The book is organized into 7 Sections, References, 7 Appendices and an Index to Plants. The first Section gives a brief introduction to butterflies, describing their life stages, behaviour like flight, courtship, migration and mud puddling, with suitable photographs. A brief account is also given of the seven Families of butterflies, with photographs of representatives. Sections 2 and 3, together covering 3 pages of text, explain the butterfly conservation strategies – the In vitro Conservation Strategy involving Butterfly Gardening and the Ex situ Conservation Strategy involving Butterfly Farming, as indicated above. The following two Sections are devoted to explaining and providing detailed guidelines on setting up these two types of Conservatories, viz.,

In situ Conservatory or Butterfly Garden and Ex situ Conservatory or Butterfly Farm. Section 4, dealing with Butterfly Garden, indicates the need to conduct a pilot study on the butterfly fauna of the proposed project area, preparation of a design, land preparation, landscaping, retention of the existing vegetation and introduction of additional native butterfly host plants and creation of new landscapes. A diagram is given to illustrate the generalized design of a Butterfly Garden. Its various components, viz., Entrance; Nature Trail; Streams and Ponds; Fountains, Sprinklers and Foggers; Cascades; Mud-puddling Spot; Irrigation System; Garden Arches and Pergolas; Garden Hedges; Information Boards; Models of Butterflies; Interpretation Centre; Curio Shop and Public Amenities are identified and their importance and making are discussed. Photographs of these components from various Butterfly Gardens are used to illustrate the ideas presented in the text. For plants which form the most important component of a Butterfly Garden, detailed instructions are given here as well as in Appendix II, on how they should be introduced by dividing the garden area into four zones or strata adjacent to the path and how they should be looked after. Brief accounts are given of Butterfly Gardens established in various States in India. The next Section starts with a diagram depicting the general design of a typical Indoor Butterfly Conservatory or Butterfly Farm/Butterfly House. In addition to the components described for the Butterfly Garden, an Indoor Butterfly House must contain some specialized facilities for breeding, maintaining and exhibiting butterflies. A glass house or net house with roofing, with provision for maintaining appropriate levels of temperature and humidity is necessary. Butterfly houses are usually made for selected butterflies because their flight cages, mating chamber, egg production facilities and larval rearing units will have to be designed based on a clear understanding of their biology and ecology. These aspects are discussed with some details on techniques and the facilities required (Section 6). The comparative advantage of in situ_conservation over ex situ conservation for conservation of butterfly genetic diversity is also discussed.

Information is given on 131 plants, with photographs, comprising 76 herbs and shrubs, 28 trees, and 27 creepers, which may be used in Butterfly Conservatories as sources of nectar, larval food or as ornamental plants. For each plant, the scientific name, common names, plant family, natural distribution range, brief botanical description and status (nectar source, ornamental or larval host of specified butterflies) are given. This is followed by a list of 135 butterflies that may be encountered in Butterfly Conservatories, with photographs and their host plants.

There are some minor deficiencies of printing and editing. For example, labelling in some figures is inadequate and some references are not arranged in alphabetical order. The following suggestions are made for the next edition of this book which I am sure will soon be forthcoming. First, re-organize the Sections as follows (present Sections shown in brackets): 1. Butterflies – an introduction [1]; 2. Butterfly conservation strategies [2, 3]; 3. Methodology for setting up an Outdoor Conservatory or Butterfly Garden (*In situ* Conservation) [4]; 4. Methodology for setting up an Indoor Conservatory or Butterfly Farm (*Ex situ* Conservation) [5, 6]; 5. A list of butterflies and their host plants [Appendix 1]; 6. A list of plants for Butterfly Conservatories that serve as butterfly larval host, nectar source or ornamental [7]. Second, in the list of butterflies (Section 5 above), print the photographs of butterflies at twice the present size. You may also cull some photographs showing repetitive themes from different Gardens, in order to improve the flow of text and reduce the cost of book.

To summarise, this book is the first, authoritative, comprehensive, well-illustrated guide for establishment of both in situ_and ex situ Butterfly Conservatories and fulfils a need. Cost estimate is the only missing information, which of course can be worked out from the details given. The book will also serve as a Pictorial Handbook for the general public, for identification of garden plants and the butterflies associated with them. Every school in India should have a copy of this book in their library.

Dr. K.S.S. Nair,
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Contents of Volume 45

No. 1

No. 2

No. 3

No. 4

SHORT COMMUNICATION

AUTHOR INDEX

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