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Olfactory and electrophysiological response of cucumber moth *Diaphania indica* (Saunders) (Lepidoptera, Crambidae) to different plants

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ABSTRACT: The behavioural response of adults and larvae of cucumber moth, *Diaphania indica* (Saunders) (Lepidoptera, Crambidae), a serious pest of cucurbitaceous crops was evaluated on different cucurbitaceous and non-cucurbitaceous plants through olfactometer bioassay. The volatile organic compounds (VOCs) present in these plants were identified by gas chromatography-mass spectrometry. Further, electrophysiological response of *D. indica* to plant extracts and synthetic volatiles were recorded by electroantennographic detection. Larvae had the highest olfactory response to wild coccinia followed by bitter gourd, coccinia and cucumber. In GC-MS analysis, á-linolenic acid, palmitic acid and dotriacontane were identified as common components in leaf extracts, whereas, benzaldehyde was the major component in headspace of dried leaves. The antennae of gravid female moths were more sensitive to plant odours than unmated females and males. Gravid females showed highest response to extracts of bitter gourd and unmated females to cucumber extract. A synthetic volatile mixture of 10µL of benzaldehyde and 30µL of benzyl alcohol were found responsible for high antennal response. Significant orientation and landing response were shown by *D. indica* moths to a mixture of 10µL benzaldehyde (10%) and 20µL benzyl alcohol (10%). These findings suggest the above blend could be employed for the development of plant volatile based management strategies. © 2024 Association for Advancement of Entomology

KEY WORDS: Host plant volatile, kairomone, electroantennogram, olfactometer, cucurbits

INTRODUCTION

UN Food and Agricultural Organization (2021) estimates a 40 per cent annual loss of crops due to different pests and diseases worldwide. The cucumber moth *Diaphania indica* (Saunders) infests a variety of cucurbits and some non-cucurbits including cotton, cowpea, amaranth etc. Therefore, this insect is considered as a major insect pest. The pest is found throughout the tropics and subtropics, ranging from the Caribbean and northern South America to sub-Saharan Africa, Asia, and the Pacific (Patel and Kulkarny, 1956; Peter and David, 1991). Generally the early instars of the larvae scrape off the lower epidermis and later instars become voracious defoliators (Debnath *et al.*, 2020; Debnath *et al*., 2021). Further, they may also eat tender shoots, flowers, and fruits under severe infestation which can result in severe crop loss and a decline in market value (Nagaraju *et al*., 2018; Debnath *et al*., 2022). It could become a serious and consistent problem in vegetable

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cultivation and to tackle this, farmers still rely on chemical insecticides (Debnath *et al*., 2023). The indiscriminate use of chemicals not only contaminate the produce with pesticide residue but also cause the development of resistance in pest, harm natural enemies and pollinators, pollute the environment and increase the cost of cultivation (Gharaei *et al.,* 2019). Several biopesticides are proven to control this pest, but none of these are practically utilized by the farmers due to its unavailability (Debnath *et al.*, 2020). Another safe option is semiochemicals which have been introduced in pest management since many years. Pheromone traps are available for many important pests; however, host plant volatiles are less studied and exploited. Plants use volatile organic compounds (VOCs), one of the most prevalent chemical signals, to interact with their environment. Insects detect these chemicals and aid in locating their habitat and host plant, evaluating the quality of their host, aggregation and herbivorous prey (Reinecke and Hilker, 2014). Based on the interaction, it could be kairomone, allomone, synomone or antimone (El-Ghany, 2019). The kairomones can attract herbivorous insects and stimulate oviposition (Baskaran *et al.,* 2018). Some insects obtain and utilize them as sex pheromones or sex pheromone precursors while, some others either produce or release sex pheromones in the presence of specific host plant volatiles (Reddy and Guerrero, 2004). It can even enhance the responsiveness to pheromones by triggering physiological and/or behavioural modifications (Landolt and Philips, 1997). Understanding the plant volatiles involved in the interaction of *D. indica* with its host plants and the nature of the response is necessary for devising efficient traps utilising attractants. Hence, this study aimed to evaluate plant extracts and synthetic volatiles for the behavioural and electrophysiological responses of *D. indica* and identify the components of the plant extract that can be used in plant volatile based control strategies.

MATERIALS AND METHODS

Larvae of *D. indica* were procured from the Instructional Farm, College of Agriculture, Vellayani. The larvae were reared on different cucurbitaceous leaves based on availability in plastic containers (diameter-10cm and height- 8cm) in the laboratory. All the pupae were carefully sexed and male and female pupae kept in seperate boxes to facilitate their emergence. Adults were provided with a 10 per cent honey solution soaked in cotton. Two days old male and female moths were paired in individual boxes to facilitate mating. Fresh leaves of either snake gourd or coccinia were furnished as oviposition sites and the fresh leaves were provided at 24 hours interval. These eggs were utilized for maintaining the culture.

Fresh and healthy leaf samples of bitter gourd (*Momordica charantia* L.), snake gourd (*Trichosanthus anguina* L.), salad cucumber (*Cucumis sativus* L.), cultivated and wild cultivar of coccinia (*Coccinia grandis* L.), culinary melon (*Cucumis melo* var. *acidulus* Naudin.), brinjal (*Solanum melongena* L.) and red amaranth (*Amaranthus tricolor* L.) were collected from Organic/ Instructional Farm, College of Agriculture, Vellayani or farmers' fields. Leaves were cleaned and shade-dried for about a week and then minced. Dried leaf extract was prepared by soaking one gram of dried leaf in 20ml of *n*-hexane for 24 hours with intermittent shaking and then filtered using Whatman No.1 filter paper. Also, fresh leaf extract was prepared by soaking one gram of chopped fresh leaves in 10 ml of n-hexane overnight. The extracts were filtered and stored in a refrigerator at 4ºC until use.

The olfactory response of 3 day old mated *D. indica* moths were examined using a Y-tube olfactometer with a stem of length 27cm and an internal diameter of 1.8cm. The arms of the Y-tube were 13.5cm long at an angle of 77^{o} between them. A piece of Whatman No. 1 filter paper (2cm X 3cm) containing 0.1mL of leaf extract was kept as odour source after letting the solvent evaporate. The odour source and control were placed in glass chambers at the end of the arms provided with an airflow of 750ml/min in each arm using an air pump. Gravid female moths were starved for one hour prior to the experiment was released singly at the open end and then closed with a piece of cotton. The first choice that it made within an hour was

recorded as the response. The response was regarded as valid only if it stayed for more than a minute. The odour source was changed after testing three insects. Each odour source was replicated three times each with a new set of moths. The experimental setup was rotated at 180° after testing three insects and the odour source and control were also alternated between the two arms. After each test, the Y-tube was cleaned and rinsed with warm water followed by acetone and dried properly. The same experiment was carried out during photophase and scotophase with fresh and crushed leaves also as odour source.

Apart from the Y-tube olfactometer which utilizes airflow, a modified type of dual-choice olfactometer was designed for the assay without airflow (Fig.1). The device was made up of an acrylic box with dimensions 50cm x7cm x 7cm. On both ends (square faces), openings (5cm x 5cm) were made to which another small cubic box could be attached. These small boxes called odour source chambers served the function of extract loading. An insect introduction chamber is attached to a hole (5cm x 5cm) at the exact middle of the long box, which can be closed using a slide mechanism. The whole setup was kept inside a black box to avoid any interference of light in the behaviour of the moths. The experiment was carried out as mentioned in the Y-tube olfactometer. Five moths were kept in the insect introduction chamber for 15 minutes before loading of odour source to acclimatize. After loading the odour source, the sliding door was opened and the movements of the moths were monitored. The experiment was replicated 6 times for each treatment. Plant extracts and combinations of synthetic volatiles were tested for behavioural responses in the modified olfactometer.

Olfactory response of larvae: The olfactory preference of *D. indica* larvae was studied using a multi-arm olfactometer in which all the treatment plants were tested simultaneously. Uniform sized third-instar larvae were used for this experiment and they were starved for 1hr prior to the experiment. Fresh leaf samples of each treatment plants were kept in each arms. 20 starved larvae were released at the centre of the olfactometer and the number of larvae entering each arm was counted after an hour. The experiment was replicated six times with randomly assigning treatment positions.

Chemical analysis: The volatile compounds present in the leaves of the treatment plants were identified through Gas Chromatography-Mass Spectrometry (GC-MS) analysis. *n*-hexane extracts of fresh leaves were used for liquid sampling, whereas, dried leaf samples were used for headspace analysis. It was carried out using a GC-MS (Shimadzu Nexis GC-2030) equipped with an autosampler AOC-30/20i and a headspace analyser. The capillary column (SH-I-5Sil MS) was having a length of 30 m, an inner diameter of 0.25mm and a film thickness of 0.25µm. The oven temperature was set from 70 to 260°C at the rate of 8°C/min, held for 2 minutes and then again raised to 280°C at a rate of 4°C/min. The carrier gas was helium with a continuous flow rate of 1.2mL/min. The injection temperature, ion source temperature and interface temperature were 250°C, 220°C and 280°C, respectively. The pressure was maintained at 76.9 kPa. The total run time was 31.75 minutes. The system utilized the software GCMS Solutions and the library used was NIST 20. The major compounds were identified according to the peak area and retention time.

Electroantennographic Detection (EAD): The electrophysiological response of one-day-old unmated male and female as well as 3-day old gravid female *D. indica* to plant extracts and synthetic volatile compounds were recorded. The synthetic volatiles were chosen based of the chemical analysis and available literature. The response was measured as the antennal depolarization potential using an EAD system (Syntech) at Regional Agricultural Research Station, Pattambi, Kerala. The insect head was carefully cut and mounted on a dual electrode probe using a conductive gel (signa gel Parker) by placing the head on one electrode and the antennal tip on the other. The probe was then mounted onto the EAD system about half a centimetre away from the mouth of the airflow tube. A continuous flow of clean and charcoal-filtered air was maintained.

Fresh leaf extract (0.1ml) was loaded on a strip of Whatman No. 1 filter paper (0.5cm x 3cm) and left for a minute for the solvent to evaporate. It was then inserted into the Pasteur pipette and connected to the stimulus controller (Syntech CS-55) via a silicon tube. A pulse of air passed through the Pasteur pipette which carry the odour stimuli to the insect antennae. The pulse duration, continuous flow rate, pulse flow rate was maintained at 0.5s, 25 ml/s and 21 ml/s, respectively as suggested by Venugopal and Subaharan (2019). The probe measured the depolarization potential of the antennae and the signals were amplified by an amplifier (Syntech IDAC-2) and recorded using EAG software (GC-EAD 2010, Syntech). All eight treatments and control were tested in the same antennae with two puffs of each. A time gap of at least 10 seconds was given between two puffs of a treatment and 30 seconds between treatments for antennal recovery. The average of the two peaks of a treatment was taken as the response. The experiment was replicated with new insect antennae (five replications) for males, unmated females and gravid females. Experiments were also carried out with different concentrations and combinations of synthetic volatile compounds, benzaldehyde and benzyl alcohol. Benzaldehyde was chosen based on GC-MS analysis and benzyl alcohol purely based on literature.

The data of both EAD and larval olfactometer experiments were analyzed by one-way analysis of variance (ANOVA) followed by Fisher's Least Significant Difference (LSD) test in the software KAU GRAPES Version 1.1.0 (Gopinath *et al*., 2020). Since only positive responses were recorded in the modified olfactometer experiment with synthetic blends, ANOVA was carried out for data analysis.

RESULTS AND DISCUSSION

Olfactometer bioassay: In both Y- tube and modified olfactometer, *D. indica* moths did not show any behavioural response to the plant extracts, while some random and inconsistent movements were shown with fresh or crushed leaf as odour source. The cause of failure of the experiment was expected to be the use of *n*-hexane extract as odour source and improper experimental conditions. But there are previous studies in which *D. indica* positively responded to the flower wax chemicals of *T. anguina* extracted using *n*-hexane (Debnath e*t al.*, 2022) and to the VOCs collected from insect damaged and undamaged plants by headspace volatile collection method (Debnath *et al*., 2023). Other insects also responded to plant extracts as in case of *Choristoneura rosaceana* (Harris) which responded to five host plant extracts (Gokce *et al*., 2005) .

The olfactory preference of *D. indica* (Fig 2) larvae was assessed by the percentage of larvae attracted to each plant. Even though wild coccinia is not commonly found infested by *D. indica* in the field, this wild cucurbit attracted highest percentage of larvae (23.33%) out of 120 larvae tested ($P< 0.05$) in this experiment. This could be due to the previous feeding experience since the larvae were reared in wild coccinia leaves prior to this experiment. So keeping apart wild coccinia, the larvae shows olfactory preference to bitter gourd (10.83%), cultivated coccinia (9.17%), cucumber (8.33%), culinary melon (6.67%), snake gourd (5.00%) brinjal (4.17%), whereas, amaranthus did not attract any larvae. The preference to cucumber by *D. indica* larvae was also noted by Gharaei *et al*. (2019) while comparing watermelon, cucumber, melon and squash for the same.

Identification of volatile compounds: A total of 17 volatile compounds were identified in the GC-MS analysis of *n*-hexane extract of the treatment plants. Out of these, two fatty acids, (Z,Z,Z)-9,12,15-octadecatrienoic acid (á-linolenic acid) and n-hexadecanoic acid (palmitic acid) and an alkane, dotriacontane were detected in five or more plants (Table 1). These fatty acids were previously reported in the leaf surface wax of *T. anguina* by Debnath *et al*. (2021), however, the predominant alkane and free fatty acids in the wax were heptadecane and stearic acid, respectively. Palmitic acid and dotriacontane were detected in the ethanolic extracts of leaf callus of brinjal by Vanitha *et al*. (2016). These compounds have different kairomonal properties in other insects. These fatty

Table 1. Compounds detected in different plants by GC-MS analysis of leaf extracts

Name	*M. charantia*	*T. anguina*	*C. sativus*	*C. grandis*	*C. grandis* (wild)	*A. tricolor*	*S. melongena*	*C. melo* var. *acidulus*
9,12,15-octadecatrienoic acid, (z,z,z)-	✔	✔	✔	✔		✔	✔	✔
9,12,15-octadecatrienoic acid, methyl ester, (z,z,z)-		✔	✔					
Benzothiazole, 2-(2-hydroxyethylthio)-	✔		✔					
Dotriacontane	✔		✔		✔	✔		✔
Phytol	✔		✔					✔
N-hexadecanoic acid		✔	✔	✔	✔	✔	✔	✔
Octocrylene				✔	✔			✔

Table 2. Compounds detected in different plants by GC-MS headspace analysis

Name	*M. charantia*	*T. anguina*	*C. sativus*	*C. grandis*	*C. grandis* (wild)	*A. tricolor*	*S. melongena*	*C. melo* var. *acidulus*
3-hexen-1-ol		✔					✔	
2,6-dihydroxybenzoic	✔	✔	✔	✔	✔	✔		
acid, 3tms derivative								
Benzaldehyde	✔	✔	✔	✔		✔	✔	
Phosphonoacetic acid, 3TMS derivative	✔	✔	✔	✔	✔	✔		
Cyclohexanone, 4-hydroxy-4-methyl-	✔	✔	✔			✔		
2-cyclohexen-1-ol, 2,4,4-trimethyl-	✔			✔	✔	✔		
2-pyrroline, 1,2-dimethyl-		✔	✔	✔		✔		
2,6-dihydroxyacetophenone, 2TMS derivative		✔	✔	✔	✔	✔		
Cyclopentanol, 2-methyl-, trans-	✔		✔	✔	✔			
Z,Z-2,5-pentadecadien-1-ol				✔	✔	✔	✔	
1,3-cyclohexadiene-1-carboxaldehyde,2,6,6-trimethyl-	✔			✔	✔	✔	✔	

Table 3. EAG responses of *Diaphania indica* moths to different plant extracts

Plant extract	EAG responses (mV) (Mean ± SD)*		
	Male	Female	Gravid female
M. charantia	0.085 ± 0.02^{b}	0.137 ± 0.02^{ab}	**0.245 ± 0.07^{a}**
T. anguina	0.078 ± 0.01 ^{b}	0.107 ± 0.03^{ab}	0.162 ± 0.05^{bcd}
C. sativus	0.080 ± 0.01^{b}	**0.140 ± 0.01^{a}**	0.200 ± 0.04^{ab}
C. grandis	0.082 ± 0.01 ^{b}	0.120 ± 0.05^{ab}	0.178 ± 0.02^{bc}
C. grandis (wild)	0.088 ± 0.02^{b}	0.127 ± 0.03^{ab}	0.182 ± 0.05^{b}
A. tricolor	0.080 ± 0.01^{b}	0.120 ± 0.04^{ab}	0.168 ± 0.02^{bcd}
S. melongena	**0.105 ± 0.01^{a}**	0.113 ± 0.02^{ab}	0.155 ± 0.01^{bcd}
C. melo var. *acidulus*	0.073 ± 0.01^{b}	0.100 ± 0.03^{ab}	0.122 ± 0.01^{d}
Control (n-hexane)	0.043 ± 0.01^{c}	0.053 ± 0.01^{c}	0.050 ± 0.01^{e}
CD (0.05)	0.017	0.046	0.052

*Mean of 5 replications

acids and some alkanes present in the leaf surface wax of a weed *Ludwigia octovalvis* (Jacq.) were found to attract a chrysomelid beetle *Altica cyanea* (Weber) and also triggered oviposition (Mitra *et al*., 2017). Palmitic acid was found to involve in the larval preference of *Helicoverpa zeae* (Boddie) (Breeden *et al*., 1996). á-linolenic and palmitic acid also act as precursors for sex pheromones in various insects. Most of the type I pheromones of lepidopterans are synthesized from the precursor fatty acids such as palmitic acid and stearic acids (Ando *et al*., 2004) as in the case of *Helicoverpa armigera* (Hubner) (Wang *et al*., 2005). Whereas linoleic and linolenic acids are the precursors for the biosynthesis of Type II diene and triene compounds, respectively (Yamakawa *et al*., 2011) and their epoxy derivatives by decarboxylation (Matsuoka *et al*., 2008). The alkane, dotriacontane have reported insect-attracting properties in *Callosobruchus maculatus* (F.) (Adhikary *et al*., 2014) and an arctiid moth, *Diacrisia casignatum* Kollar (Roy and Barik, 2012). Breeden *et al*., (1996) identified the influence of dotriacontane on moth oviposition.

In the headspace GC-MS analysis of dried leaves, more than 25 compounds were detected from different treatment plants which included alcohols, aldehydes, ketones, cyclic amines, aromatic compounds, phenolic acids, esters etc. (Table 2). Benzaldehyde was identified in all samples except wild coccinia and culinary melon. While examining the peak area of benzaldehyde in the chromatogram of different treatments, the highest percentage of peak area (32%) was observed in bitter gourd. Benzaldehyde was detected in leaf extracts of bitter gourd (Sarkar *et al.*, 2015), fruit and leaf volatiles of brinjal (Nusra *et al*., 2021) and leaf volatiles of cucumber (Gharaei *et al*., 2020) previously.

Electrophysiological response: The antennal response of unmated male, unmated female and gravid female moths of *D. indica* to different plant extracts were measured as amplitude of depolarization of antennae in millivolts (Table. 3). The results demonstrate that the volatile compounds from the host plants influences the *D. indica* gravid females more than both male and female before mating. The gravid females are electro physiologically more active towards bitter gourd (0.245 mV) and cucumber (0.200 mV) while, unmated females were most responsive to cucumber (0.140 mV) which was on par with other treatment plants. Surprisingly, male moths elicited a greater response to the extract of brinjal (0.105 mV). The behavioural response to different volatiles and its magnitude is influenced by the physiological state of the insect including mating status and the

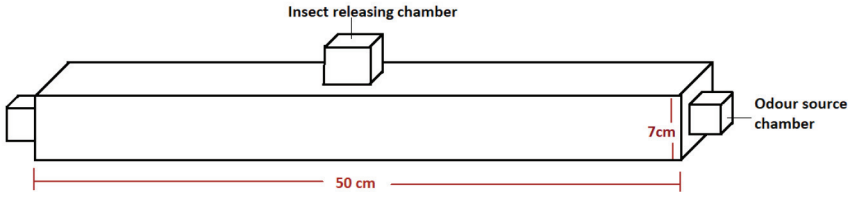


Fig. 1 Modified olfactometer

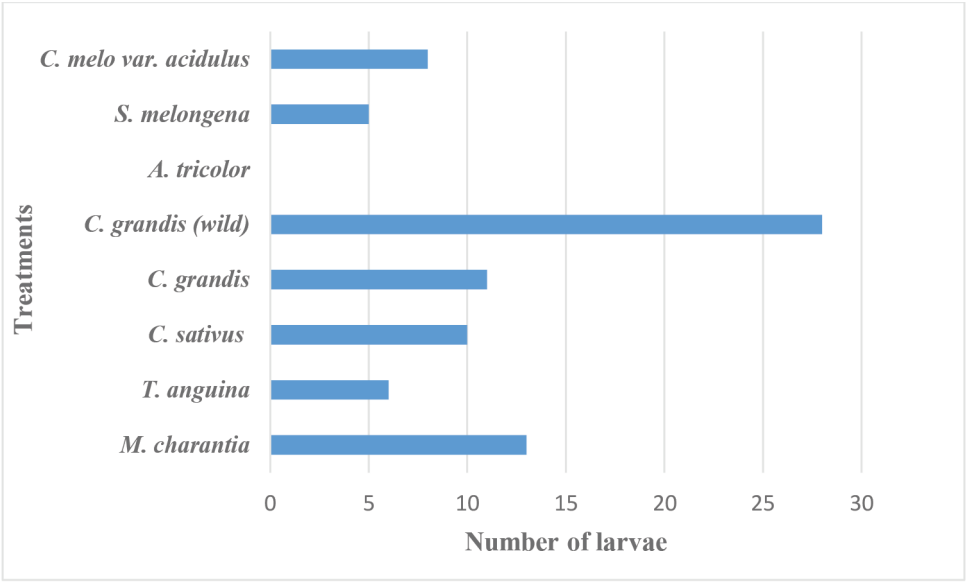
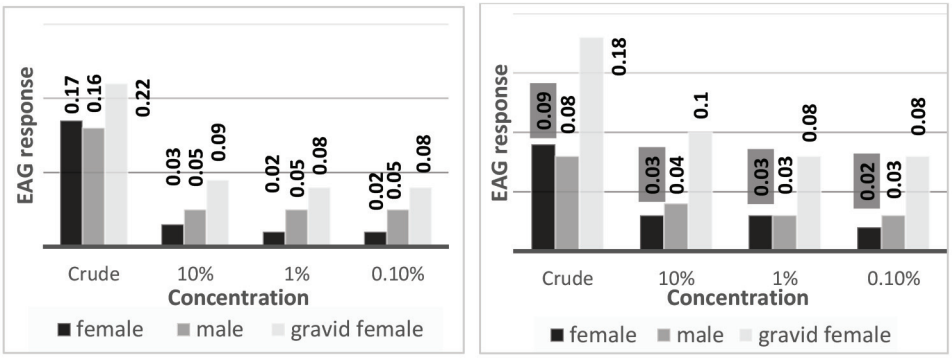


Fig. 2 Olfactory response of *Diaphania indica* larvae

Table 4. EAG responses of gravid female *Diaphania indica* moths to different combinations of benzaldehyde and benzyl alcohol

Combinations	Response(mV) (Mean ± SD)*
10µL benzaldehyde (crude) + 10µL benzyl alcohol (crude)	0.18 [a] ± 0.03
10µL benzaldehyde (10%) + 10µL benzyl alcohol (10%)	0.09 [b] ± 0.03
10µL benzaldehyde (1%) + 10µL benzyl alcohol (1%)	0.08 [b] ± 0.03
10µL benzaldehyde (crude) + 20µL benzyl alcohol (crude)	0.20 [a] ± 0.05
20µL benzaldehyde (crude) + 10µL benzyl alcohol (crude)	0.17 [a] ± 0.04
10µL benzaldehyde (crude) + 30µL benzyl alcohol (crude)	0.21 [a] ± 0.06
30µL benzaldehyde (crude) + 10µL benzyl alcohol (crude)	0.16 [a] ± 0.06
n-hexane 10µL	0.05 [b] ± 0.01
CD (0.05)	0.07



Benzaldehyde Benzyl alcohol

Fig. 3 EAG response of *Diaphania indica* to different concentrations of synthetic volatiles

environmental conditions (Anton *et al*., 2007). The physiological changes following mating increase the response of female moths to host plant odours as proved in *Pectinophora gossypiella* (Saunders) in cotton (Wiesenborn and Baker, 1990).

In the electrophysiological evaluation of *D. indica* to different concentrations of benzaldehyde and benzyl alcohol, the antennal response was highest to the crude form of both the compounds for males, unmated and gravid females (Fig. 3). The response was reduced with a decrease in concentration and gravid females were the most responsive to both compounds. While testing different combinations of these compounds (Table 4), all the combinations with different proportions of the crude chemicals showed higher responses which were not significantly different. The synthetic volatile combination 10µl of crude benzaldehyde + 30 µl crude benzyl alcohol elicited a higher EAG response (0.21 mV) which was comparable with bitter gourd and cucumber. It could be inferred that not only benzaldehyde and benzyl alcohol, but some other volatiles in the host plants also have a role in the attraction of *D. indica*. The relative proportion and concentration of different volatiles will be critical for each pest and more specifically for each stage of an insect.

Behavioural response to volatile combinations: In this experiment conducted using modified olfactometer, synthetic volatile compounds at 10 per cent concentration produced significant reactions in *D. indica* moths. The mixture of 10µL benzaldehyde (10%) + 20µL benzyl alcohol (10%) produced the highest orientation and landing response. Out of 30 insects (6 replication x 5 insects per replication) exposed to this mixture, 66.67 per cent oriented towards it and 33.33 per cent landed on it. When 10µL of each of benzaldehyde and benzyl alcohol were combined, 60 per cent of the moths moved in the direction of the source and 30 per cent landed on it. Only 50 per cent of moths responded when benzaldehyde alone was used. In a similar sudy, Gharaei *et al.* (2020) reported a higher flight response of *D. indica* to a mixture of (E, Z)-2,6-nonadienal, (E)-2-nonenal, (Z)-6-nonenal, benzyl alcohol, benzaldehyde and 4,8-dimethyl-1,3,7-nonatriene (DMNT) in a wind tunnel but only the combination of benzyl alcohol, benzaldehyde and DMNT showed a landing response.

In conclusion, the results of the study revealed that *D. indica* has electrophysiological and larval olfactory preference to bitter gourd and cucumber. The results also show that the attractiveness is depended on plant species, the volatiles it emits, the mating status of insect, previous experience and environmental conditions. Important volatiles in the host plants having kairomonal properties have been identified and that of benzaldehyde and benzyl alcohol was proved in the study. An appropriate combination of host plant volatiles along with the

pheromone components of *D. indica* can be used to device a semiochemicals based trap to manage this pest more efficiently.

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Notes on the final emergence and moulting pattern of *Ischnura senegalensis* Rambur, 1842 (Zygoptera, Coenagrionidae) and *Anax immaculifrons* Rambur, 1842 (Anisoptera, Aeshnidae)

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ABSTRACT: The complete emergence of two odonate species *Ischnura senegalensis* (Rambur, 1842) (Zygoptera, Coenagrionidae) and *Anax immaculifrons* (Anisoptera, Aeshnidae) were studied at Wardha district of Maharashtra, India. The average time to complete emergence in *Ischnura senegalensis* was 92.2 minutes and in the case of *Anax immaculifrons* the average time for the (F-0) stage larvae for emergence it into fully flying adult was 40 days. *I. senegalensis* emerges in a vertical posture and emerges between 8 00h and 16 00h during the day. Emergence of the *A. immaculifrons* was observed at night, with times ranging from 21h to 01h and it emerges in a vertical posture. The (F-1) stage larva of *A. immaculifrons* was cannibalised by the (F-0) stage larva by only cutting the thorax and separating the head and abdomen. One unsuccessful emergence was observed in *A. immaculifrons*, where one of the wings remain wrinkled and unstretched.

KEY WORDS: Odonata, emergence, exuvia, instar, moulting, pharate

INTRODUCTION

The life cycle of the amphibiotic insect order Odonata, which includes dragonflies and damselflies, comprises three stages: eggs, larvae, and adults. The eggs and larvae are aquatic, while the adults are terrestrial and aerial. When the aquatic larvae mature, they leave the water to undergo ecdysis, the final molt, which is a pivotal event in their life cycle. This process, where the adult emerges from the aquatic exuvia, involves various rhythmic movements. (Thaokar *et al.,* 2019). In contrast to Corbet (1999) who postulated four stages for the full emergence of odonata, Andrew and Patankar (2010) mentioned involvement of only three stages of odonata emergence.

The period of odonata emergence is very vulnerable, as the immobile and pregnable stage is exposed to a variety of adverse biotic and abiotic environmental factors like wind, rain, temperature, oxygen level, lack of suitable emergence support and predation

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(Boda *et al.,* 2015; Thaokar *et al.,* 2019). Odonates usually exhibits two types of emergence patterns, horizontal pattern which is commonly seen in Zygoptera and Anisoptera, and the vertical emergence which is common in the remaining groups. The two emergence patterns in odonates, horizontal and vertical, have different effects on the insects' transition from the larval to the adult stage. (Eda, 1963). The primary factor influencing the emergence patterns in odonates is the type of available substratum in their environment.However inverted emergence has also been observed in some species of Zygoptera (Rowe, 1987). The emergence posture is generally depending on the availability of substratum; availability of flat surface such as leaves, etc. influence horizontal emergence, whereas availability of vertical substratum (wooden sticks, small twigs, aquatic plant etc.) helps to emerge in vertical posture (Inoue, 1964). However, *Ceriagrion coromandelianum* can moult in both horizontal as well as vertical position (Thaokar *et al.,* 2019).

Several authors have studied the final emergence of odonates, focusing primarily on subtropical and temperate regions. Early research by Trotter (1966) and Ubukata (1981) explored emergence patterns, while Banks and Thompson (1985) and Gribbin and Thompson (1990, 1991) examined environmental factors. Corbet (1999) provided a comprehensive review, and more recent work by Haslam (2004), Baird and Burgin (2013), and Boda *et al.* (2015) continued to refine these findings. However, studies from the Indian region are limited, with contributions from Mathavan and Pandian (1977), Andrew (2010, 2012), and Andrew and Patankar (2010), along with Thaokar *et al.* (2019). Studying the final emergence of odonates is important to understand regional differences, fill knowledge gaps in underrepresented areas like India, and contribute to broader ecological insights. *Ischnura senegalensis* and *Anax immaculifrons*, both described by Rambur in 1842, are common odonates in Nagpur, central India. *I. senegalensis* is a widespread Coenagrionidae damselfly found in Africa and South-East Asia, while *A. immaculifrons* is a large Aeshnidae dragonfly ranging from Europe to Japan. Both species breed in stagnant water bodies, streams, and rivers (Andrew *et al.*, 2008).The life history and larval morphology of *Ischnura senegalensis* and *Anax immaculifrons* have been thoroughly studied, as evidenced by the works of Sangal and Kumar (1970), Kumar (1973, 1984), and Okude *et al.* (2017). The present paper describes the pattern and process of emergence of the damselfly *I. senegalensis* and dragonfly *A. immaculifrons* with a note on the mortality and larval cannibalism.

MATERIALS AND METHODS

Three larvae of *A. immaculifrons* were collected on 19 February 2023, from Kakaddara (20°52'48"N; 78°23'23"E) of Wardha district, Maharashtra. Out of three larvae, two were in (F-1) stage; one was in (F-0) stage. The six larvae of *I. senegalensis* were collected from Dham river of Pawnar (20°47'08"N; 78°39'56"E), Wardha district, Maharashtra, on 18 March 2023. All the collected larvae of *Ischnura senegalensis* were of (F-0) stage. The observations on emergence and moulting pattern were made at the Post Graduate Department of Zoology, Dr. R. G. Bhoyar Arts, Science, Commorce College, Seloo, Wardha (20°49'41"N; 78°41'58"E), Maharashtra, India. The collection of larvae was done with the help of D loop larvae collecting net and some are hand-picked. Dragonfly larvae were kept in large bottles (8cm diameter, 25cm height), while damselfly larvae were kept in small bottles (6cm diameter, 20cm height). In addition, (F-0) larvae were kept in an aquarium (26cm length, 10cm width, 20cm height) until they emerged. As emergence supports, wooden sticks and small twigs were placed in the containers. Feeding materials for *Anax immaculifrons* were prawns, water beetles, and fly maggots and for *Ischnura senegalensis* were may fly larvae, mosquito larvae. Various stages of wing development and moulting during metamorphosis were photographed using a Nikon D5300 DSLR equipped with a Nikkor Af-p 70-300 mm lens. The emergence time was recorded using an electronic stop watch. The F-0 (= Final) and F-1 (= Final minus 1) stages were determined using keys and data from (Okude *et al.,* 2021).

RESULTS AND DISCUSSION

Emergence of *Ischnura senegalensis*

Five of the six collected larvae were the emerged individuals were all female. The final emergence of the damselfly *I. senegalensis* was observed on March 20, 2023. It began at 11.27 am. and ended at 12.48 pm. Based on Andrew and Patankar (2010), the process has been divided into three observable stages, which are described below.

Stage I: At 11.27 h, the F-0 larva climbed the stick after coming out from the water. On the dry stick, it moved 14 cm prior to stopping. Larva started shaking its abdomen horizontally. After resting on the stick for ten minutes, the abdominal and head movements began. These movements started out very slowly and later moved vertically. The head and thorax were then pushed up against the stick. The abdomen's back was firmly pressed up against the base while the legs were spread out. The larva shifted the head to the side and curled up the tip of the abdomen. The head and thorax were raised, and the fore and hind legs' grip was reset. This movement continued interspaced with long intervals of motionless rest. It raised the anterior region of the body by flexing the legs, and a split appeared along the dorsal region of the thorax's cuticle. It took about 31 minutes for stage-I of moulting.

Stage - II: At 11.58h within one minute the head and thorax just elevated from the split exuvia without

Fig. 1 Image a Stage I, Image b-e Stage II and Image f-l Stage III of the final emergence of *Ischnura senegalensis*.

Fig. 2 Image a-b Stage I, Image c-f Stage II and Image g-h Stage III of the final emergence of *Anax immaculifrons*

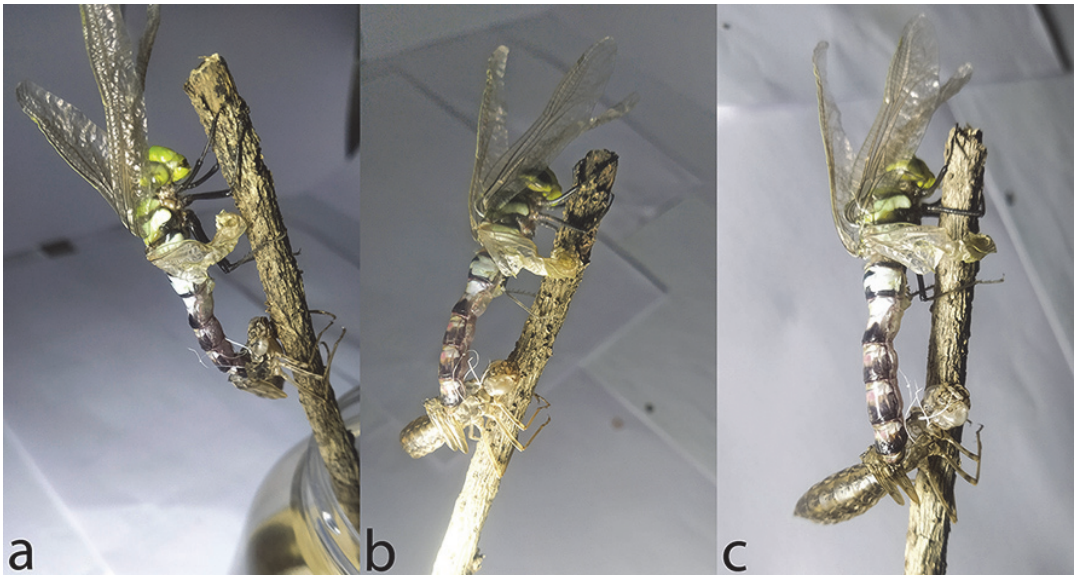

Fig. 3 Image a-c Incomplete metamorphosis during final emergence of *Anax immaculifrons*.

wriggling leaving the exuvia on the stick. The legs were straight sticking along the dorsal part of body and half of the abdomen along with head and thorax was outside the exuvia at 12.01h. The legs started flexing slowly. Initially only the forelegs exhibited movement and after few seconds all legs started moving and pawning the air and in search of substratum. The body of the pharate was still supported by the trapped abdomen. The thorax and abdomen formed an angle of 90 degree. Forelegs hold the wall of aquarium as it found suitable grip for all legs, the pharate smoothly extracted the remaining part of the abdomen from the exuvia without wriggling at 12.02h. The pharate move about 5 cm from the emergence site and hold the wall of aquarium at 12.04h for the movement all the legs played crucial role. For holding the forelegs fixed at the border wall of aquarium. The tiny compact wings lay parallel to the abdomen. It was 12.05h and the end the stage-II. This stage took only 8 minutes.

Stage -III: Fore, mid and hind legs of pharate rested on the wall of aquarium. Then telescoped abdomen and wings were expanding simultaneously, the rate of expansion of wings are faster than the abdominal expansion at 12.06h. The length of wings and abdomen same at 12.09h and continued stretching of wings at larger length as compared to abdomen. Wings were completely stretched and of greenish yellow in colour still stuck to each other at 12.10h. The pharate maintained its position and doesn't show the subject moving their legs or tightening their grasp on the tank wall. Pharate's abdomen kept growing gradually until it was fully extended at 12.20h. As the abdomen grew, the pharate forced water (15 times) out of the rectum at regular intervals to empty the gut. The thorax was pale golden in tone, and the eyes were pale brownish. The genital segments are a light golden-brown tone, and the centre of the abdomen was a soft yellow colour. In addition to the transparency of the wings, the body's pigmentation occurred concurrently on its whole surface at 12.45h, making the newly emerging imago flight-ready. The imago now displayed its distinctive species-specific colour patterning, which took 1.5 hours to complete on the adult body. Stage-III took 39 minutes.

A comparative account of five complete metamorphosis shows that, on an average the duration of Stage-I was 33.6 minutes (36.44 %), Stage-II was 14.6 minutes (15.85 %) and Stage-III was 44 minutes (47.73 %). The average time to complete emergence was 92.2 minutes (Table 1).

Emergence of *Anax immaculifrons*

Out of three captured larvae two were emerged, of which one successfully emerged and another was unsuccessful emergence. The first (F-0) stage larva collected on 19 February 2023, emerged on 2 April 2023 took 42 days for emergence. And the second (F-0) stage larva which undergoes moulting on 27 February 2023 from (F-1) stage to (F-0) stage took 38 days for emergence and emerged on 6 April 2023. The average time for the (F-0) stage larvae for emerged it into fully flying adult was 40 days. The documentation of final emergence of *Anax immaculifrons* and complete session of moulting was observed on the night of 2 April 2023. As the availability of substratum was stick so the emergence is vertical at an angle of 40- 50 degree. Some behavior of dragonfly is very prominent that they required complete darkness and zero disturbance for emergence if they feel any threatening signal then they just quickly go inside the water. The emergence time of *Anax immaculifrons* ranges from 9pm to 1am

Stage I: The underwater larva waited for sunset and no interruptions before attaching to the wooden

Table 1. *Ischnura senegalensis* duration and average timing (in minutes) of the three stages of the final emergence recorded in the laboratory

Time (h)	I	II	III	Total
11.27 - 12.45	31	8	39	78
08.36 -10.16	41	12	47	100
14.23 – 16.06	35	18	50	103
13.02 - 14.35	29	20	44	93
14.42 - 16.09	32	15	40	87
Total	168	73	220	461
Average	33.6 (36.44 %)	14.6 (15.83 %)	44 (47.73 %)	92.2

pole. At 19.15h, the larva was resting with its head and mid-thorax out of water. 2 days before emergence, the larva has only taken its head out of the water. The climbing began at 20.30h and was staggered approximately 13 inches from the water level, as the larva climb routinely on stick from 2 days before emergence, so it was ignored. Stage I was noticed only until the larva was attached to the wooden rod, and then Stage II was observed at 23.47h.

Stage II: The adult's head and thorax emerged through the split. The thorax appeared first, followed by the head. It didn't wiggle, but it did move up and down. The head and thorax hung out and jerked once by 23.55h. The abdomen was still inside the exuvia when they emerged, and pigmentation began slowly in the head and thorax while the abdomen was still inside the exuvia. The legs that were folded against the thorax began to twitch. The adult hanging out breathed heavily, expanding and relaxing his body. It has begun a prominent antero-posterior humping action in an attempt to remove its skin from larval exuviae. The pharate's body was filled with haemolymph and appeared green. The legs were entirely stretched. Pharate wings entirely extended in Stage-II at 00.06h on April 3, 2023, however transparency was present in Stage-III. The pharate grips the stick hard and forces the abdomen out of exuvia. At 00.25h, Stage II was finished.

Stage III: The pharate held the stick tightly with all three pairs of legs. The abdomen gently stretched, and finally the wings became transparent. While the abdomen was still bent, by 1.02h it had completely extended, straightened, and began to sclerotize. The pharate cleansed the gut by forcefully releasing water from the rectum at regular intervals while the abdomen expanded. The eyes and exposed mouthparts were a pale green colour. The thorax and abdomen are black and white in coloration. At 01.39h, Stage III was finished. The imago now displayed its species-specific colour patterning on the adult body, which took 4 hours.

Case of an unsuccessful emergence and larval cannibalism

On April 6, 2023, one *Anax immaculifrons* larva was seen crawling out of the water, in preparation for its eventual emergence. After the thorax had fully emerged, the notches were visible. However, the right hind wing was not quite stretched and remaining three were stretched. The pharate's abdomen became wedged inside the exuvia, was ultimately pulled out at the same time as it emerged, and continued to tilt.

Among the two *Anax immaculifrons* (F-1) larvae collected from Kakaddara on February 19, 2023, one of the (F-1) larvae had a moult to reach the (F-0) stage on February 27, 2023, eight days after the collection. By merely severing the thorax and dividing the head and abdomen, the (F-1) stage larva was cannibalised by the (F-0) stage larva on March 15, 2023. According to the observation, the (F-1) stage larva's fleshy abdomen was not fully consumed by (F-0) stage larva.

Moulting stages of the *I. senegalensis* is similar to that of the *Ceriagrion coromandelianum* as both the species belongs to same family. The average time to complete the emergence was about 92.2 minutes. After emergence, *C. coromandelianum* stand on the exuvia but *I. senegalensis* move from the place of emergence and undergoes stretching and pigmentation (Thaokar *et al.,* 2019). Due to the firmness of the substratum, the emergence is vertical and at an angle of 40 to 50 degrees. One larva of *I. senegalensis* emerged even there is absence of gill at the end of abdomen. The emergence time of *I. senegalensis* ranges from 8h to 16h and its diurnal like other Zygopterans. Out of 2 larvae of *A. immaculifrons* one larva moulted completely and another with unsuccessful emergence because of lack of hardening of wing. In Stage -II of *A. immaculifrons* some amount of wing stretching and hardening has started and abdomen of pharate protrude late from the exuvia. In both *I. senegalensis* and *A. immaculifrons* the posture of emergence was tilted vertical since substrates were sticks. In (Thaokar *et al.,* 2019) *C. coromandelianum* appears to be an opportunistic species and can moult in both horizontal as well as vertical position. The maximum time for the stretching and spreading of the body and wings

in both the groups in Stage-III were observed in both the anisopteran *A. immaculifrons* and zygopteran *I. senegalensis*. In *A. immaculifrons* some time of Stage-III reduce due to sclerotization and spreading of wing started at ending of Stage-II.

During emergence of adult odonata, mortality usually occur for three major reasons, these are failure to moult, failure to expand and harden the wings, and predation (Thaokar *et al.,* 2019). In *A. immaculifrons* one of the above-mentioned types, failure in expansion of one wing was observed. It is important to note that, during larval collection, one *A. immaculifrons* larva of (F-1) stage was collected from a waterbody of drying River bed. It was found crawling at the pond's edge about 1 m from the water. Corbet (1999) mentioned that larvae of odonates performed terrestrial locomotion unrelated to emergence, and according to him, this phenomenon most likely occurs due to stress comes from water deprivation. (F-1) stage of larvae of *Libellula depressa* has also been observed moving towards water sources from drying water body (Piersanti *et al.,* 2007).

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Management of tomato fruit borer *Helicoverpa armigera* (Hub.) (Lepidoptera, Noctuidae) in Punjab, India

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ABSTRACT: Spinosad, novaluron, neem oil, rynaxypyr, *Ha*NPV and *Bt* were evaluated to reduce the fruit damage in tomato due to fruit borer (*Helicoverpa armigera*). Novaluron recorded the maximum benefit cost ratio (29.06) and hihest improved yield (65.22 q ha^{-1}). Bt had a cost benefit ratio of 17.98, due to the lesser cost of plant protection. © 2024 Association for Advancement of Entomology

KEY WORDS: Better productivity, less toxicity, residue, benefit cost ratio

INTRODUCTION

Due to its unique nutritional content and broad production, the tomato (*Lycopersicon esculentum*) is the second most significant vegetable crop in the world and is referred to as a protective food. With a production area of 5.4 lakh ha, India ranks second globally in terms of the number of tomatoes it produces each year, producing close to 7.1 million tonnes, ranking it fifth globally (Arora *et al.,* 2012). In addition to other factors contributing to low productivity, fruit borer infestations cause significant harm by directly reducing the yield of marketable fruits by 22–38per cent (Dhandapani *et al.,* 2003). The fleshy structure of tomato fruit makes it vulnerable to a variety of insect pests and diseases (Pandey *et al.,* 2015). As a result, enormous volumes of pesticides are consumed, leaving hazardous residues (Kumari *et al.,* 2010). Because it is a crop with a short growing season and a high yield, it is significant economically. India has a climate that is ideal for growing tomatoes all year round. It is grown both outside in open fields and indoors in polyhouses so that the crop can be harvested all year long. Among the pests that attack tomato, the fruit borer (*Helicoverpa armigera*) is important. In Punjab, it is crucial for an effective eco-friendly management approach combined with other management techniques against tomato fruit borer. So, eco-friendly management against tomato fruit borer in reducing fruit damage was undertaken, in order to estimate yield losses from tomato fruit borer damage and propose biorational management measures.

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MATERIALS AND METHODS

Spinosad (45% SC @ 0.3 ml per liter), novaluron (10% EC @ 2.6 ml per liter), neem oil (1000 ppm @ 4 ml per liter), rynaxypyr (20% SC @ 0.4 ml per liter), *Ha*NPV (@ 1ml per liter), *Bacillus thuringiensis* (*Bt* @ 2ml per liter) were evaluated along with a control, on the management of fruit borer. The experiment was conducted at Entomological farm of Lovely Professional University, Phagwara, Punjab, in the Zaid season of 2022.

Estimation of infested fruit percentage: The amount of *H. armigera* in the fruits damage was recorded at each harvest. The healthy and damaged fruits were separated, and the damage fruit infestation was counted to calculate the percentage of damage percentage was worked out with the help of following formula given by Abott, 1925.

$$Percent\ of\ fruit\ damage = \frac{Number\ of\ damage\ fruit}{Total\ number\ of\ fruit\ (damaged + healthy)} \times 100$$

Management of Tomato fruit borer (Helicoverpa armigera): The number of larvae per plant was counted on five randomly selected plants in each treatment plot a day before, 3DAS, 7DAS, 10DAS, and 14DAS after each spray. Three sprays of each insecticide at a predetermined concentration were administered. The pest infestation was recorded for each plot and compared to the untreated plots after two consecutive applications of insecticides at 15-day intervals. At each picking, the total number of fruit and those damaged were recorded. The first spray was applied 12 weeks after seedling transplantation, and the second 15 days later, for a total of two sprays. The numbers of tomato fruit borers were counted at 3DAS, 5DAS, 10DAS and 14DAS. To assess the economics of the various treatments against tomato fruit borer, the benefit: cost ratio was calculated.

RESULTS AND DISCUSSION

Fruit damage:

During the initial picking the infestation (on number basis) ranged 19.04 to 29.60 percent, with spinosad recording 20.06 percent, followed by novaluron (19.04%), neem oil (25%), rynaxypyr (23.69%), *Ha*NPV (24.04%), *Bt* (24.31%) and control (29.60 %). Damaged fruit ranged from 17.34 to 29.78 per cent in the second picking, with spinosad recording 19.27 per cent, followed by novaluron (17.34%), neem oil (24.44%), rynaxypyr (21.98%), *Ha*NPV (23.45%) and control (29.78%). In the third plucking fruit damage was in the range of 25.41 to 34.19 per cent, with spinosad recording 26.31 per cent, followed by novaluron (25.41%), neem oil (33.61%), rynaxypyr (30.93%), *Ha*NPV (33.63%), *Bt* (34.19%) and control (34.19%). During the fourth plucking fruit damage was from 21.37 to 36.43 per cent in the treatments. Spinosad recorded 23.09 per cent, followed by novaluron (21.37%), neem oil (36.43%), rynaxypyr (26.90%), *Ha*NPV (28.72%), *Bt* (28.72%) and control (43.81%). In fifth picking, the fruit damage range recorded a minimum of 18.19 and a maximum of 31.06 per cent. Spinosad recorded 19.30 per cent, followed by novaluron (18.19%), neem oil (31.06%), rynaxypyr (23.94%), *Ha*NPV (26.33%), *Bt* (29.11%) and control (46.42%). In sixth picking, the fruit damage was in the range of 15.88 to 29.81 per cent. Spinosad recorded 17.23 per cent, followed by novaluron (15.88%), neem oil (29.81%), rynaxypyr (21.11%), *Ha*NPV (24.34 %), *Bt* (27.17%) and control (39.01%). The average mean of fruit damage on a number basis among various management schedules revealed that novaluron had the significantly least fruit damage (19.54%), closely followed by spinosad (20.88%). Followed by rynaxypyr (24.35%), *Ha*NPV (26.06%), *Bt* (28.37%) and control (30.06%). Statistically all the management schedules performed better than control (Table 1). Novaluron was found to be best when compared with other treatments in terms of fruit damage. This was followed by spinosad and rynaxypyr. Pooran mal kharia (2015) recorded similar pattern.

Population of tomato fruit borer in treatments:

In the first spray, during the 3DAS, larval population per plant in spinosad was found to lowl (4.73), followed by rynaxypyr (4.80), *Ha*NPV (4.93), *Bt*

(5.07), neem oil (5.13) and control (6.00). At 7DAS results were recorded best in spinosad (4.20) followed by rynaxypyr (4.27), *Ha*NPV (4.53), *Bt* (4.60), neem oil (4.67) and control (6.20). At 10DAS larval population in spinosad was 4.07, followed by rynaxypyr (4.33), *Ha*NPV (4.67), *Bt* (4.73), neem oil (4.80), and control (6.33). At 14DAS larval population slowly showed increase in all the treatments viz; spinosad (4.13) followed by rynaxypyr (4.47), *Ha*NPV (4.87), *Bt* (5.07), neem oil (5.20) and control (6.40). It was found that the population in the treatments differed significantly from each other at 3 days after first spray. The significantly lower population (4.67 larvae/plant) was recorded in novaluron, with the highest reduction, which differed significantly from the remaining six treatments at 3 days after spray. Based on these observations, novaluron was found as the most effective insecticide against tomato fruit borer at 3 days after spraying. The effectiveness of the treatments was further compared at 7 days after spray, and it was found that all the treatments were superior to control in controlling tomato fruit borer. A significantly lower population (3.93 larvae /plant) was observed in novaluron with a significant reduction as compared with other treatments. The effectiveness of the treatments was further compared at 10 days after spray, and it was found that spinosad and novaluron treatments were superior to control in controlling tomato fruit borer. A significantly lower population (3.47 larvae /plant) was observed in novaluron with a significant reduction as compared with other treatments. The population of tomato fruit borer was further recorded at 14 days after spray, which showed an almost similar trend in the effectiveness of treatments against tomato fruit borer. Based on post-treatment observations at 3, 7, 10, and 14 days after spray, it was found that all the insecticides were effective against tomato fruit borer. However,

Table 1. Fruit damage (number basis) due to fruit borer, *Helicoverpa armigera* on tomato at each picking

Treat	Fruit damage (%) on various picking (number basis)						Mean
	1st	2nd	3rd	4th	5th	6th	
T_1	20.06 (26.61)^{cd}	19.27 (26.04)^{cd}	26.31 (30.86)^{bc}	23.09 (28.72)^{ef}	19.30 (26.06)^{e}	17.23 (24.52)^{e}	20.88 (27.19)^{de}
T_2	19.04 (25.87)^{d}	17.34 (24.61)^{d}	25.41 (30.27)^{c}	21.37 (27.54)^{f}	18.19 (25.24)^{e}	15.88 (23.49)^{e}	19.54 (26.23)^{e}
T_3	25.00 (30.00)^{b}	24.44 (29.63)^{b}	33.61 (.43)^{a}	36.43 (37.13)^{b}	31.06 (33.87)^{b}	29.81 (33.09)^{b}	30.06 (33.25)^{b}
T_4	23.69 (29.13)^{bc}	20.69 (27.06)^{abc}	29.78 (33.07)^{abc}	26.90 (31.24)^{de}	23.94 (29.29)^{d}	21.11 (27.35)^{d}	24.35 (29.57)^{cd}
T_5	24.04 (29.36)^{b}	21.98 (27.96)^{bc}	30.93 (33.79)^{ab}	28.72 (32.40)^{cd}	26.33 (30.87)^{d}	24.34 (29.56)^{cd}	26.06 (30.69)^{bc}
T_6	24.31 (29.54)^{b}	23.45 (28.97)^{b}	33.63 (35.44)^{a}	32.54 (34.78)^{bc}	29.11 (32.65)^{bc}	27.17 (31.41)^{bc}	28.37 (32.18)^{bc}
T_7	29.60 (32.96)^{a}	29.78 (33.07)^{a}	34.19 (35.78)^{a}	43.81 (41.44)^{a}	46.42 (42.95)^{a}	39.01 (38.65)^{a}	37.13 (37.54)^{a}
SE(m)	0.76	0.30	0.32	0.25	0.32	0.49	1.19
C.D.	2.38	0.93	1.00	0.79	0.99	1.53	3.47

Note: T_1= Spinosad (45% SC @ 0.3 ml per liter), T_2= Novaluron (10% EC @ 2.6 ml per liter), T_3= Neem oil (1000 ppm @ 4 ml per liter), T_4= Rynaxypyr (20% SC @ 0.4 ml per liter), T_5= *Ha*NPV (@ 1ml per liter), T_6 = *Bacillus thuringiensis* (Bt @ 2ml per liter), T_7 = Control. Figures in parentheses are angular transformation (asin(sqrt (x/100))) values

Table 2. Efficacy of different treatments against larval population of tomato fruit borer (*H. armigera*) during Zaid season, 2022

	1st spray					2nd spray				
Treatment	DBS	3DAS	7DAS	10DAS	14DAS	DBS	3DAS	7DAS	10DAS	14DAS
Spinosad	5.20	4.73^{bc} (2.39)	4.20^{bc} (2.28)	4.07^{d} (2.25)	4.13^{de} (2.26)	4.13	3.67^{d} (2.16)	3.00^{d} (2.00)	2.87^{e} (1.97)	3.07^{d} (2.02)
Novaluron	5.40	4.67^{c} (2.38)	3.93^{c} (2.22)	3.47^{e} (2.11)	3.93^{e} (2.22)	3.93	3.20^{e} (2.05)	2.47^{e} (1.86)	1.93^{f} (1.71)	2.13^{e} (1.77)
Neem oil	5.60	5.13^{b} (2.48)	4.67^{b} (2.38)	4.80^{b} (2.41)	5.20^{b} (2.49)	5.20	4.93^{b} (2.44)	4.40^{b} (2.32)	4.33^{b} (2.31)	4.60^{b} (2.37)
Rynaxypyr	5.33	4.80^{bc} (2.41)	4.27^{bc} (2.29)	4.33^{cd} (2.31)	4.47^{cd} (2.34)	4.47	3.93^{d} (2.22)	3.40^{d} (2.10)	3.27^{d} (2.07)	3.40^{c} (2.10)
*Ha*NPV	5.47	4.93^{bc} (2.44)	4.53^{b} (2.35)	4.67^{bc} (2.38)	4.87^{bc} (2.42)	4.87	4.33^{c} (2.31)	3.87^{c} (2.21)	3.93^{c} (2.22)	4.27^{b} (2.30)
Bt	5.27	5.07^{bc} 2.46)	4.60^{b} (2.37)	4.73^{b} (2.39)	5.07^{b} (2.46)	5.07	4.60^{bc} (2.37)	4.13^{bc} (2.26)	4.20^{bc} (2.28)	4.47^{b} (2.34)
Control	5.73	6.00^{a} (2.65)	6.20^{a} (2.68)	6.33^{a} (2.71)	6.40^{a} (2.72)	6.40	6.47^{a} (2.73)	6.47^{a} (2.73)	6.53^{a} (2.74)	6.60^{a} (2.76)
SE (m)		0.137	0.150	0.128	0.162		0.133	0.149	0.116	0.118
C.D. 5%		0.428	0.469	0.400	0.504		0.413	0.464	0.363	0.368

DBS = Day before spraying, DAS = Day after spraying, Figures in parentheses are square root transformation ($\sqrt{x+1}$)values.

Table 3. Economics of different treatments (per ha) against *Helicoverpa armigera* on tomato

Treatment	treatment cost (Rs)	Yield (q)	Increase yield (q)	Increased value (Rs)	Net profit (Rs)	BCR
Spinosad	6300	213.89	52.06	78090	71790	11.40
Novaluron	3255	227.05	65.22	97830	94575	29.06
Neem oil	2550	186.77	24.94	37410	34860	13.67
Rynaxypyr	6000	206.65	44.82	67230	61230	10.21
*Ha*NPV	5250	197.79	35.96	53940	48690	9.27
Bt	2355	191.63	29.8	44700	42345	17.98
Control	-	161.83				

Cost of insecticides: Spinosad 45% SC – Rs1600/ 75 ml; Novaluron 10% EC- Rs 900/1000 ml;
Neem oil 10000 ppm - Rs 350/ 1000 ml; Rynaxypyr 20% SC - Rs 900/ 60 ml; *Ha*NPV 1x10^9 POB Rs 500/ 100 ml;
Bacillus thuringiensis - Rs 536/ 1000 ml. Rate of tomato fruits – Rs 15/kg

novaluron and spinosad were more effective (Table 2).

During the second spray, the number of fruit borers recorded three days after second spray revealed that the treatments differed significantly. Novaluron recorded, the significantly low population (3.20 larvae/plant) 3 days after spray, followed by spinosad (3.67), rynaxypyr (3.93), *Ha*NPV (4.33) and *Bt* (4.60). The effectiveness of the treatments was further compared 7 days after spray, and it was discovered that all the treatments outperformed the control in suppressing fruit borer. Fruit borer populations were much lower (2.47 larvae/plant) with novaluron, followed by spinosad (3.00), rynaxypyr (3.40), *Ha*NPV (3.87) and *Bt* (4.13), and were found to be more effective than neem oil (4.40) and control (6.47) after 7 days of spray. When the effectiveness of the treatments was assessed at 10 days after spraying, it was found that spinosad and novaluron treatments outperformed the control in suppressing fruit borer. Novaluron treatment recorded low population (1.93 larvae/plant), followed by spinosad (2.87), rynaxypyr (3.27), *Ha*NPV (3.93) and *Bt* (4.20), and were found to be effective than neem oil (4.33). The population of fruit borer was also recorded 14 days after spray, which revealed almost similar trend in the effectiveness of treatments against fruit borer. Based on post-treatment observations at 3, 7, 10, and 14 days after spray, it was found that all treatments were efficient against tomato fruit borer when compared to the control. Kolarath *et al.* (2015) found similar results in the efficacy of novaluron against tomato fruit borer as superior to other insecticide followed by spinosad and rynaxypyr. Bhanuprakash *et al.* (2019) reported similar result for the efficacy of insecticide among all the treatments.

Benefit-cost ratio:

The treatments were designed to generate a financial return by enhancing productivity and reducing pest damage. All treatments were deemed to be lucrative over control. Novaluron treatment had the maximum benefit cost ratio (29.06) and the highest improved yield over control (65.22 q ha^{-1}), followed by, treatment *Bt* (17.980, neem oil (13.67) and Spinosad (11.40). Rynaxypyr recorded (10.21) low cost benefit ratio due to highest cost of plant protection. Sundar Pal *et a.,* (2018) also found similar results, where the maximum return was recorded in Novaluron followed by Spinosad and Rynaxypyr as compared to others over control (Table 3).

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Field life tables and key mortality factors of *Pieris brassicae* (Linnaeus) (Lepidoptera, Pieridae) infesting cauliflower (*Brassica oleracea* var. *botrytis*) in Punjab, India

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ABSTRACT: To find out the key mortality factors of *Pieris brassicae* (Linnaeus) on cauliflower (*Brassica oleracea* var. *botrytis*), this study of field life table was conducted during 2021-22 at the research farm of the Punjab Agricultural University, Ludhiana, Punjab. Among biotic factors, *Cotesia glomerata*, *Beauveria bassiana* (Bals.), NPV, *Bacillus thuringiensis* (Berliner) were the main causes of mortality. Other unknown factors (temperature, rainfall, relative humidity) also contrived slight decline to all the immature stages of *P. brassicae.* Results revealed that the egg stage (17.46-28.35%) affected due to unknown factors, whereas, early larval instar stage (I-III) was the most sensitive, showing the highest loss (36.62-43.95%) followed by the late larval instar stage (25.77-29.43%) and pupal stage (16.19-22.41%). The trend index was positive during both seasons 16.91 (main season) and 19.17 (late season), indicating that population of *P. brassicae* increased in next season. Similar trend was observed in generation survival i.e. 0.39 (main season) and 0.32 (late season).

KEY WORDS: Biotic factors, trend index, mortality, parasitisation, survivorship curves

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis*) is one of the most crucial and widely grown vegetable crops in the world with maximum nutritive value. Many biotic and abiotic factors are responsible for low production and productivity of cauliflower crop in India. Being pest, *Pieris brassicae* (Linnaeus) (Lepidoptera, Pieridae) is the major biotic factor limiting the quality of cauliflower more than 40 per cent yield loss annually in India (Ali and Rizvi, 2007). This pest is largely managed by the use of toxic insecticidal chemicals which have their own adverse and ill-effects such as the development of insecticide resistance, pesticide residues and resurgence besides environmental pollution (Manyangarirwa, 2009). This entails the development of another possible control strategy that can be made a part of integrated pest management module. Life tables play a major role in pest management because it describes the growth, survival and fecundity (Nisar and Rizvi, 2021). It provides the format for recording all the population changes in the life cycle and quantifies the mortality in the population of the insect. These kind of ecological life tables provide a basis to

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quantify rates of death from various factors over generation (Naranjo and Ellsworth, 1999). The life table is of two types: cohort or generation life table and period life tables (Damanpreet *et al.,* 2022). The cohort or generation life table summarizes the age-specific mortality experience of a given birth cohort for its life and the period life table summarizes the age-specific mortality conditions pertaining to a given or short period of time. Through life table studies, determination of the most vulnerable stage for time-based application of insecticides for insect pest control can be known (Ning *et al.,* 2017). Various weather factors play a key role for the incidence and development of insect pests and understanding of these factors is vital to the population dynamics study, predicting pest outbreaks and in the development of pest management strategies (Chandi *et al.,* 2021). Therefore, it is vital to create life tables for *P. brassicae* under various circumstances in order to have a better knowledge of the diversity in the pest's demography. The published studies that focused on the ecology of this pest continuously over two crop seasons are not available in India, despite a significant amount of research on the influence of different abiotic and biotic factors on the development of *P. brassicae* population that has been used for constructing its life tables. The goal of the current work was to determine the key mortality factors of *P. brassicae* on cauliflower crop and develop an appropriate integrated management strategy for use in the field by analysing population variations through life tables.

MATERIALS AND METHODS

The experiment on life table studies of *P. brassicae* on cauliflower was carried out at Entomological Research Farm, Punjab Agricultural University, Ludhiana, Punjab during 2021-2022. Under Punjab conditions, cauliflower is grown in three season viz. early season (July-October), main season (September-December) and late season (December-March). But population of *P. brassicae* was observed during main season and late season crop. No incidence of *P. brassicae* was observed during early season crop. Life tables studies of *P. brassicae* were conducted on main season (September-December) and late season crop (December-March) of 2021-22.The mean temperature and RH on main season crop during the months of September, October, November, December was 28.1, 24.3, 18.7, 13.7°C and 71, 61, 61, 62 per cent, respectively. Similarly, on late season crop during January, February, March was 12.8, 14.8, 23.3°C and 83, 71, 63 per cent, respectively. The crop was grown in accordance with recommended package of practices (Anonymous, 2021). For the purpose of tracking the mortality of various pest life stages due to various parasitoids and other factors, several life stages of *P. brassicae* were taken from an unsprayed cauliflower crop and raised accordingly. Since there were overlapping generations, the life table was constructed for the entire season. *P. brassicae* was sampled from 20 quadrates of 2m x 2m of main season (September-December) and late season (December-March) crop during 2021-22 and then it was computed on hectare basis. Regular visits were made to examine the initial incidence of *P. brassicae* with respect to appearance of eggs on cauliflower crop and to determine mortality due to unviability and parasitisation. For efficient sampling of larval instars, they were grouped into two categories. The stage I-III was considered as early instars and IV-V as late instars. In each observation number of larvae was counted in randomly selected quadrates and the population was computed on hectare basis from the average obtained from the quadrates.

The different life stages were collected at weekly intervals and raised in Petri dishes with fresh leaves until pupation in order to determine mortality. The observations were recorded on mortality in different larval groups due to various biotic factors like parasitoids, bacteria, fungus and virus etc. and it was continued up to pupation. Based on the level of mortality at each developmental stage of the pest, a definite number of larvae of different larval groups were collected from cauliflower field for determination of the survival rate. To study the mortality factors during pupal stage, the pupae were collected from field and kept in cages for adult emergence and observations on number of deformed pupae, unsuccessful emergence and

unknown causes were recorded. To determine fecundity, the newly laid eggs were daily collected. For construction of life table, data was collected regarding the growth and survival of *P. brassicae* and its natural enemies. The observations recorded for pivotal age were (egg, larva, pupa, adult); number of individuals at beginning; number of individuals died; factors responsible for mortality; per cent apparent mortality; survival rate. The data on development and survival of *P. brassicae* and their natural enemies were observed for construction of life table. The different observations recorded as per given in (Table 1).

Table 1. Column heading and denotion of various parameters of life table

Heading	Denotion
x	Pivotal age
l_x	Number of individuals at beginning
d_x	Number of individuals died
d_{xf}	Factors responsible for mortality
100qx	Apparent mortality
S_x	Survival rate

The following standards and steps recommended by (Harcourt, 1963) and (Atwal and Bains, 1974) for creating the life table for various developmental stages: In order to determine egg survival (l_x) and mortality (d_x), eggs from the main and late season crops in 2021-22 were used. The first, second, and third larval instars were among the younger larvae. By directly sampling the quadrates, the l_x value for this group of larvae was determined and computed on a per-hectare basis. Fourth and fifth larval instars were among the older stages. Larval mortality owing to parasites, fungi, viruses, bacteria, and other unknown causes was subtracted from the population of younger larvae to determine the l_x value for older larvae. The mortality brought on by parasites, viruses, bacteria, fungi and other unknown factors from the older group of larvae was subtracted to determine the l_x value for pupa. Based on number of adults emerged from the pupa, the l_x for moths was determined. Mortality reported during pupal stage was subtracted from the l_x value of pupae. The Generation survival was determined by taking ratio of the number of females×2 (N3) by the number of younger larvae (N1) i.e. N3/N1. The trend index value "I" was calculated by taking population of the same developmental stage in two successive generations i.e.N2/N1 (Atwal and Singh, 1990).

Identification of key mortality factors: Determining the stage that has a significant impact on the index of population trend (I) or generation survival (SG) is the most important step in understanding population fluctuations. To determine the important variables that primarily impacted the population trend in both the main and late cauliflower crop, a separate budget was created. Richards (1961) created the key factors analysis method, and using this method, the killing power (K) of these mortality factors in each age group was calculated as the difference between the population density logarithms before and after its action. The overall killing power of "K" equals the sum of the killing powers of "k's" since a sequence of mortality factors operate in succession during the formation of a population. If,

K_0= log lx of egg stage - log lx of younger larval stage.
K_1 = log lx of younger larval stage -log lx of older larval stage
K_2 = log lx of older larval stage - log lx of pupal stage
K_n = log lx of pupal stage - log lx of adult stage
K thus equals $K_0 + K_1 + K_2 + K_n$.

Survivorship curve: The best way to display variations in *P. brassicae* population trend on the cauliflower crop was through survivorship curves, according to (Southwood, 1978). A survivorship curve is a graph in which the number (y axis) at a certain age (l_x) is plotted against age to demonstrate what percentage of a beginning group is still alive at each succeeding age (x). Typically, four different types of curves are obtained, each of which explains different mortality factor functions.

RESULTS AND DISCUSSION

During main season crop, the number of individuals at the beginning was 14850 (Table 2). The larval stages were divided into two different categorises *viz.,* early instar larvae (I-III instars), late instar

larvae (IV-V instars) and mortality factors (Figs. 1, 2) were categorised group-wise. Early instar larval stage (36.62%) had the highest mortality rate, followed by late instar larval stage (25.77%), egg stage (17.46%), and pupal stage (16.19%) (Fig. 3). The leading cause of egg mortality (17.46%) was unviability. The overall mortality recorded at this stage in early instar larvae, which originally had 12257 larvae, was 4489. *Cotesia glomerata*, a larval parasitoid, was the major factor of mortality among the numerous factors, accounting for 20.21% of all deaths, followed by Nucleopolyhedrovirus (7.88%) and unknown factors (1.39%). *Bacillus thuringiensis* (Berliner) and the fungus *Beauveria bassiana* (Bals.) were responsible for 4.70 and 2.41 per cent of the mortality, respectively. Fedosimov and Tsedev (1970) reported that *C. glomerata* killed 1 to 2 per cent of *P. brassicae* larvae and also observed numerous *Bacillus* species as well as one each of Diplococcus, Micrococcus and Vibrio shaped bacteria. *Bacillus* and *Pseudomonas* have been found in *P. brassicae* larvae, but no evidence of pathogenicity has been found.

At the end, 7768 early instar larvae were still alive. In the late instar larval stage; there was an overall mortality rate of 25.77 per cent, of which the

Table 2. Life table of *P. brassicae* for main season on cauliflower crop during 2021-22

Age interval	No. in the beginning	Factor for death	No. died	Mortality %	Survival rate
x	l_x	$d_{x\,F}$	d_x	100qx	S_x
Eggs	14850	Unviability	2593	17.46	0.82
Early instar larvae (I-III instar) (N1)	12257	*Cotesia glomerata*	2478	20.21	0.63
		NPV	967	7.88	
		Beauveria bassiana	577	4.70	
		Bacillus thuringiensis	296	2.41	
		Unknown factors	171	1.39	
		Total	4489	36.62	
Late instar larvae (IV-V)	7768	*Cotesia glomerata*	1038	13.36	0.74
		NPV	615	7.91	
		Beauveria bassiana	207	2.66	
		Unknown factors	142	1.82	
		Total	2002	25.77	
Pupa	5766	Pupal deformity	479	8.30	0.83
		Unsuccessful emergence	337	5.84	
		Unknown factors	118	2.44	
		Total	934	16.19	
Moths	4832	Sex 50 per cent			
Females x 2 (N3)	4832				
Reproducing female	2416				

Expected eggs = 289267; Number of dead/Sterile eggs = 82036; Expected viable eggs = 207231; Actual number of younger larvae in main season (N_2) = 207231; Trend index ($I=N_2/N_1$)= 16.91; Generation survival ($SG=N_3/N_1$)= 0.39

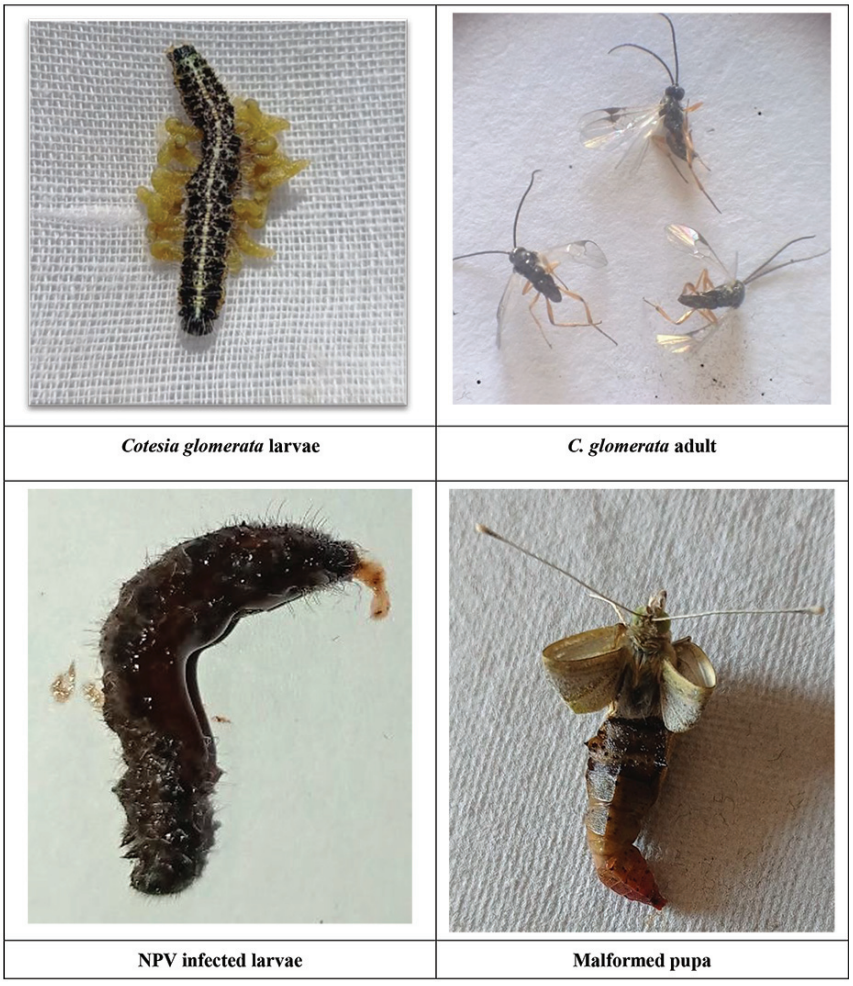

Fig. 1 Mortality factors recorded on *Pieris brassicae*

parasitoid *C. glomerata* alone was responsible for 13.36 per cent, while NPV, *B. bassiana* and unknown factors were responsible for 7.91, 2.66 and 1.82 percent of the mortality, respectively. Shapiro (1976) observed that the effect of dietary regime of the host on the growth of specific parasites, finding that *C. glomerata* parasitized 80-90 per cent of the larvae. Karnavar (1983) reported parasitism of 92.68-93.43 per cent in *P. brassicae* larvae by *C. glomerata*.

The results make it evident that *C. glomerata* caused parasitization in both early and late instar larvae. However, maximum parasitization was observed in early instar larvae which were due to the contribution of mortality of third instar larvae. Similarly, Razmi *et al*. (2011) observed the parasitism rate and parasitoid diversity of *P. brassicae* on cole crops and recorded *P. puparum* reducing pest number by 46.13-49.65 per cent, *C. glomerata* reducing pest number by 43.45-45.57 per cent in pupal stage and *B. femorata* by 2.43-4.89 per cent during different years in larval stage. Ahmad *et al*. (2007) observed that mortality of the larvae was greater during starting days due to high death rate of early instars.

There were 5766 late instar larvae alive at the end. The causes that contributed to pupal mortality in the pupal stage were pupal deformities (8.30%), unsuccessful emergence(5.84%) and unknown factors (2.44%). The main season cauliflower crop

Fig. 2 Mortality factors recorded on *Pieris brassicae*

had a positive trend index of 16.91, indicating that total mortality during this season was ineffective in causing pest population to decline and there will be more chances for population growth during the following season. The generation survival of 0.39 indicated that 39 per cent of the initial population could survive and successfully complete their generation (Table 2). The data analysis (Table 3) revealed that the highest mortality observed in early instar larval stage (K=0.1980) followed by late instar larval stage (K=0.1294), egg stage (K= 0.0833) and pupal stage (K=0.0767).

The initial population size for the late season crop was 289267 (Table 4). The early instar larval stage (43.95%) had the highest mortality rate, followed by the late instar larval stage (29.43%), egg stage (28.35%) and pupal stage (22.41%). Infertility was the leading cause of the egg mortality, which contributed about 28.35 per cent. Early instar larvae (I-III) mortality factors were primarily caused by *C. glomerata* (23.87%), NPV (9.98%), *B. bassiana* (5.63%), *B. thuringiensis* (3.66%) and unknown factors (0.80%). *C. glomerata*, NPV, *B. bassiana*, and unknown factors were the causes of larval mortality in the late larval instars (IV-V), accounting for 16.77, 7.37, 4.02 and 1.25 percent, respectively. The main causes of pupal mortality during the pupal stage were deformities (17.32%), unsuccessful emergence (4.12%), and unknown factors (1.18%). Third generation egg mortality was 35 as opposed to second generation's 28.35 per cent. Rizvi *et al.* (2009) documented that the mortality survival ratio and apparent mortality was found highest in pupal stage (0.19 and 15.91%) on Indian mustard and lowest at the pre-pupal stage

Table 4. Life table of *P. brassicae* for late season on cauliflower cropduring 2021-22

Age interval	No. of individuals in the beginning	Factor responsible for death	No. of individuals died	Mortality per cent	Survival rate
x	l_x	$d_{x\,F}$	d_x	100qx	S_x
Eggs	289267	Unviability	82036	28.35	0.71
Early instar larvae (I-III instar) (N_1)	207231	*Cotesia glomerata*	49467	23.87	0.56
		NPV	20697	9.98	
		Beauveria bassiana	11673	5.63	
		Bacillus thuringiensis	7587	3.66	
		Unknown factors	1674	0.80	
		Total	91098	43.95	
Late instar larvae (IV-V)	116133	C. glomerata	19484	16.77	0.70
		NPV	8566	7.37	
		Beauveria bassiana	4674	4.02	
		Unknown factors	1454	1.25	
		Total	34178	29.43	
Pupa	81955	Pupal deformity	14202	17.32	0.81
		Unsuccessful emergence	3377	4.12	
		Unknown factors	788	1.18	
		Total	18367	22.41	
Moths	66588	Sex 50 %			
Females x 2 (N_3)	66588				
Reproducing female	33294				

Expected eggs = 6112445; Number of dead/Sterile eggs = 2139356; Expected viable eggs= 3973089; Actual number of younger larvae in main-season (N_2)= 3973089; Trend index($I=N_2/N_1$)= 19.17; Generation survival ($SG=N_3/N_1$) = 0.32

(0.04 and 3.39 per cent) on cabbage and survival fraction was recorded highest (0.97) in the pre-pupal stage on cabbage and lowest (0.84) in pupal stage on Indian mustard.

Indicating that different mortality factors during this season were ineffective in causing the pest population to decline, the generation survival and positive trend index in the main season cauliflower crop was 0.32 and 19.17, respectively. This means that there will be a greater chance of increase in population during the following season (Table 4). The early instar larvae (K=0.2514), late larval instar stage (K=0.1513), egg stage (K=0.1448), and pupal stage (K=0.0901) contributed the most to the "K" value (Table 3). The findings are very similar to Ali

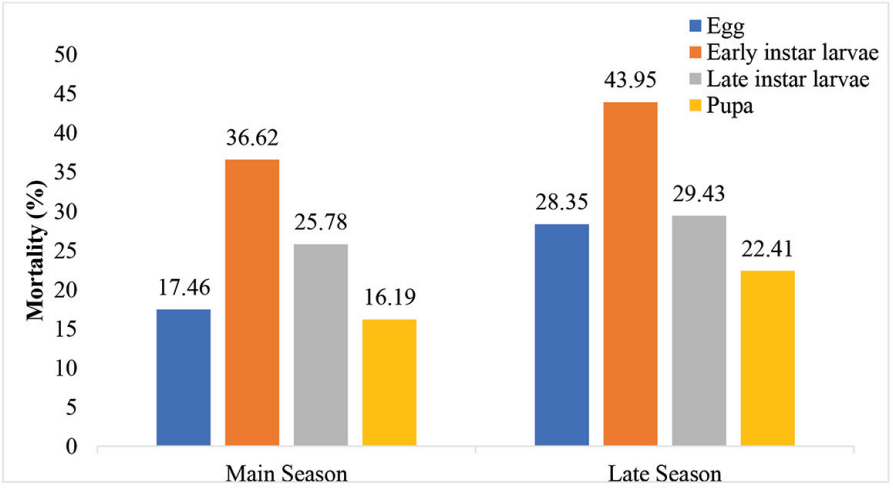

Fig. 3 Per cent mortality at different stages of *P.brassicae* for main season and late season crop during 2021-22

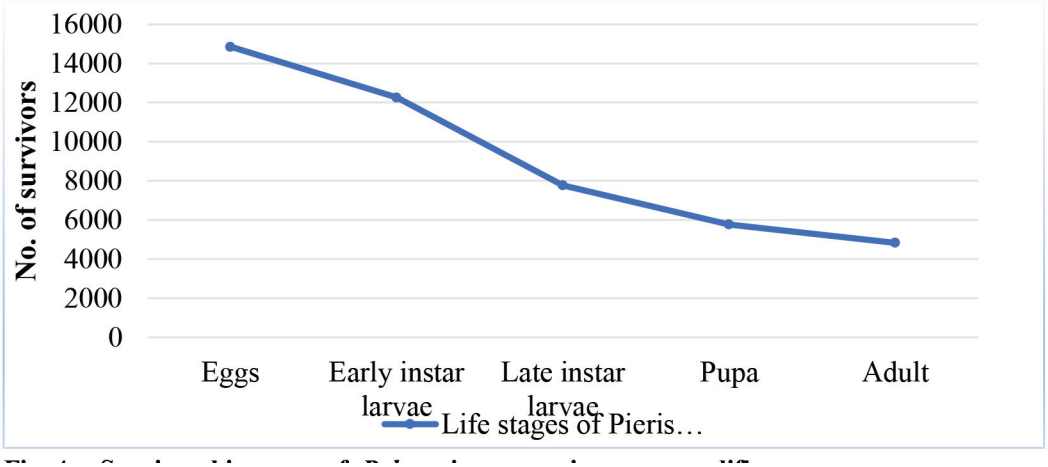

Fig. 4 Survivorship curve of *P. brassicae* on main season cauliflower crop

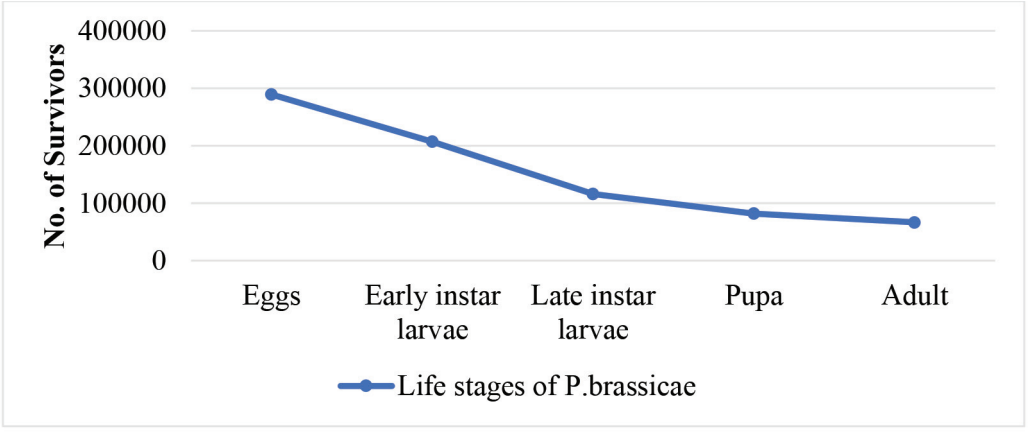

Fig. 5 Survivorship curve of *P. brassicae* on late season cauliflower crop

Table 3. Budget of *P. brassicae* on late season on cauliflower crop during 2021-22

Age interval	No's/ha		Log no's/ha		K' value	
	Main	Late	Main	Late	Main	Late
Expected eggs	14850	289267	4.1717	5.4612	0.0833	0.1448
Actual early instar larvae (I-III)	12257	207231	4.0883	5.3164	0.1980	0.2514
Actual late instar larvae after mortality	7768	116133	3.8903	5.0649	0.1294	0.1513
Actual pupae after mortality	5766	81955	3.7608	4.9135	0.0767	0.0901
Moth/ Adults	4832	66588	3.6841	4.8233	-	-
Reproducing females	2416	33294	-	-	-	
K Value					0.4042	0.4930

and Rizvi (2007) who found that the total K values of *P. brassicae* on cabbage, cauliflower, gobhi sarson, and yellow sarson, respectively, were 0.2486, 0.3042, 0.3216 and 0.3645, respectively.

***Survivorship curves*:** The most effective way to display differences of *P. brassicae* population trend on main and late season cauliflower crop. The highest mortality rate was seen in the early phases of the insect life cycle, and it was noted that the curve obtained in the current study was almost identical to type III curve. On main season as well as on late season crop, it appears that early instar larval death was more rapid (Fig. 4). Further, the survival was more in main season crop as compared to late season crop (Fig. 5). However, the combined outcome of the two curves indicated a continuous decline in *P. brassicae* survival by the pupal and adult stages. Therefore, the mortality at various developmental phases, such as the early instar larval stage, late instar larval stage, and egg stage, would have a stronger impact on population decrease of *P. brassicae* on cauliflower crop both during 2021-22. Similarly, (Rizvi *et al*., 2009) reported that the survivorship declined gradually from starting stage of development till the culmination of the generation on cauliflower. *P. brassicae* exhibited minimum mortality and maximum survival on cabbage leaves than other cole crops as it preferred cabbage for its fast and healthy development over other cole crops.

Overall, the results gave the impact that different variables play in population fluctuation in the field and for formulating prevention methods for *P. brassicae* on cauliflower. The potential of the ecosystem's natural enemies should be utilised since they are crucial in reducing the intrinsic rate of increase, which lowers the cost of insect control. By gathering the dead insects affected by the disease, the fungus attacking *P. brassicae* in natural environment should be identified and controlled. Local isolates are always a better option than commercial formulations and further research should be done to determine whether they have any potential as biopesticides. Researching field life tables of *P. brassicae* is an ongoing endeavour for identifying the main causes of mortality including biotic and abiotic factors. The identification of critical *P. brassicae* mortality factors through the study of field life tables should be emphasised for implementing an effective and long-term management programme for *P. brassicae* on cauliflower crop.

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Exploring the ecological interplay: population dynamics of an ichneumon wasp (*Xanthopimpla pedator* F.) on the Raily ecorace of *Antheraea mylitta* D. in Chhatisgarh, India

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ABSTRACT: The study provides a comprehensive examination of Ichneumon wasp damage on Raily Tasar silkworm cocoons in Chhattisgarh, offering critical insights into the prevalence and distribution of this parasitic infestation. These cocoons traditionally considered resistant to Ichneumon wasp infestations, but during the study, unexpected evident damage symptoms are exhibited during the First crop (Chaiti) harvests in June. The emergence of characteristic signs, including distinct holes at the peduncle base and pupal exit points, confirmed the presence of the Ichneumon wasp and its parasitic activity within the Raily cocoons. The investigation further revealed a notable range in the extent of Ichneumon wasp damage, with percentages ranging from 1.43 to 8.10 per cent across various forested locations in Bastar. District-wise analysis indicated that Bastar experienced the highest damage rate (23.50%), followed by Kondagoan (20.50%) and Dhantewada (17.00%). These variations underscore the localized disparities in infestation severity, emphasizing the need for targeted interventions in areas facing higher damage rates.

KEY WORDS: Bastar, tasar silkworm, insect pest, parasitoid

INTRODUCTION

Chhattisgarh State, located in central India, boasts a rich tradition of sericulture, with Tasar silk production occupying a prominent place in its cultural heritage. Second only to Jharkhand,

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Chhattisgarh has emerged as the second-largest producer of Tasar Silk, primarily due to the presence of abundant food plants for the Tasar silkworms, constituting an impressive 30 per cent of the state's total forest cover. This unique sericultural tradition is particularly significant among the tribal communities, who have cultivated the Tasar culture over generations. Raily, an endemic Tasar silkworm ecorace, is a fascinating jewel hidden in the lush tropical moist deciduous forests of Chhattisgarh and influences the socio-economic and communicational status of tasar silkworm rearers, specifically in the Bastar division (Dubey and Raut, 2022). Raily ecorace primarily feed on the leaves of *Shorea robusta* (Sal), *Terminalia tomentosa* (Asan), *T. arjuna* (Arjun), *Anogeissis latifolia* (Dhawda), among others, as they are highly adapted to their natural habitat (Sharma and Rai, 2010). This ecorace exhibits robust larvae, yielding compact and durable cocoons with rich silk content, characterized by a thick and high-denier silk thread. Raily ecorace use green coloration to blend in with the forest's Sal leaves, providing an effective camouflage mechanism for their survival. Number of Generations of tasar silkworm depends on its pupal diapause. Male and female moths exhibit distinct coloring, facilitating their mating and reproductive cycle. The follicular imprints on Raily silkworm eggs differentiate them from other ecorace Daba (Rao *et al*., 2003; Sharma and Rai, 2010; Reddy *et al*., 2010).

Tripathi and Tiwari (2021) additionally mentioned that biotic factors, including pests and diseases, contribute to the decline in the number of Raily ecorace population. Among the various pests that afflict tasar silk production, *Xanthpimpla pedator* is particularly notorious, causing substantial damage to both seed and commercial crops (Daba ecorace). The consequences of this pest infestation extend beyond the economic domain; it affects the quality, reliability, and market value of the cocoons. *X. pedator*, belonging to the family Ichneumonidae, is renowned for its parasitoid behavior, targeting Lepidopteran insects (Idris and Kee, 2002). These wasps stand out with their stout, bright-yellow bodies adorned with distinctive black spots, making them easily distinguishable within the Ichneumonidae family (Gadad *et al*., 2023). This genus predominantly thrives in tropical and subtropical regions, with a significant presence in Asia (Gómez *et al*., 2014). *X. pedator*'s life cycle involves the parasitization of *A. mylitta* silkworms during the pupal stage. The wasp uses its long ovipositor to drill through the silken cocoon and deposit a single egg in the abdominal segment. Notably, *X. pedator* is selective in its choice of hosts, preferring the early stages of cocoon formation when the cocoon is still pliable (Bhatia and Yousuf, 2013; Aruna and Devi, 2015; Marepally, 2016; Gathalkar *et al.,* 2017a; Gadad *et al.,* 2022). The cocoon toughens as the silkworm advances toward pupation, making oviposition more challenging. Despite parasitization, the silkworm completes its pupation process while the wasp egg hatches and the larva of *X. pedator* starts feeding on the silkworm pupal content. The appearance of *X. pedator* from its cocoon is marked by a unique circular opening (Fig. 1) near the peduncle (Singh *et al.*, 2019). This parasitic wasp's presence significantly threatens the Raily ecorace population, causing considerable losses in cocoon yield and quality. This study seeks to quantify and understand the extent of cocoon loss attributed to *X. predator* and its implications for tasar silk production in Chhattisgarh, India.

MATERIALS AND METHODS

In the Bastar region of Chhattisgarh, a study spanned three districts and five blocks. These blocks were further divided into four sub-blocks each, notable for the Raily cocoon collection activities. In June, cocoon samples were systematically examined at sites where tribal collectors harvested the cocoons from the selected blocks. Subsequently, the collected cocoons underwent a thorough analysis to assess the incidence of Ichneumon wasp infestation, with the percentage of damage calculated.

In addition to the examination of damaged cocoon samples, deceased cocoons were collected and subjected to a destructive sampling method to identify the presence of Ichneumon wasp infestation (Fig. 1). Detailed maps were generated to visualize

and analyze the distribution of cocoon damage caused by wasp infestation across various locations using ArcGIS Software. Further extent of damage was calculated by using the following formula.

$$\text{Percentage} = \frac{\text{No.of cocoons in a sample damaged by the ichneumon wasp}}{\text{Total no.of cocoons in a sample}} \times 100$$

In order to assess the relation between the estimated population distributions of Ichneumon wasp on Raily tasar silkworm cocoons in the forest ecosystem, the Poisson regression model was built by considering Ichneumon wasp number as the dependent variable and cocoons as the independent variable. The summarization of the insect count data was done by descriptive and exploratory data techniques.

RESULTS AND DISCUSSION

Population dynamics:

The descriptive statistics for the distribution of Ichneumon wasp sp under the host of Raily cocoons, the range distribution was 8 to 39, which produces sufficient variation and spread is more towards the right (Table 1). The Karl Pearson coefficient of skewness shows positive (>+1), which indicates that positively skewed population dynamics can be expected. Distribution of Ichneumon wasp, does not follow a normal distribution. The negative binomial regression model did not fit well to this data. Hence, the study considered the Poisson regression model for modeling the count data. The nature of the distribution of Ichneumon wasp counts was mapped in the form of a two dimensional histogram (Fig. 2, 3), which indicated approximately Poisson distributed data considered for the overall surveyed geographical area of the Raily ecorace.

Further, the Poisson regression model was built by considering Ichneumon wasp counts as a dependent variable and the number of Raily ecorace cocoons as the independent variable. The model was built separately for each district in order to understand the spatial ecological distribution of Ichneumon wasp sp under the Raily ecosystem. There is positive causal relationship between the number of wasp counts and Raily cocoons (B=0.0124** ; psudo R2=0.6213), (if there is an increase of one Raily ecorace cocoon in the forest ecosystem, then there will be chances of increment of Ichneumon wasp is about 0.12) which concludes that, there is the interaction between these two species in the ecosystem for all geographical areas of Raily ecorace of tasar silkworm. This model also explains the existence of predator-prey interaction between Ichneumon wasp as a parasitoid and raily ecorace as a host. The Psudo-R-square is about 0.6213, which indicates about 62.13 per cent of the variation in the dependent variable is explained by the independent variable, The K-S test values show significance (*) for all geographical ecosystems, which indicates the data is not from a normal population, which follows a non-normal distribution, which violates the assumptions of a classical linear regression model (Table 2).

Extent of Ichneumon Wasp Damage:

The damage ranged from 1.43 to 8.10 per cent across the various locations (Fig. 3). Examining individual districts within this forested area, Bastar district suffered the most from Ichneumon wasp damage, (23.50%). The Kondagoan district (20.50%); and the Dhantewada district recorded the least (17.00%) (Fig. 4). The district-wise variations in damage percentages underscore the

Table 1. Descriptive statistics for district wise distribution of Ichneumon wasp species

District	Min	Max	Mean	Std Dev	CV (%)	Kurtosis	Skewness
Bastar	9	39	25.63	12.19	47.56	1.75	1.20
Dantiwada	8	32	17.00	10.52	75.14	2.23	1.44
Kondagaon	17	26	20.5	4.04	20.73	1.30	1.09
Overall	8	39	22.00	9.00	44.00	1.99	1.60

Table 2. Maximum likelihood Estimates of Poison Regression Model

District	Parameter	B-Coefficient	Std. Error	Wald Chi-Square	P-Value	K-S test	Model Fitness (Pseudo $R^{2)}$
Bastar	Intercept	2.0695	0.2047	102.2104	0.000**	0.6523**	0.5637
	Raily Ecorace	0.0021	0.0004	27.5625	0.000**		
Dantiwada	Intercept	2.0532	0.4176	24.1736	0.000**	0.5841**	0.5249
	Raily Ecorace	0.0016	0.0006	7.1111	0.032*		
Kondagaon	Intercept	2.4834	0.506	24.0875	0.000**	0.5387**	0.4521
	Raily Ecorace	0.0012	0.0007	2.9388	0.041*		
Overall Data	Intercept	2.4987	0.1505	275.6482	0.000**	0.8549**	0.6213
	Raily Ecorace	0.0124	0.0013	90.9822	0.000**		

Note: * indicates Significance @ 5% level, ** indicates significance @ 1% level.

localized disparities in the infestation's severity (Fig. 5). Numerous studies and reports by researchers have thoroughly examined the infestation of the ichneumon wasp, *X. pedator*, in the commercial tasar silkworm race, Daba. These studies have covered its biology, the extent of damage, mating behavior, host location and various management strategies (Singh *et al.,* 2010; Marepally and Benarjee, 2016; Marepally and Benarjee, 2017; Gathalkar *et al.,* 2017b; Chandrashekharaiah *et al.,* 2018; Marepally, 2020). Whereas conventionally, Raily cocoons are thought to resist Ichneumon wasp infestations because of their robust and resilient nature of their silk shell. The Jata and Raily ecoraces are superior in shell weight and filament lengths, although their overall silk production is lower, and the silk filament is coarser with a higher denier compared to the commercial Daba race (Rao *et al.,* 2003; Reddy *et al.,* 2010; Chattopadhyaya *et al.,* 2018; Hemlal Sahu and Jayati, 2023. Before this study, there were no documented instances of Ichneumon wasp incidence on these durable cocoons. However, contrary to expectations, unmistakable symptoms of Ichneumon wasp damage were observed during the initial crop (Chaiti) harvests in June across the region.

This susceptibility highlights the adaptability and persistence of these parasitoids in identifying potential hosts (Gauld and Bolton, 1988; Tschopp *et al.,* 2013). Ichneumonids possess a unique capability to emerge from host pupae or cocoons through both mechanical and biochemical methods. Shaw *et al.* (2015), in their investigation of the emergence behavior within a variety of Ichneumonidae (Trogus subgroup), have indicated that the prevailing view holds true: the emergence from host pupae is primarily reliant on the action of the adult parasitoid's mandibles. However, they also suspected the possibility of using biochemicals during the emergence, as they have noticed staining around the edges of the emergence hole in some cases, such as *Nymphalis polychloros* (Linnaeus) parasitized by *Hoplismenus terrificus* (Wesmael) *Coenonympha pamphilus* (Linnaeus) parasitized by *Hoplismenus bispinatorius* (Thunberg), as well as in several Ichneumon species although it was not consistent. Similarly, Gadad *et al.* (2023) have documented instances of Ichneumonid infestation affecting the Daba ecorace of the tasar silkworm.

The research provides evidence that Ichneumon wasp infestation significantly impact the survival rates of Raily silkworms, consequently influencing their reproductive success. The ongoing threat posed by these parasitoids to the Raily population may lead to a decline in the population of Raily ecorace available for reproduction. This sustained pressure from Ichneumon wasp infestations has the potential to diminish the population size of the Raily ecorace over time, posing potential implications for the conservation and sustainability of this distinctive Tasar silk-producing lineage. Based on this available data helps the scientific team, policymakers, and

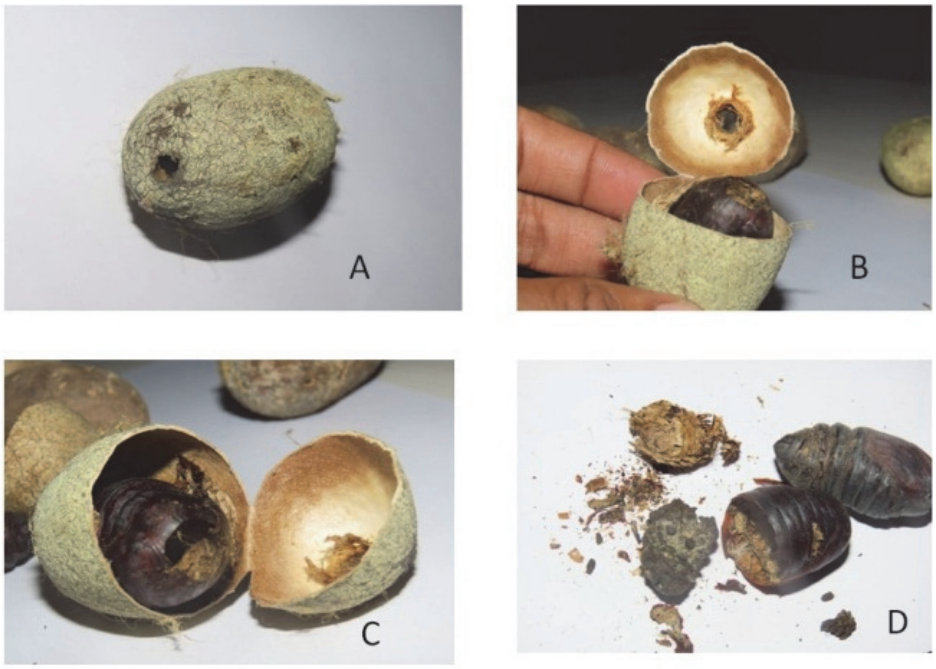

Fig. 1 A, B Ichneumon wasp emergence hole on Raily cocoon C emergence hole on pupa and D Excreta of wasp inside the pupa

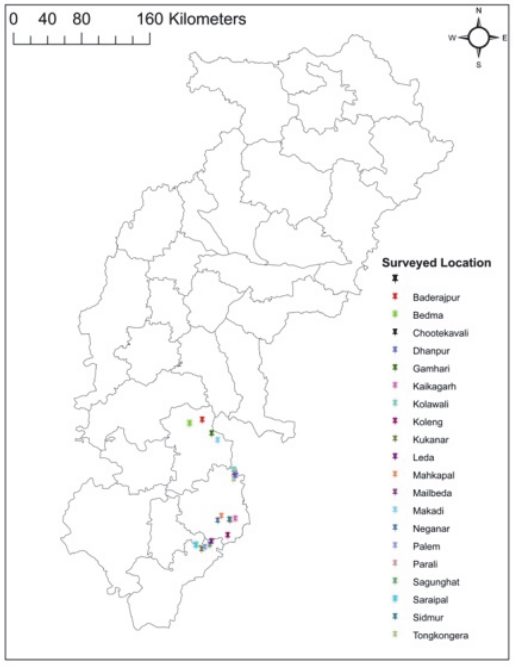

Fig. 2 Approximated poison distribution of Ichneumon wasp species

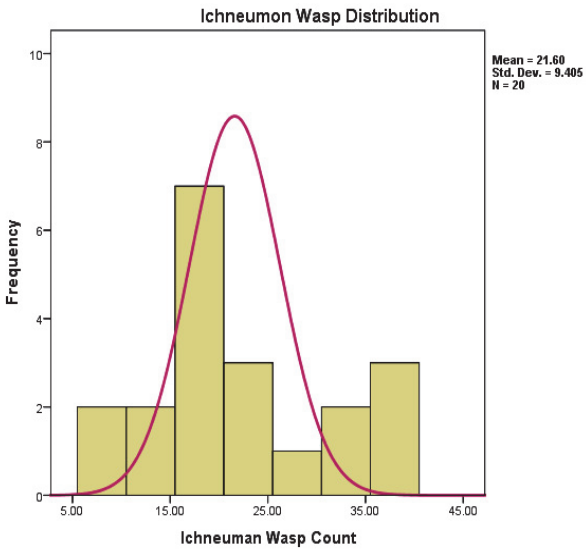

Fig. 3 Ichneumon wasp incidence recorded across the study areas

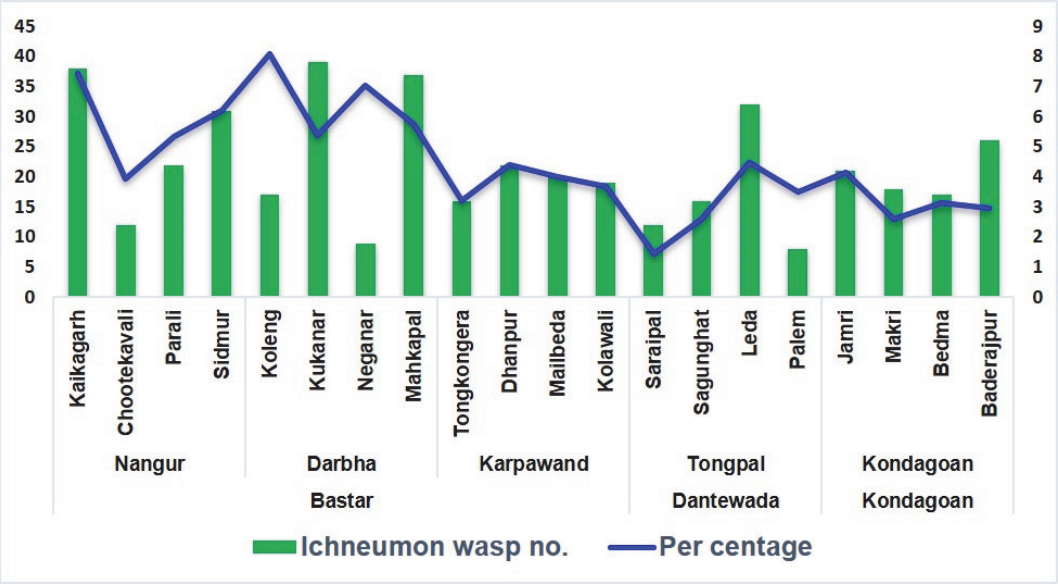

Fig. 4 Incidence and intensity of the wasp on tassar silk warm in diffrent districts of Chhattisgarh

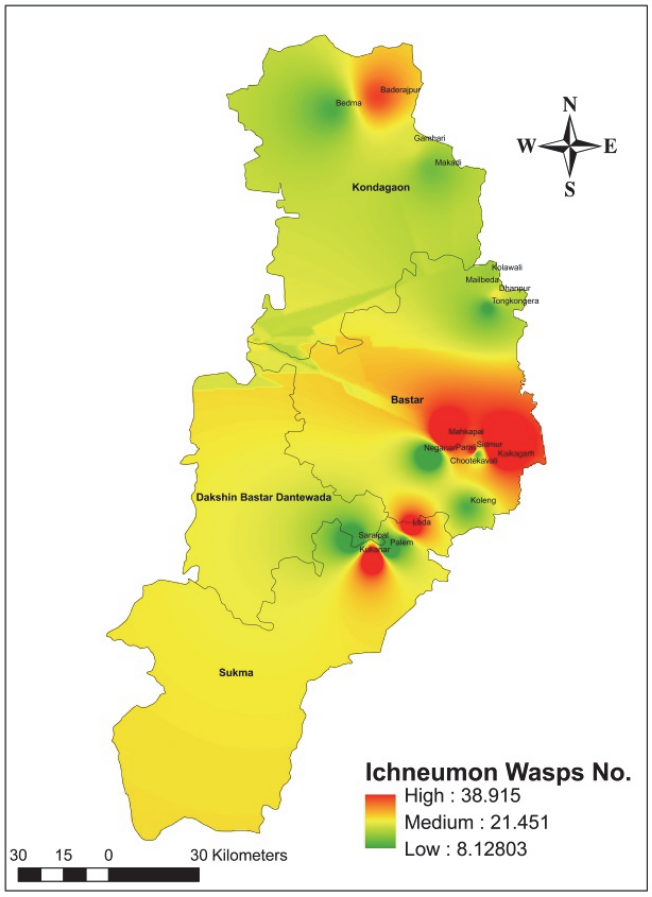

Fig. 5 Heat map showing the level of incidence of Ichneumon wasp across the study sites

tribal to make decisions for the effective conservation of Raily ecorace of tasar silkworm.

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Population dynamics of pod fly, *Melanagromyza obtusa* (Malloch) and its natural enemies on pigeonpea

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ABSTRACT: On pigeon pea pod fly infestation often noticed in the *Kharif* crop during 2022-23 and 2023-24, along with its other defoliating insects, although it persists up until the crop has been harvested. First appearance of *M. obtusa* larvae and pupa was observed in the 41st and 39th meteorological standard week (MSW). The peak larval population of 52.00 and 41.00 larvae per 100 pods was noticed in the 44th MSW at both years, while the peak pupal population of 49.00 and 40.00 pupae per 100 pods was seen during the 50th and 45th MSW. The study showed presence of two hymenopteran parasitoids viz., *Euderus lividus* (Ashmead) and *Ormyrus orientalis* (Walker) on the pigeon pea major pest, *Melanagromyza obtusa* (Malloch). The parasitism level of *E. lividus* declined from 31.82 to 10.53 and 29.72 to 7.14 per cent from 46th up to 52nd MSW and 45th up to 50th MSW, respectively. Higher pupal parasitism of *O. orientalis* was recorded in 47th (25.64%) and 44th (24.32%) MSW; While low parasitism was noted in 1st (3.22%) and 51st (3.84%) MSW at both years. Above all, correlation between weather parameters, with pod fly larvae and pupae showed that the larval population exhibited a significant positive relation with maximum temperature (r=0.646*) and (r=0.746**) at both years. The natural enemies, *E. lividus* and *O. orientalis* of *M. obtuse,* would improve the biological control of the pest population.

KEY WORDS: Hymenopteran parasitoids, *Euderus lividus, Ormyrus orientalis*, weather parameters, correlation

INTRODUCTION

Pigeon pea, *Cajanus cajan* (Millsp.) is the most significant and nutritious pulse (Sarkar *et al*., 2020). Pigeon pea is India's second-most significant pulse crop after gram and contributes to nearly ninety percent of the world's pigeon pea production. In India pigeon pea is cultivated in area of 5.05 million ha with an annual production of 4.34 million tonnes result on average yield is 859 kg per ha (Anonymous, 2022). The average yield per ha was 1014 kg in Punjab state (Anonymous, 2023). Pigeon pea associated bacteria benefit the soil through the symbiotic nitrogen fixation. This inclusion of pigeon pea in crop rotation aims to ensure the long-term preservation of soil health and fertility. Pigeon pea is a rich source of protein (21.71%), minerals (3.5%), and carbohydrate (57.6%) for vegetarian population Khamoriya *et al*. (2017).

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The pod fly, *Melanagromyza obtusa* (Malloch) (Diptera, Agromyzidae) is most obnoxious pest, leading to grain losses ranging from 20 to 80 percent due to its destructive impact (Sreekanth *et al*., 2020). Its infestation leads to significant loss of the pods and seeds of pigeon pea, resulting in reduced germination rate and rendering them unsuitable for human consumption or any other purpose (Hadiya *et al*., 2020). Pod fly oviposition occurs in tender pods and inner surface of the pods. The larvae feed on the seeds and pupate inside the pods Nair *et al*. (2017). Pod fly laid fewer eggs in December and January when temperatures are low. Pod fly population increases with temperature raise Chiranjeevi and Patange (2018). The female pod fly lays up to 80 eggs into maturing green pods. Such pods don't exhibit any visible signs of damage until the larvae emergence and same cause shot-holes in the pod walls upon maturity. Typically, one maggot requires only a single seed for its development Yadav *et al*. (2016). After hatching, the larva burrows into the pods and feeds upon tender seeds, rendering them unfit for both human consumption and further propagation. The pod fly, being an internal feeder, inhabits both larval and pupal stages within the pod wall, leaving behind a fragile papery membrane. Inside the pod, the larvae consume the developing seeds, followed by pupal development Patange *et al*. (2017). This perforation serves as an exit point for the adult flies as they emerge from the pod as described by Kumar *et al*. (2015). Egg phase typically ranges from 3 to 5 days followed by larval development duration of 6 to 11 days and further the pupal stage extends from 9 to 23 days. Yadav *et al*. (2020) also discovered that the adult insects have a lifespan of about 6 days without nourishment, but this extends to 12 days when they provided with food. Such newly emerged young ones are small and black colored. Dry pigeon pea pods exhibit one or more perforations on upper surface, indicating infestation. Seeds within infested pods appear desiccated, wrinkled, and partially consumed Sharma and Keval (2021). Various workers have established that more than 20 Hymenopteran parasitoids on this pest (Yadav and Yadav, 2011). The incidence of parasitism of *M. obtusa* was studied by several workers Yadav *et al*. (2012). Studies were undertaken to observe population dynamics of pod fly and its natural hymenopteran parasitoids, *Euderus lividus* (Ashmead, 1886) (larval ecto-parasitoid) belonging to Eulophidae and *Ormyrus orientalis* Walker, 1871 (larval-pupal endo-parasitoid) (Ormyridae) in Punjab state.

MATERIALS AND METHODS

The experiment was conducted at Experimental Research Farm of Lovely Professional University, Punjab, India during 2022-2023 and 2023-24 in a Randomized Block Design with seven treatments and three replications, to observe population dynamics of pod fly and its natural hymenopteran parasitoids. In Punjab state UPAS-120 variety of pigeon pea crop was cultivated in the mid of June with recommended agricultural practices by PAU, Ludhiana (Bisen *et al*., 2023). The variety is early sown high yield variety is not check in Punjab against pod fly. The pigeon pea variety UPAS-120 was grown in normal field condition by spacing 20 X 90 cm as per recommendation of PAU. No synthetic chemicals were applied to protect crop from natural incidence of pod fly and its parasitoids. The population of pod fly and parasitoids were weekly recorded from pod formation to maturity of crop. The immature stages (larval and pupal) along with its pod damage were counted on randomly collected 100 pods were plucked by selecting 5 plants at weekly interval in each replication (Tiwari *et al*., 2006; Yadav and Yadav, 2013). The healthy and damaged pods in pigeon pea crops were regularly monitored by dissecting each pod in the laboratory and placing them in glass vials (capacity of 30 ml) covered with muslin cloth. Larvae and pupae collected were kept at room temperature until the emergence of *M. obtusa* and various parasitoids. Number of pod fly larvae and pupae within each pod was recorded.

Correlations between the population of pod flies (larvae and pupae), parasitoids *E. lividus* and *O. orientalis* with various abiotic factors such as maximum temperature, minimum temperature, relative humidity and rainfall were worked out (Shankar *et al*., 2021). The pod fly infestation was

Table 1. Natural parasitoids associated with *Melanagromyza obtusa* (Malloch) during *Kharif*, 2022-23

SMW	Pod damage/ 100 pods	Larvae	Pupae	Emergence(%)		Temperature (°C)		Rh (%)		Rainfall (mm)
				E. lividus	*O. orientalis*	Max.	Min.	Max.	Min.	
41	29	16	10	0.00	0.00	32.00	23.00	59.00	43.00	0.00
42	42	27	28	0.00	0.00	31.00	20.00	56.00	46.00	0.00
43	56	34	30	11.76	0.00	29.00	18.00	53.00	43.00	0.00
44	78	52	32	17.31	9.37	34.00	19.00	56.00	42.00	0.00
45	69	47	28	25.53	17.86	24.00	18.00	59.00	49.00	0.20
46	79	44	41	31.82	21.95	28.00	13.00	52.00	47.00	0.00
47	72	48	39	22.91	25.64	28.00	19.00	81.00	76.00	0.00
48	65	36	42	25.00	21.43	25.00	11.00	89.00	77.00	0.00
49	70	41	45	12.19	13.33	26.00	9.00	89.00	61.00	0.00
50	68	32	49	18.75	8.16	25.00	10.00	97.00	65.00	0.00
51	57	22	46	13.64	4.35	24.00	9.00	90.00	79.00	0.00
52	43	19	27	10.53	3.70	21.00	9.00	98.00	88.00	2.00
1	31	11	31	0.00	3.22	12.00	6.00	98.00	86.00	0.00
2	17	5	8	0.00	0.00	12.00	10.00	94.00	86.00	0.00

*No incidence of pod fly on pigeonpea crop at 3rd Standard Meteorological Week of 2022-23

calculated during maturity stage. Correlation analysis by OPSTAT software. As a result, the information on parasitoids emerging from the host fly stages (larvae and pupae of *M. obtusa*) was appropriately processed to determine the percentage of parasitism and interpret the results. The following formula is used to find the percentage of parasitism Patange *et al*. (2017).

RESULTS AND DISCUSSION

During the kharif crop 2022-23 and 2023-24 the incidence of pest started with the development of pod and continued to the maturity throughout the reproductive stage of crop. The larval population was started at 16.00 and 14.00 larvae per 100 pods during the 41st and 39th SMW of both years which increased at peak level 52.00 and 41.00 larvae per 100 pods by the 44th SMW at that time maximum temperature of 34.00 and 31.32 °C, while minimum temperature of 19.00 and 13.30 °C, maximum relative humidity of 56.00 and 94.01 percent and minimum relative humidity of 42.00 and 45.82

Table 2. Correlation between the population of pod fly with weather parameters 2022-23.

factor	Temperature °C		RH (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
Damage Pods	0.550*	0.116	-0.276	-0.360	-0.161
Larvae	0.646*	0.380	-0.472	-0.515	-0.203
Pupae	0.198	-0.370	0.217	0.075	-0.140
E. lividus	0.313	0.018	-0.186	-0.160	-0.049
O. orientalis	0.194	0.021	-0.051	0.003	-0.146

* = significant at 5% level

percent. Eventually, the larval population decreased to 5.00 and 9.00 larvae in the 2nd and 52nd SMW. The pupal population of *M. obtusa* (10.00 and 7.00 pupae/ 100 pods) was observed from the 41st and 40th SMW; Which showed increasing trend, progressively, peaked at 49.00 and 40.00 pupae per 100 pods on the 50th and 45th SMW at maximum temperature of 25.00 and 29.00 °C, minimum temperature of 10.00 and 13.57 °C, maximum relative humidity of 97.00 and 93.23 percent, minimum relative humidity of 65.00 and 47.22 percent and rainfall of 0.60 mm (in 2023-24). When the temperature was very low then population decreased to 8.00 and 14.00 pupae in the 2nd and 1st SMW. Pod damage symptoms appeared on the 41st and 39th SMW in 29 and 25 percent. Increased gradually pod damage peaked on the 46th (79%) and 44th (73%) SMW with maximum temperature of 28.00 and 34.30 °C, minimum temperature of 23.00 and 19.96 °C, maximum relative humidity of 59 and 92.65 and minimum of 43.00 and 65.50 percent then population declined to 17 and 19 percent on the 2nd and 1st SMW of both years (Table 1, 3).

The findings from the current study regarding the population dynamics of the pod fly, *M. obtusa* and its impact on pigeon pea align closely with the reports of Pillai and Agnihotri (2013), indicating the highest activity of the pod fly occurred around the 46th SMW, whereas the lowest population of *M. obtusa* (31 per 100 pods) during the 49th standard week. Similarly, Patange *et al*. (2017) reported that the pod fly was first time noticed in the 48th SMW, while pods (26.00%) infestation with larvae and pupae were observed during that period. According to Chiranjeevi and Patange (2018) found that the larvae of the pod fly were initially detected during the 44th SMW with an infestation rate of 11.00 larvae, reaching a peak of 125.00 larvae during the 3rd SMW; and the larval parasitism level of pod fly from 43rd and 41st SMW on the 11.76 and 4.17 percent, which increased at 46th and 45th SMW with 31.82 and 29.72.

The pupal parasitization of *M. obtusa* was identified during 44th SMW (9.37%) and 42nd SMW (11.53%), which increased gradually until reach a peak stage i.e. 25.64 and 24.32 percent with 47th and 44th SMW during both years with maximum temperature of 28.00 and 31.32 °C, minimum temperature of 19.00 and 13.30 °C, maximum relative humidity of 81.00 and 94.01, minimum relative humidity of 76.00 and 45.82 percent. Along with decrease in temperature, the percentage of pupal population also decreased in 1st SMW with 3.22 percent. similarly next year 2023-24, the percentage of pupal population also decreased in 51st SMW with 3.84 percent with decreased in temperature. The pupal parasitization level was observed nil during the 2nd and 52nd SMW of 2022-23 and 2023-24 (Table 1, 3). According to Chakravarty *et al*. (2016), noted the presence of *O. orientalis* on pod flies. The highest natural

Table 3. Natural parasitoids associated with *Melanagromyza obtusa* (Malloch) during *Kharif*, 2023-24

SMW	Pod damage/ 100 pods	Larvae	Pupae	% of Emergence		Temperature (°C)		Rh (%)		Rainfall (mm)
				E. lividus	*O. orientalis*	Max.	Min.	Max.	Min.	
39	25	14	0	0.00	0.00	34.30	19.96	92.65	65.50	0.00
40	32	26	7	0.00	0.00	34.03	17.42	92.38	51.33	0.20
41	41	27	13	4.17	0.00	32.51	16.32	92.81	45.53	0.00
42	43	29	26	13.79	11.53	28.31	13.12	92.79	51.68	0.80
43	52	35	30	22.85	23.33	31.16	12.36	92.95	35.87	0.00
44	73	41	37	24.39	24.32	31.32	13.30	94.01	45.82	0.00
45	65	37	40	29.72	22.50	29.05	13.57	93.23	47.22	0.60
46	61	30	32	23.33	18.75	27.06	10.20	93.84	49.26	0.00
47	53	22	37	9.09	10.81	26.70	7.38	92.48	40.96	0.20
48	40	21	28	0.00	17.85	22.70	10.10	91.20	59.70	0.20
49	44	17	34	11.76	8.82	23.33	9.44	94.00	47.00	0.00
50	33	14	25	7.14	4.00	20.55	7.77	94.00	52.00	0.00
51	34	8	26	0.00	3.84	21.11	6.66	97.00	57.00	0.00
52	21	9	21	0.00	0.00	16.66	10.55	95.00	74.00	0.00
1	19	0	14	0.00	0.00	10.00	7.22	94.00	87.00	0.00
2	0	0	0	0.00	0.00	11.11	5.55	94.00	80.00	0.00

* No incidence of pod fly on pigeonpea crop at 2nd Standard Meteorological Week of 2023-24
(The Meteorology Department of Lovely Professional University, Punjab Meteorological data)

parasitization percentage (17.39%) of *M. obtusa* by these parasitoids occurred during the 51st MSW at maturity stage of crop. These results are in accordance with Chiranjeevi and Patange (2018) documented the initial observation of larval and pupal parasitization during the 46th (SMW) by *E. lividus* (41.18%) and *O. orientalis* (18.75%) with observed during the 48th MSW. Yadav *et al*. (2020) reported that parasitization in the pod fly ranged between from 14.28 to 25.71 per cent. There was an increase in parasitization during the first fortnight of March, reaching its peak at 25.71 per cent.

The correlation between abiotic factors and pod fly, ratios of larval, pupal population, indicate (Table 2, 4) that the damaged pods showed a maximum positive correlation (r=0.550*) with the maximum temperature in 2022-2023. Conversely, the relative humidity had a significant negative correlation (r=0.744**) with maximum temperature in 2023-2024. The findings were similar for the larval population of pod fly in 2022-2023 (r=0.646*), indicating a significant positive correlation with the maximum temperature. However, in 2023-2024 there was an even significant positive correlation

Table 4. Correlation between the population of pod fly with weather parameters 2023-24.

factor	Temperature °C		RH (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
Damage pods	0.482	0.027	-0.149	-0.744**	0.246
Larvae	0.746**	0.420	-0.403	-0.776**	0.376
Pupae	-0.091	-0.541*	0.127	-0.513	0.245
E. lividus	0.360	0.035	-0.055	-0.612*	0.303
O. orientalis	0.287	-0.084	-0.219	-0.564*	0.276

* = significant at 5% level

(r=0.746**) between both years. Similar type of results was also reported by Chakravarty *et al*. (2016) it revealed that there was a positive significant correlation with maximum temperature (r=0.746*). While according to, Yadav *et al*. (2011) observed that the larval population began to increase when the maximum temperature fell below 32°C, reaching its highest point before subsequently decreasing. In the 2022-23 year, the pupal population of pod flies had non-significant positive correlation (r=0.198) with the maximum temperature, but in the following year, 2023-24 there was negative significant correlation (r=-541*) with minimum temperature. Patange and Chiranjeevi (2017) reported that the data analysis revealed a moderate negative correlation (r=-0.4387) between the pupal population of *M. obtusa* and the maximum temperature. Whenever temperature rises, there is a decrease in the pupal population of pod fly. During 2022–2023, larval parasitization (*E. lividus*) of pod fly was showed non-significant positive correlation (r=0.313) with maximum temperature. However, in 2023-24 there was a showed negative correlation (r=-0.612*) with the minimum relative humidity. The pupal parasitization (*O. orientalis*) of pod flies exhibited a non-significant correlation (r=0.194) with the maximum temperature of 2022-2023. While, the pupal population of pod fly in 2023–24 demonstrated a negative significant connection (r=-0.564*) between the minimum relative humidity. The study is according to previous researcher Yadav *et al.* (2012), which identified four species of hymenopteran parasitoids namely *E. lividus*, *O. orientalis*, *Eurytoma* sp and *Pseudotorymus* sp. Makinson *et al*. (2005) conducted the initial rearing of two parasitoids, namely *Callitula* sp. (Hymenoptera, Pteromalidae) and *Ormyrus* sp. (Hymenoptera, Ormyridae) from *M. obtusa* found on *Cajanus latisepalus* pods in Australia. The current results align that those reported by Dar *et al*. (2005) indicating that *O. orientalis*, a parasitoid species was identified as the primary parasitoid of the pod fly. The current results partially coincide with the research conducted by Chakravarty *et al*. (2016), where it was shown that *E. lividus* and *O. orientalis* was detected in association with pod fly. The highest natural parasitization rate (31.82 and 25.64%) of *M. obtusa* by these parasitoids occurred during the 46th and 47th SMW period. It is concluded that the emergence of two parasitoids of *M. obtusa* (Malloch) viz., *E. lividus* (31.82%) and *O. orientalis* (25.64%) are effective to reduce pod fly population.

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Termites (Isoptera) of Kerala: An updated checklist and comprehensive review of species diversity

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ABSTRACT: This paper presents a comprehensive checklist of termites found in Kerala, including their district-wise distribution. A total of 93 species from three families and 34 genera are documented. Among these, Termitidae emerges as the dominant family, encompassing 76 species from 27 genera across four subfamilies. The recent additions to the termite fauna of Kerala include the endemic species *Ceylonitermellus sahyadriensis* Ranjith and Kalleshwaraswamy 2022 and *Prorhinotermes cotym* Joseph, Amina, and Mathew 2023. Notably, the subfamily Termitinae exhibits the highest level of endemism.

KEYWORDS: Distribution, endemism, Termitidae, Termitinae

INTRODUCTION

Termites, often overlooked in biodiversity, constitute a fascinating and diverse group of insects that play crucial roles in ecosystems worldwide. Despite their small size, termites maintain significant ecological influence, primarily as decomposers, soil engineers, and contributors to nutrient cycling. There are over 2,942 described living species belonging to 283 genera and 9 families distributed globally (Krishna *et al.,* 2013; Rajmohana *et al.,* 2019; Amina *et al.,* 2022). This diversity spans a range of ecosystems, from tropical rainforests to arid deserts, highlighting the adaptability and resilience of termites. These social insects form complex colonies, exhibiting intricate caste systems and cooperative behaviors that have evolved over millions of years (Krishna *et al.,* 2013). Preserving fauna is crucial in the present moment, activities such as deforestation, urbanization, and other human-induced changes may lead to a reduction in termite diversity (Kalleshwaraswamy *et al.,* 2018). The variety and number of termite species are influenced by land use and human interventions that modify the environment. Ants and termites, much like earthworms, serve essential ecological functions and offer valuable ecosystem services (Evans *et al.,* 2011). Studying termite diversity not only unveils the intricacies of their biology but also sheds light on the broader ecological interdependencies that sustain diverse ecosystems globally (Kalleshwaraswamy *et al.,* 2018). Although termites are quite diverse in India, more than 10 per cent of the world's termite fauna is shared by Indian termites i.e., approximately 314 species, 53 genera, and six families (Baraik *et al.,* 2024). König (1779) conducted the first-ever taxonomic study on termites in southern India and the last checklist

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was done by Mathew (2015) who reported 58 species from Kerala along with their pest status. The present study attempts to provide an updated list of termite species in Kerala, which should act as a foundation for future taxonomic research.

MATERIALS AND METHODS

Kerala, a state in southwestern India, is characterized by its diverse and unique geological features. Situated between the Western Ghats and the Arabian Sea, Kerala's geographical coordinates range from approximately 8°18' and 12°48' N latitude to 74°52' and 77°22' E longitude. The state's topography is heavily influenced by the Western Ghats, which contribute to the region's rich biodiversity and play a crucial role in the state's climate patterns. The climate is hot and humid or cold with 25-32^{0}C temperature during the hot season and 23-30^{0}C in the cool season. Kerala receives 2,923 mm of rain annually, which benefits various termites.

This checklist has primarily been based on existing literature. The classification is based on the findings of Krishna *et al.* (2013). Each species listed in the checklist includes information presented in the following sequence: name of the family, name of the genus, name of the species, Synonyms, and distribution in Kerala. The compilation of this list was done using original descriptions and based on published works by Roonwal and Chhotani (1989), Chhotani (1997), Krishna *et al.,* (2013), Amina *et al*., (2016, 2016a, 2016b, 2020, 2021, 2022), Amina and Rajmohana (2013, 2021) and Ranjith and Kalleshwaraswamy (2021).

RESULTS

The checklist documenting the three termite families and 93 species reported from Kerala, along with their district-wise distribution, is specified here. Among the reported species, Termitidae Latreille, 1802 emerges as the dominant family, consisting of 76 species across four subfamilies. The family Termitidae also exhibits the highest level of generic diversity, comprising 27 genera. This is followed by Kalotermitidae Froggat, 1897, which includes five genera, and Rhinotermitidae Froggat, 1897, with three genera. Within the dominant family Termitidae, the genus *Odontotermes* Holmgren, 1910b, belonging to the subfamily Macrotermitinae, demonstrates high species diversity (17 species). This is followed by the genus *Dicuspiditermes* Krishna, 1968, and the genus *Microcerotermes* Silvestri, 1901, both from the subfamily Termitinae, each with seven species. The endemism of termites in Kerala is notable, with 41 out of the 93 species (44.08%) and six out of 34 documented genera (17.64%) found to be endemic to South India. Furthermore, the degree of species endemism and generic endemism is notably high in the subfamily Termitinae, which comprises 18 endemic species and 4 endemic genera.

Checklist of Termites of Kerala

Family 1: Kalotermitidae Froggatt, 1897; Genus *Cryptotermes* Banks, 1906

1. *Cryptotermes domesticus* (Haviland, 1898)

Synonyms**:** *Calotermes domesticus* Haviland, 1898; *Calotermes (Cryptotermes) formosae* Holmgran, 1912; *Calotermes (Cryptotermes) kotoensis* Oshima, 1912; *Calotermes (Cryptotermes) ogasawarensis* Oshima,1913; *Calotermes (Cryptotermes) dentatus* Oshima,1914; *Cryptotermes campbelli* Light, 1924; *Cryptotermes hermsi* Kirby, 1925; *Calotermes (Cryptotermes) buxtoni* Hill, 1926; *Calotermes (Cryptotermes) gulosus* Hill, 1927; *Calotermes (Cryptotermes) repentinus* Hill, 1927; *Cryptotermes lignarius* Jepson, 1931; *Cryptotermes tectus* Jepson, 1931.

Distribution**:** Trivandrum (Roonwal and Chhotani 1989; Krishna *et al.,* 2013; Mathew 2015).

2. *C. dudleyi* Banks, 1918

Synonyms: *Calotermes havilandi arasite* Wasmann, 1910; *Calotermes (Cryptotermes) jacobsoni* Holmgren, 1913c; *Planocryptotermes nocens* Light, 1921b; *Cryptotermes thompsonae* Snyder, 1922; *Cryptotermes (Planocryptotermes) primus* Kemner, 1932; *Cryptotermes (Planocryptotermes) javanicus* Kemner, 1934; *Cryptotermes melloi* Chhotani, 1970.

Distribution**:** Kozhikode, Wayanad, Kannur (Roonwal and Chhotani 1989; Amina and Rajmohana, 2014).

3. *C. roonwali* Chhotani, 1970

Distribution: Kannur (Chhotani 1970; Krishna *et al.,* 2013; Mathew 2015)

Genus *Glyptotermes* Froggatt, 1897

4. *Glyptotermes chiraharitae* Amina and Rajmohana, 2016

Distribution**:** Kozhikode (Amina and Rajmohana, 2016)

5. *G. coorgensis* (Holmgren and Holmgren, 1917)

Synonym**:** *Calotermes (Glyptotermes) coorgensis* Holmgren and Holmgren, 1917.

Distribution**:** Palakkad (Holmgren and Holmgren 1917; Bose 1984; Roonwal and Chhotani 1989; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Amina and Rajmohana 2014; Mathew 2015).

6. *G. ceylonicus* (Holmgren,1911)

Distribution**:** Kottayam (Joseph *et al.,* 2022).

Genus *Neotermes* Holmgren, 1911

7. *Neotermes fletcheri* (Holmgren and Holmgren, 1917)

Synonym**:** *Calotermes* (*Neotermes*) *fletcheri* Holmgren and Holmgren, 1917

Distribution**:** Kerala.

8. *N. keralai* Roonwal and Verma, 1972

Distribution**:** Trivandrum (Roonwal and Verma 1972; Bose 1984; Roonwal and Chhotani 1989; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015)

9. *N. nilamburensis* Thakur, 1978

Distribution: Malappuram (Thakur 1978; Bose 1984; Roonwal and Chhotani 1989; Krishna *et al.,* 2013; Mathew 2015)

Genus *Postelectrotermes* Krishna 1961

10. *Postelectrotermes bhimi* Roonwal and Maiti, 1965

Distribution**:** Kottayam (Roonwal and Maiti 1965; Bose 1984; Roonwal and Chhotani 1989; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015)

11. *P. nayari* Roonwal and Verma, 1971

Distribution**:** Trivandrum (Roonwal and Verma 1971; Bose 1984; Roonwal and Chhotani 1989; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015).

Family 2: Rhinotermitidae Froggat, 1897; Subfamily Coptotermitinae Holmgren, 1910; Genus *Coptotermes* Wasmann, 1896

12. *Coptotermes beckeri* Mathur and Chhotani, 1969

Distribution**:** Kozhikode (Mathur and Chhotani 1969; Bose 1984; Roonwal and Chhotani 1989; Maitii 2006; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Amina *et al.,* 2016).

13. *C. ceylonicus* Holmgren, 1911

Distribution: Trivandrum, Thrissur (Roonwal and Chhotani 1989; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015).

14. *C. heimi* (Wasmann, 1902)

Synonyms: *Arrhinotermes heimi* Wasmann, 1902; *Coptotermes parvulus* Holmgren, 1913b.

Distribution**:** Idukki, Ernakulam (Bose 1984; Varma and Swaran 2007; Mathew 2015)

15. *C. kishori* Roonwal and Chhotani, 1962

Distribution: Kerala (Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015)

Subfamily Heterotermitinae Froggat, 1897; Genus *Heterotermes* Froggat, 1897

16. *Heterotermes indicola* (Wasmann, 1902)

Synonym**:** *Leucotermes indicola* Wasmann, 1902.

Distribution**:** Malappuram, Kasaragod (Poovoli and Rajmohana 2013; Mathew 2015)

17. *H. malabaricus* Snyder, 1933

Distribution**:** Kottayam, Palakkad, Malappuram (Krishna *et al.,* 2013; Mathew 2015; Velayuthan *et al.,* 2022)

Subfamily Prorhinotermitinae Quennedey and Deligne, 1975; Genus *Prorhinotermes S*ilvestri, 1909

18. *Prorhinotermes cotym* Joseph, Amina and Mathew, 2023

Distribution**:** Kottayam (Joseph *et al.,* 2023a)

Family 3: Termitidae Latreille, 1802; Subfamily Apicotermitinae Grassé and Noirot, 1955; Genus *Euhamitermes* Holmgren, 1912

19. *Euhamitermes chhotani* Maitii, 1983

Distribution: Malappuram (Chhotani 1997; Ranjith *et al.,* 2023)

Genus *Eurytermes* Wasmann, 1902

20. *Eurytermes topslipensis* (Chaterjee and Thapa, 1963)

Synonym**:** *Beesonitermes topslipensis* Chaterjee and Thapa, 1963.

Distribution: Wayanad (Nair and Varma,1985)

Genus *Speculitermes* Wasmann, 1902

21. *Speculitermes chadaensis* Chaterjee and Thapa, 1964

Distribution: Wayanad, Thrissur (Amina *et al.,* 2016a).

22. *S. emersoni* Bose, 1984

Distribution: Idukki (Bose 1984; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

23. *S. sinhalensis* Roonwal and Sen-Sarma, 1960

Synonym: *Speculitermes cyclops sinhalensis* Roonwal and Sen-Sarma, 1960.

Distribution in Kerala**:** Kottayam, Ernakulam, Wayanad (Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015; Kalleshwaraswamy *et al.,* 2018).

Subfamily Termitinae Latreille, 1802; Genus *Angulitermes* Sjöstedt, 1924

24. *Angulitermes acutus* Mathur and Sen-Sarma, 1961

Distribution**:** Palakkad (Amina and Rajmohana 2021).

25. *A. keralai* Verma, 1984

Distribution: Thrissur (Verma 1984; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

Genus *Dicuspiditermes* Krishna, 1968

26. *Dicuspiditermes achankovili* Verma, 1985

Distribution**:** Kollam, Kottayam, Ernakulam (Verma 1985; Chhotani 1997; Varma and Swaran 2007; Krishna *et al.,* 2013; Mathew 2015).

27. *D. gravelyi* (Silvestri, 1922)

Synonyms: *Capritermes gravelyi* Silvestri, 1922.

Distribution**:** Kozhikode, Wayanad (Bose 1984; Chhotani 1997; Krishna *et al.,* 2013; Amina *et al.,* 2016b).

28. *D. hustoni* (Kemner, 1926)

Synonyms**:** *Capritermes hutsoni* Kemner,1926; *Dicuspiditermes hutsoni* (Kemner, 1965).

Distribution**:** Wayanad (Amina *et al.,* 2021)

29. *Dicuspiditermes incola* (Wasmann, 1893)

Synonyms**:** *Eutermes incola* Wasmann, 1893; *Capritermes longicornis* Wasmann, 1902; *Dicuspiditermes fletcheri* (Holmgren and Holmgren, 1917); *Dicuspiditermes pername* Thakur and Chatterjee, 1971.

Distribution: Malappuram, Wayanad (Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

30. *D. obtusus* (Silvestri, 1923)

Synonyms: *Capritermes obtusus* Silvestri, 1923; *Capritermes obtusus bbreviates* Silvestri, 1923.

Distribution: Ernakulam, Palakkad, Wayanad (Amina and Rajmohana 2021).

31. *D. sisiri* Chhotani, 1997

Distribution**:** Palakkad (Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

32. *D. leghugathrae* Amina and Rajmohana, 2021

Distribution**:** Palakkad (Amina *et al.,*2021).

Genus *Homallotermes* John, 1925

33. *Homallotermes pilosus* (Mathur and Thapa, 1962)

Synonym: *Microcapritermes pilosus* Mathur and Thapa, 1962.

Distribution: Idukki (Mathur and Thapa 1962; Bose 1984; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

Genus *Indocapritermes* Chhotani, 1997

34. *Indocapritermes aruni* Chhotani, 1997

Distribution: Palakkad (Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

Genus Krishnacapritermes Chhotani, 1997

35. *Krishnacapritermes dineshan* Amina and Rajmohana, 2020

Distribution: Idukki (Amina *et al.,* 2020)

36. *K. maitii* Chhotani, 1997

Distribution**:** Idukki (Krishna *et al.,* 2013; Amina *et al.,* 2020).

37. *K. manikandan* Amina and Rajmohana, 2020

Distribution**:** Idukki (Amina *et al.,* 2020).

38. *K. thakuri* Chhotani, 1997

Synonym**:** *Pericapritermes travancorensis* Mathew and Ipe, 2018.

Distribution: Trivandrum, Kollam, Kottayam, Thrissur, Palakkad (Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015; Amina *et al.,* 2020).

Genus *Labiocapritermes* Krishna, 1968

39. *Labiocapritermes distortus* (Silvestri, 1922)

Synonyms**:** *Capritermes distortus* Silvestri, 1922; *Pericapritermes vythirii* Verma, 1983.

Distribution**:** Thrissur (Silvestri 1922; Verma 1983; Bose 1984; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

Genus *Microcerotermes* Silvestri, 1901

40. *Microcerotermes beesoni* Snyder, 1933

Synonyms**:** *Microcerotermes championi* Snyder, 1933a; *Microcerotermes lanceolatus* Mathur and Thapa, 1965.

Distribution: Kozhikode (Amina and Rajmohana 2014; Mathew 2015).

41. *M. cameroni* Snyder, 1934

Distribution: Ernakulam (Snyder 1934; Bose 1984; Chhotani 1997; Krishna *et al.,* 2013; Shanbhag and Sundararaj, 2013; Mathew 2015).

42. *M. fletcheri* Holmgren and Holmgren, 1917

Distribution**:** Thiruvananthapuram, Idukki, Ernakulam, Malappuram (Chhotani 1997; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Amina and Rajmohana 2014; Mathew *et al.,* 2015).

43. *M. heimi* Wasmann, 1902

Distribution**:** Kerala (Mathew 2015).

44. *M. minor* Holmgren, 1914

Distribution**:** Wayanad (Chhotani 1997; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Amina *et al.,* 2016b).

45. *M. pakistanicus* Akhtar, 1974

Distribution**:** Kottayam (Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015; Harit *et al.,* 2021).

46. *M. lahorensis* Akthar, 1972

Distribution**:** Kottayam (Joseph *et al.,* 2023).

Genus *Pericapritermes* Silvestri, 1914

47. *Pericapritermes dunensis* (Roonwal and SenSarma, 1960)

Distribution**:** Pathanamthitta, Idukki, Ernakulam (Amina and Rajmohana 2021)

48. *P. travancorensis* Mathew and Ipe, 2018

Distribution: Kottayam (Mathew and Ipe, 2018)

49. *P. topslipensis* Thakur, 1976

Distribution: Kottayam (Krishna *et al.,* 2013; Amina and Rajmohana 2021).

Genus *Procapritermes* Holmgren, 1912

50. *Procapritermes dakshinae* (Chhotani and Ferry, 1995)

Synonym**:** *Malaysiocapritermes dakshinae* Chhotani and Ferry, 1995.

Distribution**:** Trivandrum (Chhotani and Ferry 1995; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

51. *P. keralai* (Chhotani and Ferry, 1995)

Synonym**:** *Malaysiocapritermes keralai* Chhotani and Ferry, 1995.

Distribution**:** Ernakulam (Chhotani and Ferry 1995; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

Genus *Pseudocapritermes* Kemner, 1934

52. *Pseudocapritermes fletcheri* (Holmgren and Holmgren, 1917)

Synonyms: *Capritermes fetcheri* Holmgren and Holmgren, 1917; *Pseudocapritermes fontanellus* Mathur and Thapa, 1961; *Pseudocapritermes goanicus* Thakur and Chatterjee, 1969; *Pseudocapritermes roonwali* Verma, 1985a.

Distribution: Wayanad (Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

53. *P. kunjepu* Mathew, 2020.

Distribution: Kottayam (Ipe *et al.,* 2020).

Genus *Rinacapritermes* Amina and Rajmohana, 2022

54. *Rinacapritermes abundans* Amina and Rajmohana, 2022

Distribution: Kottayam, Kozhikode, Wayanad (Amina *et al.,* 2022).

55. *Rinacapritermes silvius* Amina and Rajmohana, 2022.

Distribution: Kottayam, Idukki, Ernakulam, Kozhikode, Wayanad (Amina *et al.,* 2022).

Genus *Synhamitermes* Holmgren, 1912

56. *Synhamitermes quadriceps* (Wasmann, 1902)

Synonyms**:** *Amitermes quadriceps* Wasmann, 1902.

Distribution: Thrissur (Chhotani 1997; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015).

Subfamily Macrotermitinae Kemner, 1934; Genus *Hypotermes* Holmgren, 1913

57. *Hypotermes obscuriceps* (Wasmann, 1902)

Synonyms: *Termes obscuriceps* Wasmann, 1902; *Odontotermes (Hypotermes) marshalli* Kemner, 1926.

Distribution**:** Kerala (Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013).

58. *H. xenotermits* (Wasmann, 1896)

Synonyms: *Termes xenotermits* Wasmann, 1896; *Hypotermes nongpriangi* Roonwal and Sen-Sarma, 1956.

Distribution: Kozhikode (Poovoli and Rajmohana 2019).

Genus *Macrotermes* Holmgren, 1909

59. *Macrotermes convulsionarius* (König, 1779)

Synonyms**:** *Termes convulsionarii* König, 1779; *Termes estherae* Desneux, 1908.

Distribution: Trivandrum (Chhotani 1997; Rao *et al.,* 2012; Krishna *et al.,* 2013; Mathew 2015).

Genus *Microtermes* Wasmann, 1902

60. *Microtermes obesi* Holmgren, 1912

Synonyms: *Microtermes anandi* Holmgren, 1913b; *Microtermes anandi curvignathus* Holmgren, 1913b.

Distribution**:** Thrissur, Malappuram (Chhotani 1997; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015).

61. *M. unicolor* Snyder, 1933

Synonyms**:** *Microtermes pubescens* Snyder, 1933b.

Distribution: Wayanad (Amina *et al.,* 2016b).

Genus *Odontotermes* Holmgren, 1910

62. *Odontotermes anamallensis* Holmgren and Holmgren, 1917

Synonyms: *Odontotermes (Odontotermes) anamallensis* Holmgren and Holmgren, 1917.

Distribution: Ernakulam, Palakkad, Malappuram, Kozhikode (Chhotani 1997; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015; Bhavana *et al.,* 2015; Velayuthan *et al.,* 2022).

63. *O. assmuthi* Holmgren, 1913

Synonym: *Odontotermes (Odontotermes) assmuthi* Holmgren, 1913b.

Distribution**:** Kottayam, Ernakulam, (Chhotani 1997; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015)

64. *O. bellahunisensis* Holmgren and Holmgren, 1917

Synonyms**:** *Odontotermes (Cyclotermes) bellahunisensis* Holmgren and Holmgren, 1917.

Distribution**:** Palakkad, Kannur (Bose 1984; Chhotani 1997; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015; Velayuthan *et al.,* 2022)

65. *O. brunneus* (Hagen, 1858)

Synonyms: *Termes (Termes) brunneus* Hagen, 1858; *Odontotermes mathadi* Roonwal and Chhotani, 1964a.

Distribution: Palakkad (Chhotani 1997; Rao *et al.,* 2012; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015; Velayuthan *et al.,* 2022).

66. *O. ceylonicus* (Wasmann, 1902)

Synonyms: *Termes ceylonicus* Wasmann, 1902; *Odontotermes meturensis* Roonwal and Chhotani, 1959.

Distribution: Ernakulam, Thrissur, Palakkad, Malappuram (Chhotani 1997; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015; Velayuthan *et al.,* 2022).

67. *O. escherichi* (Holmgren, 1911)

Synonym: *Termes escherichi* Holmgren, 1911a.
Distribution: Kerala (Krishna *et al.,* 2013; Mathew, 2015)

68. *O. feae* (Wasmann, 1896)

Synonyms: *Termes feae* Wasmann, 1896; *Odontotermes indicus* Thakur, 1981.

Distribution: Kollam, Thrissur, Ernakulam, Palakkad, Malappuram (Chhotani 1997; Rao *et al.,* 2012; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015).

69. *O. globicola* (Wasmann, 1902)

Synonyms: *Microtermes globicola* Wasmann, 1902; *Termes (Termes) dehraduni* Snyder, 1933b; *Odontotermes roonwali* Bose, 1975.

Distribution: Palakkad, Malappuram (Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015; Velayuthan *et al.,* 2022).

70. *O. guptai* Roonwal and Bose, 1961

Synonyms**:** *Odontotermes bellahunisensis guptai* Roonwal and Bose, 1961; *Odontotermes lokanandi* Chaterjee and Thakur, 1967.

Distributon**:** Ernakulam, Thrissur (Chhotani 1997; Rao *et al.,* 2012; Krishna *et al.,* 2013; Mathew 2015; Varma and Swaran 2007).

71. *O. horni* (Wasmann, 1902)

Synonyms**:** *Termes ho*rni Wasmann, 1902; *Termes peradeniyae* Holmgren, 1911b; *Odontotermes horni hutsoni* Kemner, 1926; *Odontotermes horni minor* Kemner, 1926.

Distribution: Ernakulam, Palakkad, Malappuram, Kannur (Chhotani 1997; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015; Varma and Swaran 2007; Velayuthan *et al.,* 2022).

72. *O. malabaricus* Holmgren and Holmgren, 1917

Synonym: *Odontotermes (Odontotermes) malabaricus* Holmgren and Holmgren, 1917.

Distribution: Malappuram (Holmgren and Holmgren 1917; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

73. *O. microdentatus* Roonwal & Sen-Sarma, 1960

Distribution: Kerala (Krishna *et al.,* 2013; Mathew 2015)

74. *O. obesus* (Rambur, 1842)

Synonyms: *Termes obesus* Rambur, 1842; *Termes fatalis* König, 1779; *Odontotermes (Cyclotermes) bengalensis* Holmgren, 1912a; *Odontotermes (Cyclotermes) assamensis* Holmgren, 1913c; *Odontotermes (Cyclotermes) bangalorensis* Holmgren, 1913c; *Odontotermes (Cyclotermes) favomaculatus* Holmgren and Holmgren, 1917; *Odontotermes (Cyclotermes) obesus oculatus* Silvestri, 1923b; *Termes (Cyclotermes) orissae* Snyder, 1934; *Termes obesus assmuthi* Van Boven, 1969.

Distribution: Ernakulam, Palakkad, Malappuram, Wayanad (Chhotani 1997; Rao *et al.,* 2012; Krishna *et al.,* 2013; Mathew 2015; Bhavana *et al.,* 2015).

75. *O. redemanni* (Wasmann, 1893)

Synonym**:** *Termes redemanni* Wasmann, 1893

Distribution: Idukki, Palakkad, Malapuram (Chhotani 1997; Rao *et al.,* 2012; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015; Velayuthan *et al.,* 2022).

76. *O. vaishno* Bose, 1975

Distribution: Palakkad, Kozhikode, Wayanad (Bose 1975, 1984; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015; Velayuthan *et al.,* 2022).

77. *O. wallonensis* (Wasmann, 1902)

Synonyms: *Termes obesus wallonensis* Wasmann, 1902; *Odontotermes brunneus kushwahai* Roonwal and Bose, 1964.

Distribution: Palakkad (Bose 1984; Chhotani 1997; Rao *et al.,* 2012; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015; Velayuthan *et al.,* 2022).

78. *O. yadevi* Thakur, 1981

Distribution**:** Palakkad, Kozhikode, Wayanad (Thakur 1981; Chhotani 1997; Krishna *et al.,* 2013; Amina *et al.,* 2016b).

Subfamily Nasutitermitinae Hare, 1937; Genus *Ampoulitermes* Mathur and Thapa, 1962

79. *Ampoulitermes wynaadensis* Mathur and Thapa

Distribution: Wayanad (Mathur and Thapa 1962a; Bose 1984; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

Genus *Ceylonitermellus* Emerson, 1960

80. *Ceylonitermellus periyarensis* Amina and Rajmohana, 2013

Distribution: Idukki (Amina and Rajmohana 2013).

81. *C. sahyadriensis* Ranjith and Kalleshwaraswamy, 2022

Distribution: Wayanad (Ranjith and Kalleshwaraswamy, 2022).

Genus *Ceylonitermes* Holmgren, 1912

82. *Ceylonitermes indicola* Thakur, 1976

Distribution**:** Wayanad (Thakur 1976; Bose 1984; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

83. *C. paulosus* Ipe and Mathew, 2019

Distribution: Kottayam (Ipe and Mathew 2019).

Genus *Emersonitermes* Mathur and Sen-Sarma, 1959

84. *Emersonitermes thekadensis* Mathur and Sen-Sarma, 1959

Distribution: Trivandrum, Idukki (Mathur and Sen-Sarma 1959; Bose 1984; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

Genus *Grallatotermes* Holmgren, 1912

85. *Grallatotermes niger* Chatterjee and Thapa 1964

Distribution: Idukki, Wayanad (Chatterjee and Thapa 1964; Bose 1984; Chhotani 1997; Krishna *et al.,* 2013; Amina *et al.,* 2016b).

Genus *Hospitalitermes* Holmgren, 1912

86. *Hospitalitermes monoceros* (König, 1779)

Synonym: *Termes monoceros atrum* König, 1779.

Distribution: Idukki (Amina *et al.,* 2013; Mathew 2015).

Genus *Nasutitermes* Dudley, 1890

87. *Nasutitermes anamalaiensis* Snyder, 1933

Synonyms: *Nasutitermes (Rotunditermes) anamalaiensis* Snyder, 1933b; *Alstonitermes favescens* Thakur, 1976a.

Distribution**:** Kerala Krishna *et al.,* 2013; Mathew 2015; Vidyashree *et al.,* 2018).

88. *N. brunneus* Snyder, 1934

Synonym: *Nasutitermes (Nasutitermes) brunneus* Snyder, 1934

Distribution: Ernakulam, Malappuram, Kozhikode (Snyder 1934; Bose 1984; Chhotani 1997; Verma and Swaran, 2007; Krishna *et al.,* 2013; Shanbhag and Sundararaj 2013; Mathew 2015).

89. *N. indicola* (Holmgren and Holmgren, 1917)

Synonyms: *Eutermes (Eutermes) indicola* Holmgren and Holmgren, 1917; *Eutermes (Eutermes) processionarius* Schmitz, 1924; *Nasutitermes beckeri* Prashad and Sen-Sarma, 1959.

Distribution: Wayanad (Holmgren and Holmgren 1917; Bose 1984; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

90. *N. matangensis matangensis* (Haviland, 1898)

Synonyms: *Termes matangensis* Haviland, 1898; *Eutermes (Eutermes) matangensiformis* Holmgren, 1913c; *Eutermes djemberensis* Kemner, 1934.

Distribution**:** Wayanad (Amina *et al.,* 2016b).

91. *N. cherraensis* Roonwal and Chhotani,1962

Distribution: Palakkad (Amina and Rajmohana, 2021).

92. *N. kali* Roonwal and Chhotani, 1962

Distribution: Palakkad (Amina and Rajmohana, 2021).

Genus *Trinervitermes* Holmgren, 1912

93. *Trinervitermes biformis* (Wasmann, 1902)

Synonyms*:* *Eutermes biformis* Wasmann, 1902; *Eutermes heimi* Wasmann, 1902; *Nasutitermes* (*Trinervitermes) longinotus* Snyder, 1934.

Distribution: Malappuram, Kannur (Bose 1984; Chhotani 1997; Krishna *et al.,* 2013; Mathew 2015).

DISCUSSION

A compiled list of species in a specific area provides a foundation for future investigations. The complete termite fauna of Kerala has never been thoroughly examined, despite the contributions made by numerous scientists since Wasmann in 1896. In Kerala, there are 93 termite species belonging to three families, namely Kalotermitidae, Rhinotermitidae, and Termitidae. The family Termitidae stands out as the predominant family, encompassing 76 species across four subfamilies, followed by Kalotermitidae with 10 species and then by Rhinotermitidae with 7 species across three subfamilies. This suggests that there has been an addition to the termite fauna in the state of Kerala following comprehensive research by Mathew (2015) who reported a total of 58 species from 28 genera and 6 subfamilies belonging to 3 families. Later, one subfamily, Prorhinotermitinae (Joseph *et al.,* 2023a), six genera*, Prorhinotermes* (Joseph *et al.,* 2023a), *Pericapritermes* (Mathew and Ipe, 2018), *Rinacapritermes* (Amina *et al.,* 2022), *Hypotermes* (Poovoli and Rajmohana, 2019), *Ceylonitermellus* (Amina and Rajmohana, 2013) and *Grallatotermes* (Amina *et al.,* 2016b) and 33 species were reported from Kerala to date. The degree of endemism among termites found in Kerala is remarkably high. According to Baraik *et al.* (2024), out of the 196 endemic termite species identified in India, 23 are found in Kerala. Of the 93 identified species, 41 (44.08%) are reported as exclusive to southern India. Furthermore, out of the 34 documented genera, 6 (17.65%) are recognized as endemic to southern India. The most recent additions to termite diversity in Kerala include *Ceylonitermellus sahyadriensis* Ranjith and Kalleshwaraswamy 2022 (Ranjith *et al.,* 2022) and *Prorhinotermes cotym* Joseph, Amina and Mathew 2023 (Joseph *et al.,* 2023a) which are endemic to southern Western Ghats and reported only from the type localities in Kerala. The inclusion of the *Prorhinotermes cotym* Joseph, Amina, and Mathew, 2023 adds the genus and the subfamily Prorhinotermitinae, to the termite fauna of Kerala. Furthermore, *Microcerotermes lahorensis* Akhtar, 1974 and *Euhamitermes chhotani* Maitii, 1983 were the two newly recorded species from Kerala by Joseph *et al.* (2023) and Ranjith *et al.* (2023) respectively. Therefore, this study emphasizes Kerala as a region characterized by abundant termite diversity and endemism. The richness of species and endemism is attributed to the presence of the Western Ghats, which encircles approximately half of the state. Given this region's unique environment and geographical positioning, it is reasonable to anticipate the discovery of numerous additional endemic genera and species. This update and review of the termite fauna of Kerala could serve as a valuable resource for researchers, enabling them to anticipate additions

to the termite fauna in the region. It also directs attention towards the conservation of endemic species, guiding efforts aimed at preserving the unique biodiversity of termite fauna of Kerala.

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Nesting pattern of *Apis dorsata* F. in urban Nagpur. Maharashtra, India

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ABSTRACT: The purpose of this research was to examine the *Apis dorsata* distribution and nesting habits in urban Nagpur. According to the findings, there were about 75 nests in urban Nagpur. Among these 73 per cent were active nests and 21 per cent were abandoned nests. The nesting preference was found to be among the tall building (60%). Out of these nests, 30 per cent were found shielded from the rain and wind, 57 per cent exposed and 13 per cent partially protected. It was noted that the *A. dorsata*'s habit of building nests was unaffected by the existence of a nearby body of water, as most of the nests were located away from the waterbody.

KEY WORDS: Apini, giant honey bee, rock bee, nests characteristics, nest site preferences, honey bee nests

INTRODUCTION

The members of family Apidae, subfamily Apinae is distinguished in four tribes: Euglossini, Bombini, Meliponini, and Apini (Michener, 2000). Generally, members of the *Apis* genus make up the Apini tribe. The *Apis dorsata* F. of the Apini tribe is also known as the Asian gigantic honeybee, is often found on a range of structures, including towering trees, buildings, rock cliffs, water tanks, and flyovers (Hepburn *et al.,* 2014; Nagaraja 2012; Jerzy Woyke *et al.,* 2012a). Due to migratory behaviour, whenever the environment and floral supplies are favourable, *A. dorsata*, return to its former nesting location (Koeniger and Koeniger, 1980; Neumann *et al.,* 2000; Reddy and Reddy, 1993). Bee colonies appear to be immune to natural diseases and pests due to their yearly migrations, which occur at least twice per year (Liu *et al.,* 2007; Nagaraja and Rajagopal, 2019). The availability of food sources and favourable nesting conditions help the survival of bee colonies in their natural habitat. It also gets its sustenance from nearby farms and wild vegetation (Bawa, 1990; Kahono *et al.,* 1999). Prior studies have examined *A. dorsata* nesting habits in the tropical regions of southeast and south-east Asia (Liu *et al.,* 2007; Neupane *et al.,* 2013; Roy *et al.,* 2011; Ruttner, 2013; Jerzy Woyke *et al.,* 2012a; Jerzy Woyke *et al.,* 2012b; Jerzy Woyke *et al.,* 2016a; Jerzy Woyke *et al.,* 2016b). The study on the nesting behaviour of *A. dorsata* in Urban area of Nagpur was undertaken. Furthermore, also to investigate the impact of urbanization on the nesting pattern of Asian giant honeybees, as well as the key factors determining their nesting preferences.

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MATERIALS AND METHODS

Nagpur City is the state capital, following Mumbai. Its ecosystem is composed of the dry deciduous forest type and tropical dry vegetation (Raut *et al.,* 2022). Known as the geographic centre of the country, it is the third largest city in Maharashtra and the 13th largest urban accumulation in India (Dhyani *et al.,* 2018). Gardens and parks account for 8% of the city's total land area, based on the land use pattern of the city (Dhyani *et al.,* 2021). The natural topography that originally served as the city's limit is now inside the municipal boundaries as a result of recent socioeconomic developments, urbanization, population increase, and administrative boundary expansion (Lahoti *et al.,* 2019). The study was conducted in Nagpur's urban area. The survey method was used to investigate the factors that influence nest distribution and the circumstances surrounding the nests. In addition, a convenient method was employed to track *A. dorsata* nests in metropolitan areas. The following criteria were investigated to better understand the nesting pattern: the nest's state, the substrate to which it was connected, the arrangement of the nest, the presence of a water source near the nest, the number of nests present at one site, the height of the nest from the ground, and site selection. The Epicollect5 app was used to document these traits as well as the nest locations.

The data was downloaded from the Epicollect5 website in 'CSV' format for processing. From January to December 2023, a total of around 75 nests were seen. The average time spent on the observation was three hours. The CSV dataset was uploaded to Google Earth to obtain a GPS map of the nest distribution in the metropolitan region. A pie chart and clustered column charts were used to conduct fundamental analysis of the nests' properties and the factors driving their distribution in Microsoft Excel.

RESULTS AND DISCUSSION

Distribution of nesting site: From 2023 to the present, 75 *Apis dorsata* nests were detected in Nagpur's metropolitan area. The pin on the map reflect the nest locations in Nagpur's urban area (Fig. 1). The *A. dorsata* nest distribution was uneven, clustered, and distributed over the metropolitan region.

Characteristics of Nests sites: The nests of *A. dorsata* were classified as abandoned, active, or damaged based on their status. Around 73 per cent nests were active and in good shape, with unaffected combs and a solid construction. Twenty one per cent nests were dry, discolored, with hollow chambers, and devoid of bees, hence the name abandoned nests. Damaged nests were those that were damaged, infested, or loosely attached. Some sites had both active and damaged nests.

The surfaces to which the nests connected were classified according to the substrate, which included concrete, wood, metal surfaces and granite. *A. dorsata* indicated that concrete was the preferred substrate. Approximately 90.54 per cent nests were affixed to concrete, with only one attached to granite. The wood and metal had 4.05 and 2.70 per cent nest, respectively.

The arrangement of *A. dorsata* nests to guard against external factors such as gusts of high wind, rainfall, storms, and bright sunlight was also investigated. Nests that were protected by trees, walls, pillars, or other structures were designated as protected on the basis of coverage from the four sides i.e. front, back and both sides. Nests that were covered on three or all sides were classed as protected nest arrangement. Approximately 29.73 per cent of the nests were built in a protected manner. Similarly, nests which were protected by two sides were classed as semi-protected and the nest which were open and not covered from any sides are noted as unprotected. Under unprotected there were 56.76 per cent, whereas in semi-protected it was 13.51 per cent. *A. dorsata* selected nesting sites that include buildings, a metro line, a water tank, and trees. Buildings are the most common (60.81%), followed by metro lines (28.38%) and the trees and water tank least chosen (5.41%).

Some nest locations contain more than one nest. There were 14 sites with two nests next to each other, 57 sites with only one nest, and three sites

with three or more nests. *A. dorsata* nests have varying heights from ground level. The heights were measured by the floors of the buildings (approx. 9 ft) and the Haga altimeter. There were 26 nests found at an altitude of more than 40 feet, 12 nests at an altitude of more than 60 feet, and four nests at more than 20 feet, 80 feet, and 90 feet. Nine nests were discovered at both 50 and 70 feet. The lowest nests, six in number, were found at more than 20 feet.

In the study of water body near the nesting site, showed that 63.51 per cent of nests were established with no water body nearby and 36.49 per cent were built near a water body. In addition, the nesting direction was investigated. The nests directions also differed. Out of 75 nests, 28 are in the east, four in the west, and nine and fifteen in the south and north, respectively. Three nests were found in the northeast and northwest, while 7 and 5 nests were found in the southeast and southwest directions.

The current study presents a fresh direct calculation of the *A. dorsata* nest distribution and effect of external influences on the nesting pattern of the bees. *A. dorsata* colonies were discovered to be establishing nests on multi-story structures and metro lines. The study's findings revealed a variation in nest site selection and a preference for building and metro lines as nest construction sites. As in wild *A. dorsata* prefer tall trees and rocks for nesting however due to the scarcity of tall rocks and deforestation in urban area they have adapted to preferring concrete as their nesting base. The increasing predilection for buildings and metro lines as nesting sites can be attributed to the number of suitable locations. This is supported by Nagaraja (2017), that buildings are the favoured nesting sites in Bengaluru's metropolitan areas. *A. dorsata* never built nests on ancient structures, weak branches, or dead trees because it was not robust enough to hold the weight of the nest (Neupane *et al.,* 2013).

The placement of the nests suggested that they were constructed in an unprotected setting rather than a protected and subsequently semi-protected environment. It was discovered that as *A. dorsata* adapted to the urban environment, bees were driven to make nests in relatively vulnerable locations. This layout made the nests vulnerable to the wind, severe rains, and sunshine. Sattigi and Kulkarni (2001) found that appropriate protection from the wind, slashing rains, and sunlight resulted in a greater distribution of nests on buildings in urban areas. Crane (1999) discovered that *A. dorsata* swarms

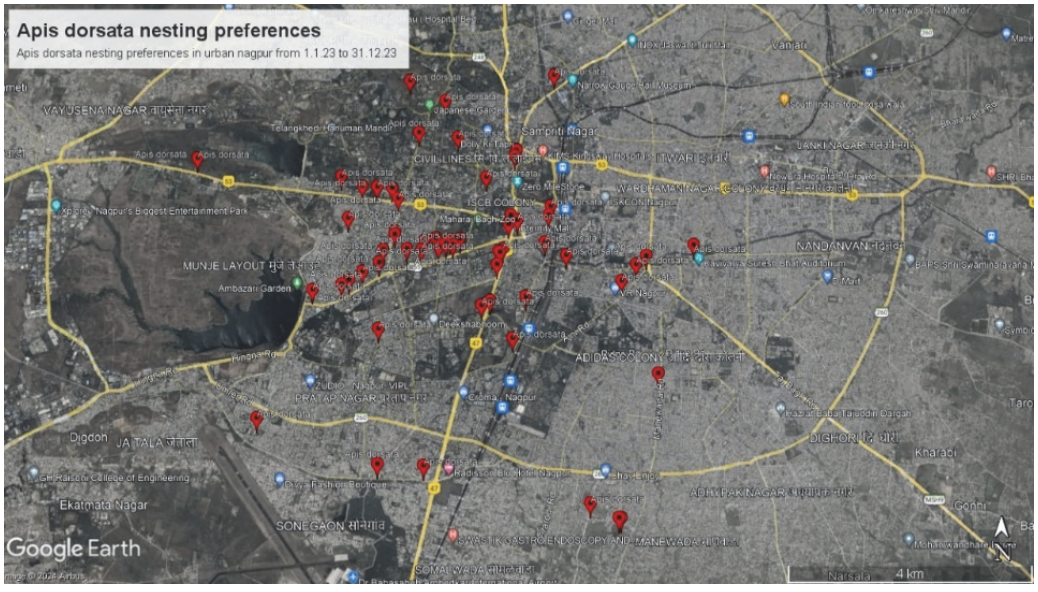

Fig. 1 Distribution of *Apis dorsata* nests in Urban Nagpur

frequently chose nest sites that were partially protected and not immediately exposed to wind currents. In contrast, Starr (1987) found that *A. d. dorsata* prefer to build their nests in open areas and keep them clean with liane plants. Weihmann *et al.* (2014) also revealed that *A. d. dorsata* prefers to build nests in open areas where predators can easily see them.

According to Sharma *et al.* (2015), *A. dorsata* exhibits migratory behaviour. *A. d. dorsata* migrated at least twice per year. It was caused by poor environmental factors, such as weather conditions, limited availability of food, and parasite-eating larvae and pupae (Makinson *et al.,* 2014; Momose *et al.,* 1998; Paar *et al.,* 2004; Rattanawannee and Chanchao, 2011; Sharma *et al.,* 2015; Woyke *et al.,* 2004).

Wild honey bees will return to their old nesting site and establish a nest if the environment is not altered (Neumann *et al.,* 2000). The empty combs provided clues for identifying past nest sites that would be reoccupied by arriving colonies (Thapa, 1998). This is the primary explanation for the abandoned and shattered nest discovered during surveying. The abandoned nests were the result of migratory bees, while the split and damaged ones were caused by honey hunters. There are also sites where there are more than two nests, some of which are abandoned or injured, while others remain active.

A. dorsata favoured a height of 40 feet for making nests. The highest nest was found 120 feet above the ground. Ten percent colonies of *A. d. binghami* were found at the height of less than 10 meter from ground surface and more than 90% nests were within 10 meters height from ground (Nagir *et al.,* 2016). Kahono *et al.,* (1999) also reported that *A. dorsata* nests were discovered at a height of less than 10 meters from the ground surface throughout a two-year period. According to Weihmann *et al.,* (2014), *A. dorsata* prefers lofty trees for nesting. Previous studies also reported that *A. dorsata* prefer areas with a height of more than 10 meters to build nests (Hadisoesilo, 2001; Kahono *et al.,* 1999; Starr, 1987).

All nesting locations were discovered near water sources (Sharma *et al.,* 2015). Water is used to cool the nest on the honeycomb (Ruttner, 2013). It was also discovered that *A. d. binghami* workers were at the closest water source (Nagir *et al.,* 2016). According to H Randall Hepburn and Radloff (2011), the scarcity of water supplies will force bee colonies to relocate. During field observations, it was revealed that the majority of the nests were constructed in the absence of a nearby significant waterbody.

Small sources of water are available in metropolitan areas, making it easier even if there is no presence of a water body as a source of water because modern infrastructure provides a plentiful supply of water. Throughout the survey, it was discovered that nests preferred the East direction for their nesting site, but no clear reason for this preference was identified. In the future, the significance of the direction on the nesting location of *A. dorsata* can be investigated. The results indicated that *A. dorsata* is well distributed in Urban area of Nagpur. The bees have adapted effectively to urbanization and have evolved nesting conditions appropriate for urban areas. The only criterion that was hard to comprehend and interpreted was the orientation of the nesting site. More observation and inquiry are required to better understand the role of nesting orientation in the nesting pattern.

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First report of some praying mantids (Insecta, Mantodea) from Mizoram state, India

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ABSTRACT: Seven species of mantids viz. *Humbertiella affinis* Giglio-Tos, 1917, *Acromantis montana* Giglio-Tos, 1915, *Anaxarcha acuta* Beier, 1963, *Creobroter laevicollis* (Saussure, 1870), *Statilia maculata* (Thunberg, 1784), *Statilia nobilis* (Brunner de Wattenwyl, 1893) and *Tenodera aridifolia* (Stoll, 1813) are newly reported from Mizoram state, India. © 2024 Association for Advancement of Entomology

KEY WORDS: Mantid fauna, new records, Mizoram

Despite their ecological importance as biological control agents, the praying mantids have been largely neglected in the studies of taxonomy, ecology, biology, ethology and phylogeny worldwide, including in India. At present, 171 species of mantids belonging to 70 genera and 13 families are known from the country (Kamila and Sureshan, 2024a; Kamila and Sureshan, 2024b). The mantid fauna of Assam, Meghalaya and Arunachal Pradesh are better documented compared to the other North-Eastern Indian states (Sureshan & Kamila, 2023). Ahmed *et al.* (2021) listed mantids of North-East India comprising seven species from Mizoram without providing any data or source on specimens examined or literature. In this paper, seven species in six genera and three families are reported from the state for the first time.

This study is based on the specimens deposited in the Orthoptera Section, Zoological Survey of India, Kolkata, India. The specimens were examined using Leica EZ4 stereo zoom microscope and photographed using Nikon D7500 digital camera. The classification of Schwarz and Roy (2019) and the terminology of Brannoch *et al.* (2017) are followed. Species identification is largely based on keys provided by Mukherjee *et al.* (1995).

Systematic account

Insecta: Mantodea; Family: Gonypetidae Westwood, 1889; Subfamily: Gonypetinae; Tribe: Gonypetini

Genus *Humbertiella* Saussure, 1869

1. Humbertiella affinis Giglio-Tos, 1917 (Fig. 1)

Humbertiella affinis Giglio-Tos, 1917. *Bull. Soc. Ent. Ital.*, 48: 83.

Diagnosis: Body medium-sized. Color brown.

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Lower frons with black band, upper edge arched in middle. Vertex grooved. Pronotum with round distinct tubercles. Fore femur with 4 posteroventral and 4 discoidal spines; small tubercles present between posteroventral spines. Costal area of fore wings with irregular veinules.

Materials examined: 2 Male, INDIA, Mizoram, Saiha, 6.iv.1994, Coll. Dr. A. K. Hazra & Party. 1 Male, INDIA, Mizoram, Circuit house campus, Saiha, 9.iv.1994, Coll. Dr. A. K. Hazra & Party.

Distribution: India; Karnataka, Kerala, Maharashtra, Mizoram (new record), Odisha. Elsewhere: Pakistan, Sri Lanka.

Family: Hymenopodidae Giglio-Tos, 1915; Subfamily: Acromantinae; Tribe: Acromantini

Genus *Acromantis* Saussure, 1870

2. Acromantis montana Giglio-Tos, 1915 (Fig. 2)

Acromantis montana Giglio-Tos, 1915. *Boll. Musei Zool. Anat. Comp. R. Univ. Torino.*, 30(702): 7.

Diagnosis: Vertex with a small tubercle. Lateral edges of pronotum with small denticles; metazone of prosternum blackish. Fore femur without hump-like structure on upper edge; with 4 posteroventral and 4 discoidal spines; all long anteroventral and discoidal spines completely black. Apex of wings truncated.

Materials examined: 1 Male, INDIA, Mizoram, Rawngtla, 18.ix.1993, Coll. R. S. Mirdha. 1 Male, INDIA, Mizoram, Circuit house campus, Saiha, 9.iv.1994, Coll. Dr. A. K. Hazra & Party. 2 Male, INDIA, Mizoram, Aibawk, FRH, 15.xi.1995, Coll. M. S. Shishodia & Party.

Distribution: India; Andaman Island, Arunachal Pradesh, Maharashtra, Meghalaya, Mizoram (new record), Tamil Nadu, Tripura. Elsewhere: Borneo; Indonesia.

Subfamily: Hymenopodinae; Tribe: Anaxarchini

Genus *Anaxarcha* Stål, 1877

3. Anaxarcha acuta Beier, 1963 (Fig. 3)

Anaxarcha acuta Beier, 1963. *Stuttgart Beitr. Naturk.,* 106: 9.

Diagnosis: Lower frons pentagonal, with a triangular long tubercle in middle. Lateral edges of pronotum denticulate. Fore femur with 4 posteroventral and 4 discoidal spines; all long anteroventral spines black. Tibial spur groove proximal to middle with a black spot at anterior end.

Material examined: 1 Female, INDIA, Mizoram, Lauent Rai (N), 18.ix.1993, Coll. A. R. Lahiri & Party.

Distribution: India; Meghalaya, Mizoram (new record), Sikkim, West Bengal. Elsewhere: Bhutan.

Tribe: Hymenopodini

Genus *Creobroter* Audinet- Serville, 1839

4. Creobroter laevicollis (Saussure, 1870) (Fig. 4)

Creobotra laevicollis Saussure, 1870. *Mitt. Schweiz. Ent. Ges.*, 3: 242.

Diagnosis: Body medium-sized. Eyes oblong, extending beyond the level of head. Vertex with a tubercle. Pronotum short, metazone a little longer than prozone. Fore femur with 4 posteroventral and 4 discoidal spines; all spines black at apex only. Fore wings green, opaque, basally with a round yellow spot, eyespot a little proximal to middle. Hind wings pinkish at base and smoky in middle.

Materials examined: 1 Male, INDIA, Mizoram, Aibawk, FRH, 16.xi.1995, Coll. M. S. Shishodia & Party. 1 Male, INDIA, Mizoram, Teirei, 11.xi.1995, Coll. M. S. Shishodia & Party.

Distribution: India; Andhra Pradesh, Assam, Bihar, Chhattisgarh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram (new record), Sikkim, West Bengal. Elsewhere**:** Indonesia.

Family: Mantidae Latreille, 1802; Subfamily: Mantinae

Genus *Statilia* Stål, 1877

5. Statilia maculata (Thunberg, 1784) (Fig. 5)

Mantis maculata Thunberg, 1784. *Nov. Ins. Spec.*, 3: 61.

Mantis orientalis Saussure, 1870. *Mitt. Schweiz. Ent. Ges.*, 3: 233.

Pseudomantis haani Saussure, 1871. *Mem. Soc. Hist. Nat. Geneve.*, 21: 185.

Statilia maculata var. *hyalina* Giglio-Tos, 1927. *Tierreich.*, 50: 411.

Diagnosis: Body brownish. Lateral edges of pronotum with denticles; prosternum with a black patch near supra-coxal junction. Fore coxa with 6 spines on upper edge; ventrally blackish at basal end. Fore femora ventrally with a black patch adjacent to yellowish tibial spur groove; with 4 posteroventral and 4 discoidal spines; all long anteroventral spines black.

Materials examined: 1 Male, INDIA, Mizoram, Manpui, 17.ix.1993, Coll. A. R. Lahiri. 1 Female, INDIA, Mizoram, Lawngtlai, 17.ix.1993, Coll. A. R. Lahiri. 1 Female, INDIA, Mizoram, Tuipui, 20.ix.1993, Coll. A. R. Lahiri. 1 Female, INDIA, Mizoram, Lawngtlai, 17.ix.1993, Coll. R. S. Mirdha.

Distribution: India; Andaman Island, Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chhattisgarh, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram (new record), Odisha, Sikkim, Telangana, Uttar Pradesh, West Bengal. Elsewhere**:** Borneo, China, Indonesia, Japan, Labuan, Laos, Malaysia, Myanmar, Nepal, New Guinea, Pakistan, Philippines, Russia, South Korea, Sri Lanka, Taiwan, Thailand, United States of America, Vietnam.

6. Statilia nobilis (Brunner de Wattenwyl, 1893) (Fig. 6)

Mantis nobilis Brunner de Wattenwyl, 1893. *Annali Mus. Civ. Stor. Nat. Genova.*, 13(33): 70.

Mantis indica Mukherjee, 1995. *Orient. Insects*, 29: 300.

Diagnosis: Fore coxa with 6-7 spines on upper edge; ventrally without any patches. Fore femur with 4 posteroventral and 4 discoidal spines; all long anteroventral spines black; tibial spur groove yellowish, proximally with a black patch and distally with a black line.

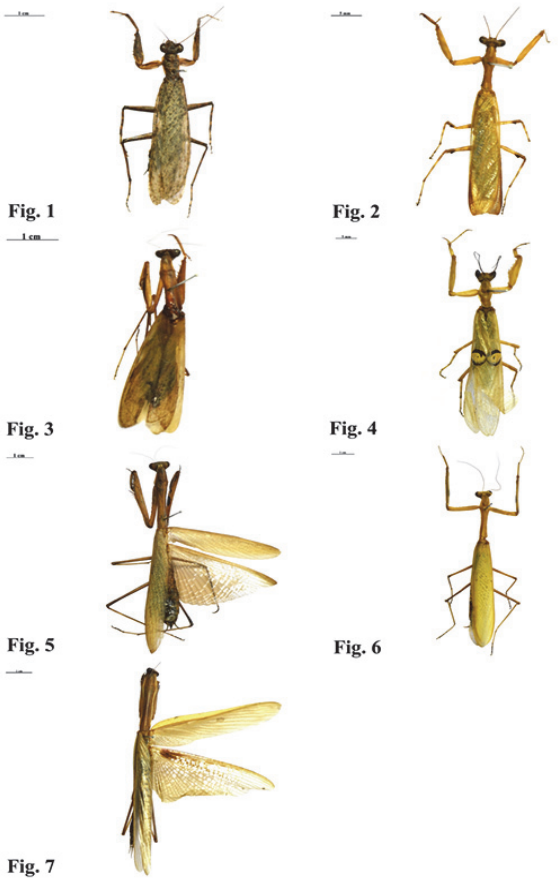

Fig. 1 *Humbertiella affinis* Giglio-Tos, 1917,
Fig. 2 *Acromantis montana* Giglio-Tos, 1915,
Fig. 3 *Anaxarcha acuta* Beier, 1963,
Fig. 4 *Creobroter laevicollis* (Saussure, 1870),
Fig. 5 *Statilia maculata* (Thunberg, 1784),
Fig. 6 *Statilia nobilis* (Brunner de Wattenwyl, 1893),
Fig. 7 *Tenodera aridifolia* (Stoll, 1813)

Material examined: 1 Male, INDIA, Mizoram, Tungvel, 18.ix.1994, Coll. I. B. Dutta & Party.

Distribution: India; Himachal Pradesh, Manipur, Mizoram (new record), West Bengal. Elsewhere**:** Myanmar.

Subfamily: Tenoderinae; Tribe: Tenoderini

Genus *Tenodera* Burmeister, 1838

7. Tenodera aridifolia (Stoll, 1813) (Fig. 7)

Mantis aridifolia aridifolia Stoll, 1813. *Represent. Spectres. Mantes.*, 65.

Mantis japonica Saussure, 1871. *Mem. Soc. Hist. Nat. Geneve.,* 21: 238.

Mantis mandarinea Saussure, 1871. *Mem. Soc. Hist. Nat. Geneve.*, 21: 289.

Diagnosis: Body large. Lower frons pentagonal, bicarinate. Pronotum slender. Fore femur with 4 posteroventral and 4 discoidal spines. Costal area of fore wings green, opaque. Hind wings hyaline, with a large reddish patch near base and brownish patches beneath costal area.

Material examined: 1 Male, INDIA, Mizoram, Twampui, 19.ix.1993, Coll. A. R. Lahiri.

Distribution: India; Arunachal Pradesh, Assam, Himachal Pradesh, Maharashtra, Mizoram (new record), Sikkim, Tamil Nadu, Uttar Pradesh, West Bengal. Elsewhere**:** Borneo, China, Indonesia, Japan, Malaysia, Myanmar, Nepal, Taiwan, Thailand, United States of America.

Mizoram is one of the Seven Sister States in the North-Eastern India, which is the southernmost state sharing borders with Myanmar and Bangladesh. The state has the highest percentage area covered by forests among the Indian states with a variety of forest types and rich flora and fauna, making it a significant region for biodiversity. This is the first report of mantid fauna from the state with seven species in six genera and three families. Since Mizoram is a part of Indo-Burma biodiversity hotspot, the possibility of finding more interesting species of mantids from this area is very high. More extensive surveys are needed in this region.

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Northernmost record of the endemic damselfly *Indosticta deccanensis* (Laidlaw, 1915) (Odonata, Zygoptera, Platystictidae) from Western Ghats, Karnataka, India

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ABSTRACT: *Indosticta deccanensis* (Laidlaw, 1915) (Odonata, Platystictidae) is an endemic damselfly found in the evergreen forests of Western Ghats of southern India. This species was observed and photographed at Madugundi, Chikkamagaluru district, Karnataka. This is the first photographic record for Karnataka and the northernmost in Western Ghats. © 2024 Association for Advancement of Entomology

KEY WORDS: Odonata, endemic species, range extension, Madugundi

Odonata (Dragonflies and Damselflies) are predatory freshwater insects seen in various ecosystems, including wetlands, forest streams, marshes, rivers, and paddy fields where they help to maintain the population of smaller insects and control a variety of disease-carrying vectors such as mosquitos (Subramanian, 2018, Vatandoost, 2021). There are about 6322 species of odonates present worldwide and roughly 500 species are present in India of which 186 species are endemic to India (Sandall *et al.,* 2022; Subramanian, 2018); Kalkman *et al.* 2020). The damselflies that belong to the family Platystictidae have a unique morphology, slender reed-like abdomens, delicate bodies, and characteristic small wings. Platystictidae of India comprises three genera i.e. *Protosticta* Selys, 1885, *Drepanosticta* Laidlaw, 1917, and *Indosticta* Bedjanic, 2016 with twenty-two species distributed throughout India (Subramanian and Babu, 2024). The genus *Indosticta* is monobasic with *I. deccanensis* (Laidlaw, 1915) and restricted to India, this taxon was formerly assigned to the genus *Platysticta* Selys, 1860, is currently restricted to Sri Lanka (Fraser, 1933; Bedjanic *et al*., 2016). *Indosticta deccanensis* closely resembles *Platysticta* Selys, 1860 but does not resemble any other genus morphologically that belongs to the family Platystictidae in India. According to Bedjanic *et al*. (2016), the genus *Indosticta* differs from Genus *Platysticta* having a brown base colouration on the thorax rather than black, and the sides of the thorax in males are light blue or white with a lateral stripe. S10 in both males and females is of dark colour and not dorsally blue. *Indosticta deccanensis* was previously documented from the states of Kerala (Nair *et al.,* 2021, 2022) and Tamil Nadu (P. Vinod, personal communication, October 28, 2024). Thus, the currently known distribution of the species is from southern and the lower central Western Ghats.

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The authors came across *Indosticta deccanensis* while on a field visit to Madugundi, Chikkamagaluru district, Karnataka. Five Individuals were observed and photographed from Madugundi (13°07'49.9" N;75°26'56.4"E) (764 m, Netravati River) in a small forest stream surrounded by dense vegetation. The habitat was tropical evergreen with dense canopy cover. Photographs were taken using Nikon DSLR cameras. Specimens were identified using Fraser (1933) and Bedjanic *et al*., (2016). Quantum GIS (QGIS) version 3.3.2 was used to create a map of site records of the species.

According to Fraser (1933), the male has a yellowish labium, an azure labrum and anteclypeus, a dark reddish black prothorax, and a bright red thorax that changes to golden yellow down and below. Legs are reddish brown, whereas the coxae and trochanters are golden yellow. The abdomen is dark red with brown obscuring and golden yellow at the ends of each segment, while segments 8 and 9 are azure blue. Anal appendages are black.

Fraser (1933) described the females as differing significantly from males, far more than is typical in the subfamily. The head looks identical to the male, and the prothorax is likewise the same colour. The thorax is brick red, and half of the mesepimeron is black. The legs and abdomen are similar to the male, but segment 1 is bright red on the sides. Abdominal segments 1–8 are identical to males, except segment 9 has a large circular yellow spot and segment 10 is very short, just like the male. Anal appendages are short, no longer than segment 10.

Indosticta deccanensis Laidlaw, 1915, is a moderately-sized damselfly with a saffron body and turquoise blue end segments of the abdomen. It is an uncommon damselfly found in the Western Ghats inhibiting streams surrounded by thick riverside vegetation with a distinctive blue marking on its tail standing out against the darker background, setting it apart from other species (Subramanian, 2009). The is a Western Ghats endemic species, designated as vulnerable on the IUCN Red List. The genus *Indosticta* comprises a single species, *I. deccanensis*, which is distributed in the Western Ghats, Kerala, and Tamil Nadu. This infrequently encountered species occurs

Table 1. Details of previous site records of *Indosticta deccanensis* (Laidlaw, 1915) in Western Ghats

Site records	Landscape (State)	Reference
Aralam	Coorg-Kannur (Kerala State)	(Palot and Kiran, 2016)
Wayanad	Wayanad landscape (Kerala State)	Gnanakumar *et al*. (2012)
Chimmony	Nelliampathies–Anamalais landscape (Kerala State)	Gnanakumar *et al*. (2012)
Athirapally	Nelliampathies–Anamalais landscape (Kerala State)	Varghese *et al*. (2014)
Thattaekkad	Nelliampathies–Anamalais landscape (Kerala State)	Varghese *et al*. (2014)
Pooyamkutty	Lower Periyar landscape, Anamalais (Kerala State)	Pradeepkumar *et al*. (2014)
Idduki and Kattappana	Cardamom Hills landscape Anamalais (Kerala State)	Pradeepkumar *et al*. (2014)
Achankovil	Pandalam Hills Landscape (Kerala)	Sadasivan *et al.* (2022)
Rockwood	Shendurney Landscape (Kerala state)	Nair *et al*. (2021)
Ponmudi–Kallar valley	Agasthyamalai (Kerala State)	Nair *et al*. (2021)
Peppara and Neyyar WLS	Agasthyamalai (Kerala State)	Nair *et al*. (2021)
Mundanthurai TR	Agasthyamalai (Tamil Nadu State)	(P. Vinod, personal communication, October 28, 2024).

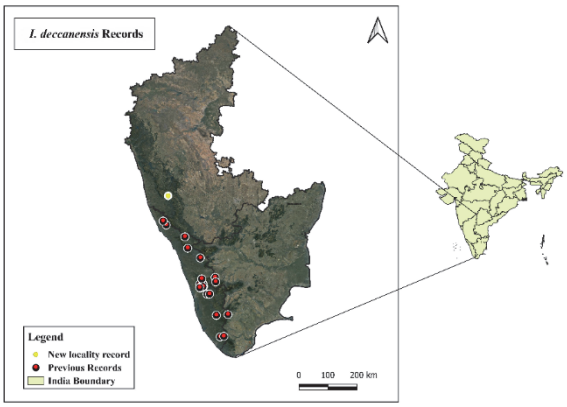

Fig .1 Known distribution of *Indosticta deccanensis* Laidlaw, 1915 throughout the Western Ghats

in diverse habitats across Kerala and Tamil Nadu at elevations below 900 meters. In these regions, *Indosticta* Bedjanic, 2016, is represented by a single species. The site records are Aaralam of Coorg–Kannur landscape (Palot and Kiran, 2016), Wayanad (KS) of Wayanad landscape, Silent Valley (KS) of Nilgiri– Silent Valley landscape, Chimmony (Gnanakumar *et al.,* 2012), Athirapally and Peechi (KS) of Nelliampathies–Anamalais landscape, Thattaekkad (Varghese *et al*., 2014) and Pooyamkutty (KS) of Lower Periyar landscape, Periyar Tiger Reserve (KS), Idukki (KS) and Kattappana (KS) of Cardamom Hills landscape, Konni (Pradeepkumar *et al*., 2014) and Achankovil (KS) of Pandalam Hills landscape, Rockwood in Shendurney WLS, Ponmudi–Kallar Valley (KS), Peppara and Neyyar (KS) of Agasthyamalais landscape (Nair *et al.,* 2021) and Kalakad, Mundanthurai Tiger Reserve (TN) (Paulmathi Vinod, personal communication, October 28, 2024).

The discovery of *Indosticta deccanensis* in Madugundi, Chikkamagaluru, Karnataka extends the known distribution of this strikingly coloured damselfly by approximately 133 kilometres northward from its previously documented range in Kerala. This new record suggests the presence of *I. deccanensis* in suitable habitats within the Western Ghats. Given its restricted habitat preference for evergreen forests and riparian regions, further studies are crucial for understanding its ecology which is essential for developing effective conservation strategies.

Fig 2. *Indosticta deccanensis* (Laidlaw 1915): A- Lateral view of male; B- Lateral view of female

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Population dynamics of sucking pests, natural enemies, and the incidence of yellow mosaic disease on *Vigna radiata* (L.) Wilczek in relation to weather factors

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ABSTRACT: The investigation on population dynamics of sucking pests, their natural enemies, and the per cent disease incidence (PDI) of mung bean yellow mosaic disease (YMD) on *Vigna radiata* was conducted. During the harvest of the crop, the population of *Aphis craccivora*, *Empoasca kerri*, ladybird beetle, and the PDI of YMD was the highest on the 17th Standard meteorolo gical week (SMW). In contrast, the population of *Bemisia tabaci* was at its peak on the 15th SMW. The minimum temperature had highly significant positive correlation with the population of *A. craccivora*, *E. kerri*, *B. tabaci,* ladybird beetle, and the PDI of YMD. Moreover, there was a significant positive correlation between wind velocity and the population of ladybird beetles. Furthermore, a significant positive correlation was found between the PDI of YMD and the population of *B. tabaci*. © 2024 Association for Advancement of Entomology

KEY WORDS: Aphid, jassid, ladybird beetle, whitefly, yellow mosaic disease, PDI, correlation

Mung bean, *Vigna radiata* (L.) Wilczek is the third important pulse crop after chickpea and pigeon pea, cultivated extensively in Uttar Pradesh, Madhya Pradesh, Rajasthan, Maharashtra, Odisha, Karnataka, Andhra Pradesh, Gujarat, Bihar, Haryana, and Delhi during both *Kharif* and summer (Singh and Singh, 2015). In India, it occupied an area of 5.5 million ha having a total production of 3.17 million tons and productivity of 570kg/ha in 2022 (Anonymous, 2022). In Gujarat, it is grown in an area of 2.30 lakh ha with a production of 1.21 lakh tons and productivity of 526kg/ha (Anonymous, 2019). More than twelve species of insect pests were found to infest *V. radiata*. Among them, aphid, *Aphis craccivora* Koch., jassid, *Empoasca kerri* Pruthi, and whitefly, *Bemisia tabaci* Gennadius cause serious damage to *V. radiata* and are found at all crop growth stages (Parmar and Ghetiya, 2023). *A. craccivora* feed on the sap of leaves, shoots, flower and pods, causing withering shoots and malformed pods. Jassids, *E. kerri* also damage by sucking cell sap and injecting toxic saliva. *B. tabaci* not only feed on cell sap, but also transmit the Mung bean Yellow Mosaic disease (YMD) to *V. radiata* (Patil, 2006). Weather conditions in a region play a critical role in the occurrence and subsequent buildup of pests, natural enemies, and diseases. Understanding the population dynamics

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of pests, natural enemies, and disease incidence in relation to environmental factors is imperative for developing effective pest management strategies (Singh *et al.* 2023). Therefore, the present investigation was undertaken to study the population dynamics of sucking pests, natural enemies, and the incidence of YMD on *V. radiata* and their correlation with weather parameters.

The investigation was conducted at the Soil and Water Management Research Unit (SWMRU) farm, Navsari Agricultural University (NAU), Navsari, Gujarat, India during summer 2021-22. The farm is located at 20°92′ N latitude and 72°89′ E altitude. Green gram *var*. GM-4 (Gujarat Mung 4) was sown on 26/02/2021 during the Eighth Standard Meteorological Week (SMW). The crop was grown in a plot of size 20m × 20m (400m^2) with the recommended spacing of 45cm × 10cm. Fertilizers were applied at a rate of 20: 40: 00 kg ha^{-1} NPK with all recommended agronomic practices. The crop under the experiment was free from any insecticidal sprays.

The incidence of sucking pests, natural enemies, and YMD on *V. radiata* was recorded at weekly intervals starting from one week after sowing (ninth SMW) till the harvest of the crop (17th SMW). The whole plot was divided into four quadrates (10m × 10m) and 15 plants were randomly selected from each quadrate for observation. Three leaves from the top, middle, and bottom of each plant were observed for the presence of nymph and adult of *A. craccivora*. The population of *A. craccivora* was noted and classified into different grades based on the severity of the infestation, ranging from no aphids present on the plant to severe damage and withering of the plant. This classification was based on the aphid infestation index (AII) as described by Bakhetia and Sandhu (1973) and Parmar and Ghetiya (2023). Similarly, observations were made on the presence of *E. kerri* and *B. tabaci* adults and nymphs on three leaves of each plant. The presence of natural enemies on the leaves and other plant parts was also recorded. Additionally, the number of plants infected with YMD was noted, and the percentage disease incidence (PDI) was calculated using a specific formula.

$$\text{Percent Disease Incidence (PDI)} = \frac{\text{(Number of infected plants in a row)}}{\text{(Total number of plants in a row)}} \times 100$$

Data on weather parameters, maximum and minimum temperature, morning and evening relative humidity, sunshine hours, and wind velocity were used to study the effect of weather parameters on the population of sucking pests, *A. craccivora*, *E. kerri,* and *B. tabaci* and the incidence of YMD. The simple correlation coefficient was worked out.

The population of *A. craccivora* (0.80 AII/ trifoliate leaves) appeared from the 12th SMW and remained active throughout the crop period. The pest population steadily increased, reaching its peak of 1.15 AII/ trifoliate leaves during the 17th SMW, coinciding with the peak of flowering and pod formation (Table 1). According to Tamang *et al.* (2017) in West Bengal, the *A. craccivora* population attained the peak during the peak stage of flowering and pod formation which supports the present findings. Borah (1995) in Assam, India observed that *A. craccivora* appeared on green gram in the first week after germination, with the population increasing until harvest. The peak population of 18.5 aphids/5 plants was in the third week of April. The differences might be due to variations in geographical location, climate, soil conditions, and other factors. Furthermore, the population of *A. craccivora* exhibited a highly significant positive correlation with minimum temperature (r = 0.940**) (Table 2). Similar results were reported by Kumar *et al.* (2000) who observed that the aphid population exhibited a positive correlation with temperature.

The *E. kerri* population on *V. radiata* commenced from the 10th SMW (0.60 *E. kerri*/ trifoliate leaves) and reached a peak (1.18 *E. kerri*/ trifoliate leaves) in the 17th SMW during the harvest of the crop (Table 1). The present findings are similar to those of Arvindarajan (2017) and Patel *et al.* (2021) who observed the peak population of jassid on the 7th and 6th Week After Sowing (WAS), respectively. Kumar *et al.* (2023) observed the peak population of jassid on the 6th and 7th WAS depending on seasons. The population of *E. kerri* on green gram exhibited a highly significant positive correlation with

Table 1. Population dynamics of *Aphis craccivora*, *Empoasca kerri*, *Bemisia tabaci*, and ladybird beetle on *Vigna radiata* per trifoliate leaves from 9th to 17th SMW during 2021-22

SMW	AII	*E. kerri* (no.)	*B. tabaci* (no.)	ladybird beetles (no.)
09	0.00	0.00	0.00	0.00
10	0.00	0.60	0.62	0.00
11	0.00	0.75	1.77	0.00
12	0.80	0.68	3.03	0.25
13	0.70	0.80	4.52	0.40
14	0.85	0.92	5.57	0.55
15	0.98	1.00	6.40	0.59
16	1.08	1.10	6.25	0.63
17	1.15	1.18	6.10	0.65

Note: SMW - Standard Meteorological Week;
AII - *A.craccivora* infestation index

minimum temperature (r = 0.845**) (Table 2). In contrast, Manju *et al.* (2016) in Bikaner, Rajasthan reported that the minimum temperature showed a negative significant correlation with the *E. kerri* population, which deviated from the present findings. The differences might be due to differences in geographical location, climate, soil conditions, and other factors.

The population of *B. tabaci* (0.62 *B. tabaci*/ trifoliate leaves) appeared from the 10th SMW and remained active throughout the crop period. The pest population increased gradually and reached the peak population of 6.40 *B. tabaci*/ trifoliate leaves during the 15th SMW. Later on, it declined to 6.10 *B. tabaci*/ trifoliate leaves at the time of harvest of the crop (Table 1). These findings are similar to those of Arvindarajan (2017) and Patil *et al.* (2020) who observed the peak population of 7.23 *B. tabaci* per plant during the 7th WAS. Kumar *et al.* (2023) observed the peak population of whiteflies on the 6th and 7th WAS depending on seasons. The

Table 2. Correlation coefficients of the population with weather parameters on *Vigna radiata* from 9th to 17th SMW during 2021-22

Weather parameters	Correlation coefficients				
	A. craccivora	*E. kerri*	*B. tabaci*	Beetle	PDI of YMD#
Temperature -Max	0.221	0.341	0.225	0.209	0.950**
Temperature -Mini	0.940**	0.845**	0.986**	0.992**	0.349
Morning RH	0.013	-0.347	-0.073	-0.098	0.916**
Evening RH	0.417	0.200	0.323	0.385	-0.204
Wind velocity	0.699	0.534	0.682	0.729*	0.261
Sunshine hours	-0.286	-0.146	-0.256	-0.234	0.587

*Significant at the level of 5% (r = ±0.707); **Significant at the level of 1% (r = ±0.834);
- Percent Disease Incidence (PDI) of Mung bean Yellow Mosaic disease (YMD) with the *Bemisia tabaci* population

population of *B. tabaci* exhibited a highly significant positive correlation with minimum temperature (r = 0.986**) (Table 2). Kumar *et al.* (2004) also reported a positive correlation of the population of *B. tabaci* with temperature.

Population of ladybird beetle (0.25/ trifoliate leaves) appeared from the 12th SMW and remained active throughout the crop period. The population increased gradually and reached the peak population of 0.65 ladybird beetle/ trifoliate leaves during the 17th SMW at the time of crop harvest (Table 1). This peak population of ladybird beetles could be attributed to the high population of its prey, such as *A. craccivora* and *E. kerri.* Tamang *et al.* (2017) also observed the peak level of ladybird beetle on the 10th WAS. The population of ladybird beetle exhibited a highly significant positive correlation with minimum temperature (r = 0.992**) and wind velocity (r = 0.729*) (Table 2). Shruthi *et al.* (2018) noticed a positive correlation between ladybird beetle population with temperature.

PDI of YMD (6.50%) appeared from the 11th SMW. The PDI increased gradually and reached a peak (32.35%) during the 17th SMW at the time

of crop harvest. The rise in YMD incidence may be attributed to the high population of *B. tabaci*. Similarly, Patil *et al.* (2020) observed a peak of (44.5%) PDI on the 9th WAS. Furthermore, the PDI exhibited high significant positive correlation with the *B. tabaci* population (r = 0.950**) and minimum temperature (r = 0.916**) (Table 2). These findings are alike those of Patil *et al.* (2020).

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First report of *Glenea multiguttata* Guerin-Meneville, 1843 (Cerambycidae, Lamiinae) from Goa, India

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ABSTRACT: Flat faced longhorn beetle (Cerambycidae, Lamiinae) collected in the Ambulor Verna (Goa), was identified as *Glenea multtigutta.* This species is being reported for the first time from Goa State. Furthermore, the geographical distribution, morphological characters, natural images and taxonomic photo plate are given. © 2024 Association for Advancement of Entomology

KEY WORDS: Morphology, distribution, natural images, taxonomic photos

The members of Cerambycidae are one of the most diverse groups of existing beetles which includes approximately 37,000 described species (Tavakilian and Chevillotte, 2020). Out of which subfamily Lamiinae comprising roughly 20,248 described species under 3052 genera are known (Roguet, 2012). Previously, Kariyanna *et al.* (2017) published a checklist of 1536 species of Cerambycidae from India; of them, 10 species under 10 genera among 4 subfamilies from Goa State were recently presented by Gadekar *et al.* (2023). Members of the flat faced longhorn beetles belong to the subfamily Lamiinae, which are mostly xylophagus and polyphagus insects (Ozdikmen and Caglar, 2004). There are 719 species in the genus Glenea, 99 non-nominal subspecies, and 36 subgenera (https://lamiinae.org/glenea.group-11692.html). The species *Glenea multiguttata* was described by Guerin-Meneville in 1843, under the genus *Saperda*. It is a generally known as flat faced longhorn beetle which is distributed known from following states of India viz., Assam, Bihar, Karnataka, Kerala, Maharashtra and Tamil Nadu, Uttarakhnd and also reported from Bangladesh (Beeson and Bhatia, 1939; Kariyanna *et al.,* 2017). This sapwood borer was identified using diagnostic characters and keys provided by (Gahan, 1887; Kariyanna *et al.,* 2019). While, survey and samplings of longhorn beetle from Goa this specis recorded. There is no previous report from Goa State on this species.

***Glenea multiguttata* (Guerin-Meneville, 1843) (Images 1-6)**

*Saperda (Sphaenura) multiguttata*Guerin-Meneville, 1843: 60.

Glenea multiguttata Gahan, 1897: 492 (Syn.)

Material examined**:** Goa - Ambulor (Verna): Male, 13.x.2022, at light source, altitude (0 m), coordinates (15. 3511509° N; 73. 9222043° E), time (09: 37: 13

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Fig. 1-2, *Glenea multiguttata* Guerin-Meneville, 1843 from Ambulor Verna (Goa): Dorsal view

Fig. 3-6, Morphology of Glenca multigulata (Guerin-Moneville): 3-4 Dorsal and ventral ciew; 5. Lateral view; 6. Front view of head

pm), Coll. Sanjay Sawant, host plant-unknown.

Adult (female): Body length: 12.9 to 13mm; width: about 3.6 to 4mm. Medium-sized beetle, elongate, and slender. Dorsal side entirely covered with yellow pubescence, head is not broader than prothorax, eyes black in colour and widely separated, antennae extending beyond elytral apex in female, first segment slightly enlarged as compared to other segments, antennal tubercle black, frons covered with yellow pubescence with median longitudinal black band, genae and vertex covered with yellow pubescence, the maxilla, labium and submentum are chocolate brown in colour, mandible brownish to black; pronotum covered with yellow pubescence, somewhat rounded or oval shaped black spots, slightly rounded at lateral margins, prothorax partially subquadrate which is broad and longer in female, a small edge like appearance at the central region of pronotum, lateral margins with a black spot; elytra brownish to yellow and slightly angled at humeri, somewhat narrow at apical region, not extending beyond the apex of abdomen and sharp spines at outer angle of each elytron and elytron covered with irregular, and somewhat rounded black spots starting from base and reaching to apex. Ventrally brownish to yellow in colour, with irregular black stripes at metepisternum and metasternum and horizontal black strips at abdomen sternite, entire legs covered with chocolate brown in colour, claws widely separated with thin brownish hairs.

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Comparative morphometric studies between black and yellow strains of Indian honeybee - *Apis cerana*

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ABSTRACT: The study aimed to investigate the morphological differences between the strains of the *Apis cerana* honey bee revealed that there were no major variations with morphology of black and yellow morphs but the proboscis length and number of hamuli on forewing showed some differences. The black and yellow morphs are reproductively isolated and differ slightly in two morphological characteristics out of the 13 examined. The study establishes that without any geographic restriction, population at higher and lower elevations exhibited differences in these two morphological characteristics of honey bees.

KEY WORDS: Feral colony, variations, strains, proboscis, hamuli

Honeybees are valued for their contributions to mankind and its essential role during pollination of agriculture and horticultural crops is overwhelming. A special feature of the honeybee community is its explicit organismal focus and is social insects and lives together in nests or hives. The honeybee is remarkable for the dancing movements it performs in the hive to communicate information to its fellow bees about the location, distance, size, and quality of a particular food source in the surrounding area. Maa (1953) divided honeybees into 3 genera based on the morphological features of the honeybees, i.e., *Micrapis, Megapis* and *Apis* (European and Asian cavity nesting bees). Ruttner (1988) re-investigated and summarized morphometric information on the eastern cavity-nesting bees, which he considered as one species *A. cerana.* And further grouped the *A. cerana* populations into four subspecies, Northern subspecies – *A. cerana*, Japanese subspecies – *A. cerana japonica,* Himalayan subspecies – *A. cerana himalaya* and Southern subspecies – *A. cerana indica***.** Though *A. cerana* is a single species, Oldroyd *et al*. (2006) demonstrated that Indian cavity-nesting bees (*A. cerana*) are reproductively isolated between the two morphs, black and yellow strains. The classification of morphs was based on the first 3 tergites on abdomen. Also, two morphs thrive themselves in hill regions (black) and plain lands. Considering these studies Chethana *et al*. (2014) tried to check if these morphs are diverse at genetic level utilizing the four different mitochondrial genes. Recently Shanas *et al*. (2022) ensured that the yellow and black strains taken as the study group

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Table 1. Morphological differences analyzed with 13 different characters between 20 black morph and 20 yellow morph - *Apis cerana*

Characters	Black morph		Yellow morph	
	Range	Mean	Range	Mean
Body length	13.21 -13.26	13.231+0.42	13.18-13.21	13.196+0.09
Head length	4.25-4.28	4.268+0.24	4.34-4.37	4.355+0.03
Head breadth	3.34-2.38	3.357+0.22	3.34-3.37	3.349+0.10
Proboscis length	5.45-5.49	5.469+0.11	4.80-4.85	4.283+0.14
Antenna length	3.95-3.98	3.96+0.09	3.93-3.96	3.942+0.05
Forewing length	3.95-3.98	7.89+0.05	7.79-7.82	7.802+0.02
Forewing breadth	2.64-2.67	2.65+0.15	2.58-2.61	2.594+0.08
Hindwing length	5.57-5.60	5.582+0.08	5.51-5.55	5.528+0.05
Hindwing breadth	1.55-1.58	1.564+0.12	1.51-1.55	1.529+0.05
Hamuli no.	16-17	16.5+0.05	19-20	19.4+0.10
Tibia length	2.79-2.82	2.802+0.14	2.76-2.80	2.776+0.9
Metatarsus	1.95-1.98	1.964+0.10	2.00-2.03	2.015+0.02
Abdomen length	3.72-3.76	3.737+0.09	3.82-3.85	3.832+0.03

are indeed one species (either *A. cerana, A. indica or A.karinjodian*). The present study aimed to find if there are morphological differences which categorize the *A. cerana* into black and yellow morphs.

Morphological studies were carried out to resolve differences between yellow and black strain of *A. cerana.* The feral colonies were selected for better understanding of the native bees. Samples of yellow morphs (n=29) were collected from the plain lands of Doddaballapur (800m elevation), and black morphs (n=25) from the hilly regions of Madikere (1392m elevation) in Karnataka state. The sampled bees were immediately stored in 70% ethyl alcohol for further study. Subsequently sample was transferred to fresh ethanol after two days. Twenty bees from each (black and yellow strain) colony were employed for morphometric analysis utilizing the techniques and few characters as illustrated by Ruttner (1978, 1988). It was not accurate way to infer the two different morphs with only a single morphological criterion to define or identify species and hence 13 morpho characters were considered for studies. Therefore, feral black and yellow colonies sampled from their respective colonies were considered. A total of 13 characters were evaluated: body length, head length and breadth, antenna length, proboscis length, forewing length and breadth, hindwing length and breadth, number of hamuli on wing, tibia length, metatarsus length, abdomen length. The measurements were carried out using Motic Image Plus 2.0^{ML} microscope and a computer aided measuring system based on Motic multimedia software offered by China Group Co. Ltd. The prepared slides were stored and deposited in Department of Entomology, University of Agriculture Sciences, Bengaluru, Karnataka. The microscope was calibrated to determine the value of each division on the ocular micrometer. The obtained value of the division was used in measuring the size of the characters. The microscope was calibrated with three different sizes *i.e.,* 1X, 2X and 4X. In the studies to compare two different morphs of *A. cerana* 13 different morphological characters were analaysed (Fig. 1, Table 1).

The morpho characters studied among 20 samples

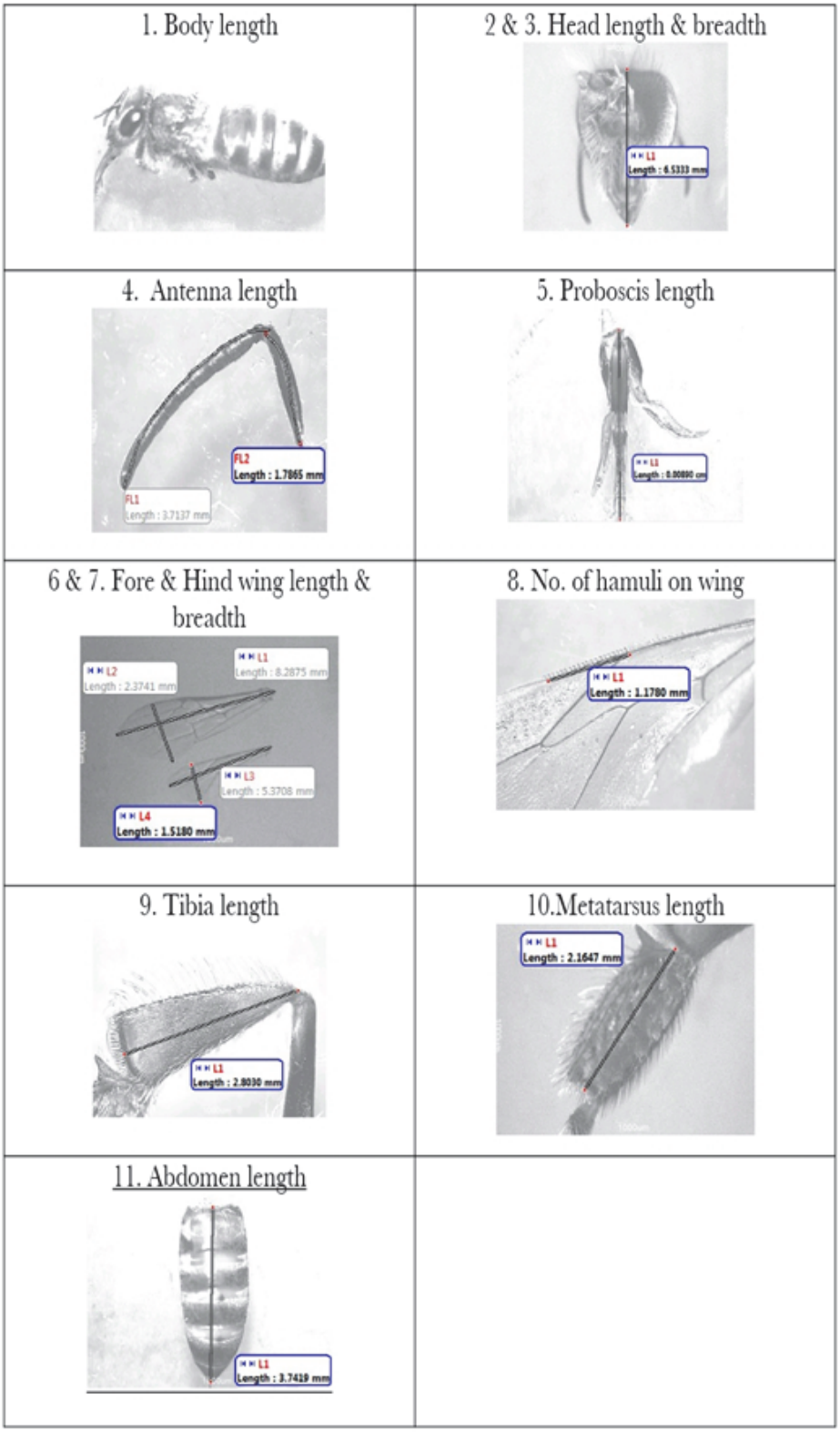

Fig.1 List of morphological characters considered for the study

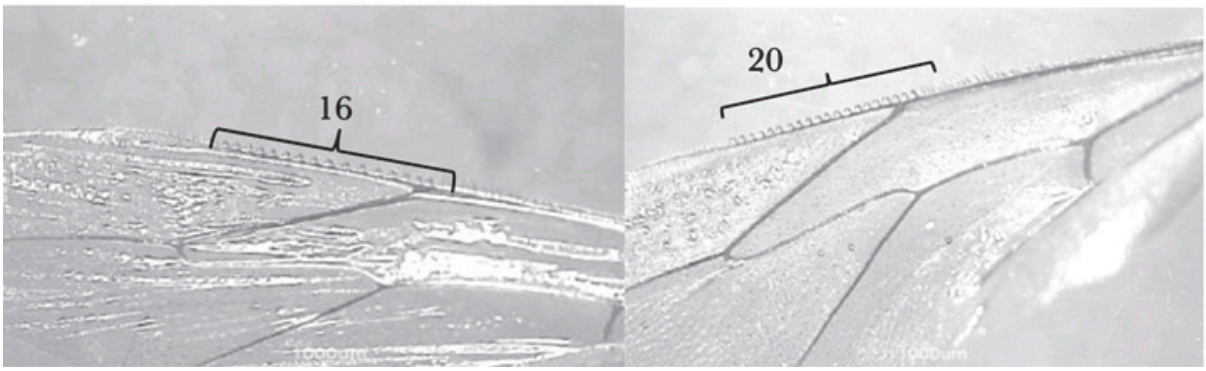

Fig. 2 Hamuli in black and yellow morphs

of each morph revealed the physical characteristics of the black and yellow morphs of *A. cerana*. Careful investigation revealed no major morphological differences between the black and yellow morphs, except for the proboscis length and the number of hamuli on the forewing showed some differences. The mean length of proboscis of the black morph was 5.469±0.11mm and yellow morph was 4.283±0.14mm and the mean number of hamuli on forewing of black morph was 16.5+0.05mm and yellow morph was 19.4±0.10mm. The other characters were quite similar, with negligible variations that did not contribute to significant differences.

During sampling of worker bees, an interesting observation was made that the tergites on the abdomen of the worker bee varied in its colouration, as discussed in earlier reports (Smith and Hagen, 1996; Oldroyd *et al*., 2006; Bhaskaran, 2011). Usually, worker honeybee will have 8 tergites in which 5 are clearly visible and the rest are modified into the sting at the tip of the abdomen. The visible tergites were yellow colour in few bees and black in the others. The current study set out to determine whether the two different-colored bees were members of the same morpho-cluster or if any additional characters would distinguish them from one another. This issue raised the question of whether the two species were distinct from one another or if they were cryptic species or sister species. Morphological characteristics have created an interest towards two morphs showing more differences rather than tergites colouration (Kapil, 1956; Kshirsagar and Ranade, 1981). It was quite interesting to know that there were variations among two morphs for characters like proboscis length and the number of hamuli on the hindwing. Szabo (1990) who carried out in Sri Lankan bees, stated that the effect of temperatures might have caused these variations in the two different morphs.

The proboscis length of black strain was 5.469±0.11 and yellow strain was 4.283±0.14mm. The length of proboscis in hill strain is longer than the plain bees. The present results were congruent with previous morphological studies (Kapil *et al*., 1956; Mattu *et al.,* 1984a; Verma *et al*., 1989; Verma, 1992) which indicated that nearness to sea influenced over the size of tongue of the bees might be a cause for such variations (Hepburn *et al.,* 2001a, b). This further may be ascribed to the kind of floral diversity at higher elevation would have made these bees to adapt with longer proboscis to collect the nectar and pollen during foraging.

Hamuli, which are hooks present on the anterior margin of the hindwing, are used for wing coupling and for fanning nectar to evaporate water content to produce honey. Their number perhaps may have role in the flight efficiency. In the present analysis, significant variation in hamuli number was evident (Fig. 2). The highest number of hamuli in the plain (yellow) bees was 20, and the least number in the hill (black) bees was 16, with mean numbers of 19.4±0.10 in yellow bees and 16.5±0.05 in black bees. The places of higher altitude >900m had bees with a lesser number of hamuli when compared

with that of lower altitude <6000m above mean sea level. In other words, plain morphs had more number of hamuli than the hilly morphs. However, there was no similar trend in the number of hooks in the bees from north and south India (Kapil *et al*., 1956; Jain *et al*., 1967; Kshirsagar *et al*., 1976; Mattu *et al*., 1984a; Singh *et al*., 1990). Present results were completely contrary to the earlier studies arising questions for the reasons behind this drastic divergence. It is predicted that extreme temperature conditions may have certain bearing on these parameters. Plain land would had led to high flight efficiency, increasing the distance of foraging rather than hilly region, resulting in a higher number of hamuli in plain bees.

The present study concludes that the black and yellow morphs are reproductively isolated and differ slightly in two morphological characteristics out of the 13 examined. However, extensive genetic studies are required to decide if the black and yellow strains are eco-races or subspecies of *A. cerana.* The elevation always has unique vegetation that attracts honeybees to fly higher, and these vegetations have flora that attracts bees which adapt to it with longer proboscis and the number of hamuli number to be higher for better flighting. The length of the proboscis is closely related to the deepness of the nectar glands of flowers recognized to be the best sources of food.

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Assessing the role of RNA in manifesting the potential of mendione as an effective insecticide against *Dysdercus cingulatus* F.

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ABSTRACT: The impact of sublethal concentrations of menadione was evaluated on the RNA content of gonads, fat body, and brain in *Dysdercus cingulatus* F. Three sublethal concentrations viz. 0.5, 0.75, and 1.0 µg were used topically using a Hamilton syringe. The test insects were dissected after the intervals of post-treatment days 2, 4, and 6. Organs of the treated insects were evaluated and compared for the RNA content with control insects. The biochemical results revealed a gradual significant decline in the RNA content of various tissues under investigation. Hence it was concluded that menadione not only hampers the protein and DNA metabolism, but it roots back to the RNA level to induce histopathological changes in organs to finally act as a reproductive inhibitor and life cycle disruptor.

KEY WORDS: Sublethal concentration, naphthoquinone, reproductive inhibitor, DNA metabolism

Menadione is a synthetic compound, which is an analogue of an effective natural pesticide, plumbagin (Magdum *et al.*, 2001). It is known to have insecticidal properties against a cotton pest, *Dysdercus cingulatus* F. (Hemiptera, Pyrrhocoridae) (Singh-Gupta *et al.*, 2015). Moreover, it is biodegradable by bacteria in soil (Li, Song and Gao, 2011) and is light-sensitive. Hence menadione may serve the purpose of protecting the crop from pests. Menadione was found to decrease the content of carbohydrates (Singh-Gupta *et al.*, 2013) and proteins in the different organs of *D. cingulatus* (Singh-Gupta and Magdum, 2019). The decline in carbohydrate content could be explained based on the antifeedant property of the plumbagin and menadione. However, the decline in the protein content cannot be stated simply. Eventually, the Nucleic acids are the master macro molecules controlling all the morphological development and metabolic activities of insects either directly or indirectly. Hence in the present work, the effect of menadione on RNA content was explored. Moreover, the effect of menadione on the gonads of *D. cingulatus* has been noted, as it is an analogue of a known chemosterilent, plumbagin (Magdum *et al.,* 2001). Menadione has produced several histological deformities (Singh-Gupta and Magdum, 2016), (Singh-Gupta *et al.,* 2014) in the gonads, and brain of *Dysdercus*, which is a reflection of a reduced amount of protein (Singh-Gupta and Magdum, 2019) and DNA content (Singh-Gupta *et al.*, 2020). The current research has been designed to find out the toxic effect of menadione on the RNA content in gonads, fat body and brain of *D. cingulatus*.

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Insects were procured from the Zoology Department, Deshbandhu College, Delhi University. The adult male and female were separated by observing the size, as males are smaller as compared to females. Four pairs of adult insects were released in each rearing jar. These insect jars contain wet moist soil forming a layer at the bottom and the mouth of these jars was closed using muslin cloth and tied with a rubber band. The insects were fed on soaked cotton seeds. The females after mating laid eggs three times during the period of 3 to 4 days. A single female laid around 70 to 80 eggs. The life cycle of *D. cingulatus* consists of 5 intermediate nymph stages before molting into final adult form. Newly molted adult *D. cingulatus* were treated topically with different sub-lethal concentrations of Menadione 0.25µg, 0.5 µg and 0.75 µg (standard solution of 1mg/ml Menadione in acetone) using a Hamilton syringe and they were dissected on different post-treatment days (PTD) viz. 2, 4 and 6 in chilled insect ringer's solution. The tissues of the treated and control males and females were separated. These tissues were homogenized separately using Eppendorf and pestle in 10 per cent chilled Buffered Saline {0.15M Sodium Chloride (NaCl) + 0.015M Sodium tri Citrate (Na_3 Citrate)}. This solution was then subjected to centrifugation at 5000 rpm for 20 minutes at cold conditions (4°C) and the supernatant was used for the estimation of RNA (Raksheskar, 2012). Later, RNA was quantified by the method of Orcinol reaction.

The results of colorimetric analysis showed universal decline in the RNA content of tissues under investigation upon treatment with different doses of Menadione. The significance of these changes was calculated by applying the T-test using the software "Minitab 14" and was noted. With the increase in the concentration of Menadione and the post treatment days, the amount of RNA declined in the tissues under investigation (Table 1).

Protein is one of the main biomolecules in an organism which plays a crucial role in regulating various metabolic pathways. Any fluctuations in the protein content are directly going to affect the functioning of an organism. Menadione has been known to induce a decline in protein content (Singh-Gupta and Magdum**,** 2019). The quantity of protein in an organism is a result of a delicate equilibrium between the rate of protein synthesis and degradation. Several factors may come together to influence the quantity of protein in the organs of *Dysdercus*. These factors operate at three different levels to regulate the quantity of protein in a tissue. The first level is at DNA, as Menadione is known to alter the DNA structure and bases as a result of Reactive Oxygen Species formation, which consequently leads to its degradation. So, this damage to DNA could be the probable cause of protein decrease (Jena, 2012). The second level is RNA, as the synthesis of RNA plays an important role in the process of protein synthesis. So, the inhibition of RNA synthesis at the transcription level or degradation of RNA may also affect the protein level (Lin-Quan Ge, 2009). Even any disturbance in the translation process owing to oxidative stress caused by menadione will also lead to a decline in protein content. (Kong and Li, 2010). The third level is at the protein level, where either the decrease is due to the diversion of energy when an animal is under stress (Manoharan and Subbiah, 1982; Mommnsen and Walsh, 1992) or it's due to the degradation of proteins, which could be possible through actions such as impaired incorporation of amino acids into polypeptide chains (Singh *et al.,* 1996) or formation of reactive oxygen species by Menadione.

In light of the above-discussed interrelations and the fact that menadione has led to the decline in protein and DNA (Singh-Gupta *et al.*, 2020) content of various organs, the present work has incorporated the evaluation of RNA in gonads, fat bodies, and brain. A significant decline in RNA content of tissues was in accordance with many workers like Attrib and Ravi (1980 a and b); Naqvi *et al.* (1989*,* 1993), who focused on the fact that Insect growth regulators could act as a pesticide and exhibit a moderate to high level of inhibition of both RNA and DNA. Similarly, Phillips and Loughton (1979) reported sixty percent inhibition in RNA in *Locusta migratoria* after Dimilin treatment. According to him, even protein synthesis was also inhibited. Perveen (2012) also reported the decline in the DNA and RNA content after

Table 1. RNA content (µg/ml) in the gonads/ fat body/ brain of the treated male and female *Dysdercus cingulatus* (** - Highly significant and * - significant)

Organ	Menadione (µg)	RNA (µg)±SD on PTD 2	RNA (µg)±SD on PTD 4	RNA (µg)±SD on PTD 6
Testes	Control	48.49±1.14	65.16±0.51	58.42±1.81
	0.5	47.99±0.14	63.94±0.69*	54.13±0.66*
	0.75	47.43±0.68	62.20±0.84**	50.5±1.66**
	1.0	44.19±0.79**	53.25±0.24**	50.50±1.66**
Ovary	Control	226.6±8.08	284.6±14.2	274±10.500
	0.5	219.6±4.04	279.6±2.88	267.3±14.0
	0.75	205.3±14.4*	261.6±7.5*	263±8.66
	1.0	199.3±14.6*	232.6±9.23**	231.06±9.07**
Male fat body	Control	65.04±0.41	63.3±1.15	62.70±0.28
	0.5	64.12±1.00	62.39±0.41	61.76±0.30**
	0.75	63.00±0.38**	60.34±0.60**	59.51±0.81**
	1.0	59.02±1.17**	54.11±0.27**	53.72±1.13**
Female fat body	Control	69.02±0.42	72.48±0.69	68.65±1.02
	0.5	69.02±0.42	71.54±0.78	65.62±4.89
	0.75	68.19±0.93	68.36±1.00**	64.64±0.95**
	1.0	64.41±1.06**	64.39±0.81**	63.56±0.75**
Male Brain	Control	53.67±0.88	52.43±0.75	51.42±1.91
	0.5	53.42±1.15	52.27±1.03	49.8±1.26
	0.75	51.55±1.50	51.14±0.71	49.59±1.01
	1.0	50.00±0.32**	50.49±0.40**	49.59±1.02
Female Brain	Control	53.77±1.22	52.47±0.76	52.56±1.15
	0.5	53.10±0.81	51.64±0.47	51.80±0.76
	0.75	52.26±0.00	50.14±1.34*	51.80±0.76
	1.0	48.17±1.42**	50.18±0.34*	49.43 ±0.37*

Chlofluazuron treatment in *Spodoptera litura.* Devi *et al.* (1985) also noted a decline in the content of RNA of the fat body of *Dysdercus koenigii* during the treatment of Actinomycin-D. In the present work, RNA was inhibited by the Menadione during ovaries, testes, and egg development. The decline is noted at all three levels. However, the percent decline in DNA, RNA, and protein is not the same which shows that menadione affects the protein content of gonads at different levels by affecting or degrading DNA, RNA and Protein. The disparity of DNA and RNA content decline is in accordance with Chinzei and Tojo (1972) and Premkumar *et al.* (1991) who noted a similar disparity in DNA and RNA contents when observed in *Bombyx mori* and water scorpion, respectively. These reports were also supported by Perveen (2012) that, the percentage of DNA and RNA was dissimilar after treatment with sublethal doses of Chlorfluazuron even when they were noted on the same day and at the same stage of *Spodoptera litura*. Hence, this decline in the RNA content of gonads is partially responsible for the overall decline observed in the protein content of gonads upon Mendaione exposure. Eventually, this effect was reflected in the histopathological deformities in gonads that ultimately affected the reproductive potential of *D. cingulatus* (Singh-Gupta *et al.*, 2013; Singh-Gupta and Magdum, 2016).

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Life cycle of *Megymenum distanti* Kocorek & Ghate, 2012 (Heteroptera, Dinidoridae) on *Momordica indica* L.

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ABSTRACT: The life history of a dinidorid bug *Megymenum distanti* Kocorek & Ghate, 2012 was examined under controlled laboratory conditions. The female bug laid about 32 eggs after mating. Only 8 of these 32 eggs actually hatched, for a hatching ratio of only 25 per cent and these 8 nymphs were observed further. The eggs required 11 to 13 days to hatch. There were five nymphal stages, lasting 48 days in total. The nymphal periods for the first, second, third, fourth, and the fifth instars were 11, 9, 8, 7 and 13 days, respectively. Male adults survived 21 days on average, whereas female adults lived 32 days on average after mating. Within 82-93 days, the entire life cycle was completed. Except for the first instar nymph, both nymphs and adults feed on leaves of *Momordica indica* L.

KEY WORDS: Dinidoridae, life history, nymphs, adult longevity

The family Dinidoridae (Hemiptera, Heteroptera), is a small family with roughly a hundred species distributed among16 genera (Lis *et al*., 2012). However, there is no common name for this family. This family includes the subfamilies Dinidorinae and Megymeninae and four tribes Megymenini, Dinidorini, Thalmini, and Eumenotini (Durai, 1987). There are about 26 species in the genus *Megymenum* Guerin, that are distributed in the Oriental, Australian and Sumatra Regions (Rolston *et al.,* 1996; Kocorek and Lis, 2000) and only 6 of these are found in India (Rolston *et al.,* 1996; Kocorek and Lis, 2000; Kocorek and Ghate, 2012). During field work, the first author, observed this bug on the host plant *Momordica indica* L. (during mating phase) on July 7, 2022. A single mating pair of bugs was collected from Dodamarg Tehsil (Lat. 15. 681004° N and Long. 74.96668° E) at an elevation of 51 m. These bugs were brought to the laboratory and then placed in an insect rearing cage (size is 15×15×15 cm) for further observations of their life history. The bug was identified as belonging to the genus *Megymenum* based on Distant (1902) and further identified as *M. distanti* based on Kocorek and Ghate (2012).

Megymenum distanti Kocorek and Ghate, 2012

Adult body large, somewhat ovoid, dark brownish to black, with metallic tinge (Plate I - Fig. 2, 13). Head brownish to black, punctured, mandibular plates deeply concave, preocular part swollen with very sharp process; mandibular plates longer than

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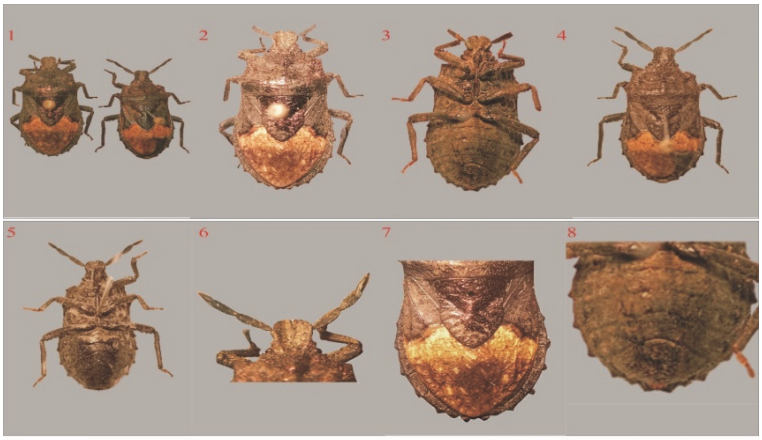

Plate - 1. (*Megymenum distanti*). 1. female and male, 2. Dorsal view of female, 3. Ventral view of female, 4. Dorsal view of male,5. Ventral view of male, 6. Antennae and head, 7. Scutellum and membrane, 8. abdominal segments

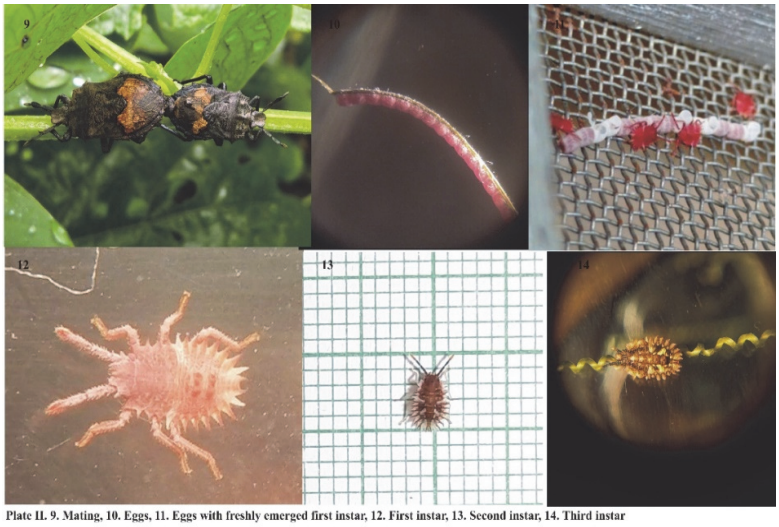

Plate II. 9. Mating, 10. Eggs, 11. Eggs with freshly emerged first instar, 12. First instar, 13. Second instar, 14. Third instar

Plate III. 15. Fourth instar, 16 & 17. Dorsal and ventral view of fifth instar, 18. Fifth instar in rearing cage, 19& 20. Moulted skin of fifth instar (dorsal and ventral view), 21. Freshly emerged adult with creamy white colour, 22. Adult with moulted skin

clypeus; eyes brownish and rounded, ocelli light brown in colour. Antennae four segmented, brownish to black, first segment short, not extending beyond the head, second segment longer than other antennal segments and slightly flattened, segment fourth narrow, spindle shaped with apex pointed

(Plate I - Fig. 6); rostrum light brown extending beyond fore coxae, segment first extending beyond the base of head, bucculae lobed and dark brown. Pronotum dark brown, with punctures on its anterior surface and numerous fine ridges, antero-lateral margin rounded while lateral pronotal margins bearing a single pointed projection (Plate I - Fig. 2). Scutellum dark brownish to black, with distinct punctures on its surface, triangular (Plate I - Fig. 7); corium shorter than scutellum, with fine punctures, membrane light brown , with dark brownish patches on its surface, not reaching tip of abdomen, with numerous veins. Abdomen as broad as pronotum at base. Legs brownish black, tarsal segments brown, ventral surface of all femora with small spines. Abdomen ventrally brownish to black with fine punctures on its lateral margin, connexivum exposed (Plate I - Fig. 8). Measurements (in mm based on single male/ female). Male: total body length 12. 5 to 13 and Female: total body length 13.4 to 13.9.

Adult dinidorid bug was first discovered on the campus of Pune University. After a ten-year gap, this species was again discovered in Dodamarg, on different host plant on July 7, 2022. The life history of *Mygemenum distanti* was studied under laboratory conditions. The descriptions and illustrations of the stages from eggs to fifth instar nymphs are given below. For this life cycle study, only a single mating pair was collected. After mating, female bug laid 32 eggs on the tendrils of host plants (Plate II, Fig. 10). Only 8 of these 32 eggs hatched, and all these eight nymphs developed into adult stage. Of the eight adults, 5 were females, and the rest were male. Eggs are tiny, barrel-shaped, white and about 1.2mm in length after the oviposition, and then turn into brownish red, as the development proceeds. The eggs are laid as continuous chains on the tendrils.

First instar (Plate II, Fig. 11, 12)**:** The eggs hatched after 11 days. The first instars were dark reddish (Plate II, Fig. 11) and 4mm in length. The early instars showed colour variation. The first instar nymphs move around the eggs without feeding (Plate II, Fig. 11). Body less elliptical, flat, newly emerged nymph covered with reddish colouration on head, antennae, pronotum, abdomen, legs, rostrum, and ventral region then turn into brownish yellow and ventrally pale cream coloured. Eye brownish and rounded, preocular spine prominent, pronotum with a thin angular process, mandibular plate and clypeus of head distinct; abdominal segmental suture visible with lateral projection on connexival areas, legs with fine black spinulus, wing pads not developed, spiracles visible.

Second instar (Plate II, Fig. 13): nymph (about 8 mm in length) began feeding on the leaves and was more active than the first instar; duration of this stage was around nine days. Body flat, mandibular plates longer than clypeus and distinct, eye brownish and rounded, preocular spine prominent; antennae robust with spinules, not longer than body, antennal segment 1st to 3rd are black, apical segment pale ochraceous with pointed, segment 1st small as compared to others, not reaching apex of head; pronotoum reddish ochracecous, lateral margin sinuate (Plate II, Fig. 13), covered with brown patches; abdomen pale brownish with brown patches and spots, crenulate on connexival area (Plate II, Fig. 13); dorsal abdominal glands well developed, scutellum not well developed. Ventrally pale ochracecous, spiracles are visible and distinct.

Third instar (Plate II, Fig. 14): nymphs (11mm) increased in size compared to earlier instar, were more active, and its total duration was only 8 days. Body darker in colour (Plate II, Fig. 14), mandibular plates longer than clypeus and distinct, eyes well developed, brownish and rounded, preocular spine prominent. Antennae black only 4th segment pale ochracecous, pronotum with brownish patches and spots with lateral margin, sinuate; abdomen pale ochracecous, oval, wider than pronotum, with lateral spinules on connexival area (Plate II, Fig. 14); dorsal abdominal glands well developed; spiracles are clearly visible; legs brownish white in colour.

Fouth instar (Plate III, Fig. 15): nymph was considerably larger than one in its third instar, has a more active feeding capacity, and it has a body surface that is brown. Nymphs spent 7 days in their fourth instar stage. Head pale ocharacecous, Eyes brownish, preocular spine dark and prominent with

concave, antennae black, segment first short, segment 1st to 3rd black, segment 4th pale ocharacecous with pointed tip (Plate III, Fig. 15); pronotum covered with brownish patches and spots and laterally sinuate; abdomen, pale ochracecous, oval shaped, broader than pronotum, with lateral spinules on connexival area, dorsal gland well developed, trichobothria visible and in pairs situated below spiracles, spiracles visible and dark brown, labium pale ocharacecous, extending beyond the prostrnum; wing pads developed (Plate III, Fig. 15).

Fifth instar (Plate III, Fig. 16, 17, 18)**:** nymphs, were much larger than those in the previous instars, were actively feeding on the host plant. These have body parts that are well developed and darker in colour. This stage just needs 13 days to finally moult into an imago. Head pale ocharacecous, mandibular plates longer than clypeus and joined in front of median lobe, eyes well developed, brownish and rounded, preocular spines sharp and prominent (Plate III, Fig. 16). Antennae black, segment first short, not reaching apex of head, segment second long as rest of antennal segment, segment 1st to 3rd black and segment 4th pale ocharacecous with pointed tip; Pronotum well developed than 3rd and 4th instar, and covered with brownish black irregular spots, anterior margin concave behind head (Plate III, Fig. 16), fine teeth like appearance on its lateral margin, dentate on its posterior border, lateral angles with small blunt spine like structure; abdomen well developed, broader than pronotum, dark brownish, with irregular brown to blackish spots and patches, spinules like appearances on connexival areas (Plate III, Fig. 16); wing pads well developed with brown spots, dorsal glands dark and prominent; scutellum not fully developed, its surface covered with brown spots; ventrally dark brown to blackish spots laterally (Plate III, Fig. 17); rostrum pale ocharacecous extending beyond the fore coxae; femora darker, with small ventral spinules, tarsi brownish and two segmented claws well developed; spiracles dark brown and visible, trichobothria located below spiracles.

The lives on the host plant *Mormodica india* and is the second recorded host plant for this species, where it completes its whole life cycle. The entire life cycle was completed within 82-93 days. Of the two adults collected and reared in lab, the female survived more than male, female bug spent 32 days after laying eggs, while male survived only 21 days. From first instar to fifth instar nymphal period is about 48 days in total. Adults that have recently emerged are creamy white (Plate III, Fig. 21), with the exception of their antennae and eyes.

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First record of water mite larvae, *Hydrachna* sp. (Acari, Hydrachnidae) parasitism as quiescent nymphophan on two major aquatic insects of Coleoptera and Hemiptera from West Bengal and Odisha, India

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Month	Host no.		Infested host no.		Prevalence (%)		Parasite no.		**Infection** intensity		Body location	
	Hy	Le	Hy	Le	Hy	Le	Hy	Le	Hy	Le	Hy	Le
December, 2021	8	0	1	0	12.5	-	1	0	1	-	Hind tarsus (right)	-
April, 2022	13	1	3	1	23	100	6	98	**2**	98	Foreleg coxa, pronotum, metasternal process	Scutellum, wings, prosternum, coxal region
August, 2022	2	0	0	0	0	-	0	0	0	-	-	-
December, 2022	9	0	0	0	0	-	0	0	0	-	-	-
April, 2023	9	0	2	0	22.2	-	4	0	**2**	-	Hind tarsus (left), foreleg coxa, prosternum	-
August, 2023	1	0	0	0	0	-	0	0	0	-	-	-

Hy – *Hydrophilus*, Le – *Lethocerus*

1) column named "Average intensity" will be "Infection intensity"
2) Read 0.46 as 2
3) Read 0.44 as 2

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