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Fig. 1-5 *Acanthocoris scabrator.* 1. Syntype (Natural History Museum, London), 2. Mass of eggs and hatched out egg shells, 3. early instar nymphs, 4. nymphs congregated for feeding, 5. adult
For details see page No. 472 of this issue

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BIOLOGY AND MORPHOLOGY OF *LAMPETIS MIMOSAE* (BUPRESTIDAE, COLEOPTERA) FROM IRAQ

Muslim Ashor Al-Etby* and Husien Ali Al-Amery

Department of Plant Protection, College of Agriculture, University of Basrah, Iraq
*Email: muslim.abdel_wahed@uobasrah.edu.iq (corresponding author)

ABSTRACT

This study includes study on 138 specimens of a flat-headed borer *Lampetis mimosae* (Klug) 1829 (Buprestis) collected from Basrah province, southern Iraq. These were collected from March 2019 to April 2021. The morphological characters analysed include those of head, thorax and abdomen (females and males). The distinguing characters include body strongly chitinized, elongate, subcylindrical and covered by fossae, with elytra bronze coloured having metallic shine. The specimens were observed attacking jujube trees *Ziziphus spina-christi* (L.) Desf.

Key words: *Lampetis mimosae*, Iraq, identification, taxonomy, distinguishing characters, *Ziziphus spina-christi*, biology

The buprestid beetle *Lampetis mimosae* (Klug, 1829) under the order Coleoptera and the suborder Polyphaga is along with about 15,000 species (Bellamy, 2008) of which seven species are known from Al-Anbar province of Iraq (Ezeddin and Iman, 2021; Knopf, 1971). The members of this inhabit wet tropics andsemi-desert zones. These are distributed in Algeria, Chad, Djibouti, Egypt, Eritrea, Ethiopia, Greece, Jordan, Lebanon, Libya, Morocco, Oman, Saudi Arabia, Senegal, Sudan, Syria, Tunisia, Turkey, UAE, and Yemen (Bily et al., 2011). From Iran, 480, species are known (Ghahari et al., 2015), and these are usually xylophagous in larval stage developing under the bark or in the sapwood of trees and shrubs (Donald and Dwight, 1964). Of these, the metallic wood boring beetles *Lampetis* Dejean (1833), formerly considered a subgenus of *Psiloptera* are economically important. According to Bellamy (2003), this genus is one of the most speciose in the subfamily Chrysochroinae, tribe Dicercini. Ten *Lampetis* (*Spinthoptera*) species are known from North America, and eight species are from Mexico (Kerremans, 1893), six are from the West Indies (Corona, 2005), and three are from Iraq's Al-Anbar Province (Ezeddin and Iman, 2021). In view of their diversity and importance of *Lampetis mimosae* (Klug, 1829), this study from Iraq focused on its taxonomy.

MATERIALS AND METHODS

The study was conducted from March 2020 to June 2021. Specimens were collected from orchards in the Shatt al-Arab region (30.7391° N, 47.8427° E) in Basra Province. Dissecting, imaging, and measuring were done in the Entomology Laboratory, Agriculture College, University of Basrah. Adult specimens of *L. mimosae* (90 females and 48 males) were collected by direct catching from the following trees: athel tree, *Tamarix aphylla* (L.) Karst; and *Tamarix chinensis* Lour.,; jujube, *Ziziphus spina-christi* (L.) Desf.,; river-red gum, *Eucalyptus* sp., and mesquite, Prosopis juliflora (Sw.) DC.; while the larvae were collected from jujube trees Z. spina-christi. The morphological analysis of specimens was done following Nadia et al. (2013). Important characters in the head, thorax, and abdomen were studied (Al-Mallah, 2016). The images were captured using a Leica EZ4 stereozoom microscope in the Plant Protection Department, College of Agriculture, University of Basrah.

Identifcation followed the taxonomic keys (Wellso et al., 2017; Corona, 2005), and confirmed by Dr. Hassan Ghahari (Department of Plant Protection, Yadegar -e- Imam Khomeini (RAH) Branch, Islamic Azad University, Tehran, Iran,) and Dr. Mark Kalashian (Institute of Zoology, Scientific Center of Zoology and Hydroecology of the National Academy of Sciences of the Republic of Armenia, P. Sevak str. 7, Yerevan, 014, Armenia,). The plants were identified by Dr. Taha Y. Al-Edany (Department of Plant Protection, College of Agriculture, University of Basrah). The synonymy given follows the Global Biodiversity Information Facility (GBIF, 2021).

RESULTS AND DISCUSSION

Lampetis Dejean, 1833

Buprestodes Carter, 1924; *Eolampetis* Pongrácz, 1935; *Hesychiastes* Gistl, 1848; *Lampetis* Chevrolat, 1834; *Lampetis* Spinola, 1837; *Spinthoptera* Casey, 1909

Lampetis mimosae (Klug, 1829)

Buprestis mimosae Klug, 1829; *Lampetis cuprina* Alfieri, 1976; *Lampetis cyanea* (Alfieri, 1976); *Psiloptera cyanea* Alfieri, 1976; *Lampetis mimosae* (Klug, 1829)

Redescription

Head: Three species of *Lampetis* are known from Al Anbar Province: *L. mimosae*, *L. argentata* Mannerheim, 1837, and *Lampetis* sp. Adult insects are about 16-27 mm long and 5-9 mm wide, and their colour ranges from light to dark brown with a metallic reflection (Ezeddin and Iman, 2021). These have elytra with parallel striae, which join at the wing end. The elytron is dotted, as in prothorax. Head little wider than half width of thorax. *Lampetis mimosae* has the beetles medium sized (♀: length 22.3-28.9 mm, width 8.0 mm-10.6 mm);♂: length 15.5 -21.19 mm, width 6.16-7.87 mm), elongate subcylindrical, flat at front of head and sharply tapered at ends of wings and abdomen, body strongly, short antennae, bronze color (metallic shine), fossae on dorsal and ventral surfaces, ventral surface more glossier than dorsal surface. The head approximately circular (length 4.7-5.9 mm, width 5.9-6.0 mm), compound eyes relatively small, elongated and its length about 2.5x as maximum width, carving face clear, antennal cavities large, vertex nearly). broad. Antenna long (5.9- 6.0 mm) consists of 11segments; scape rounded, 2x as long as the pedicle, with flagellum having nine flagellomeres, 1 and 2 similar, 4-9 subtriangle and serrated. Mouthparts hypognathous, labrum bronze metallic, wider than long, distal area with row of short bristles; mandibles short, symmetrical, slightly curved, robust, approximately 2x longer than wide, condyle protruding, long and teeth simple; maxilla articulate with the head capsule through their basal sclerite cardo and stipes, elongated stipes, lacinia narrower than galea, apex rounded and covered with short bristles, oval-shaped galea, and thin and rigid bristles bordering the apical and lateral regions. and well developed with four segments, the first one shortest, while the second longest with short setulae; labium with prementum smaller than the mentum, the apical surface rounded, glossa small with a few bristles in the mid-apical region; labial palp three segmented, first of which smallest, and the third segment has a truncated apex with long hairs.

Thorax: Pronotum convex, broad about twice as wide as long (♀ wide 6.3-7.9 mm, length 3.72- 5.50 mm), anterior margin curved, posterior margin narrower than elytra, carving pattern very clear; prosternum with microbristles closed and rounded thigh cavities, scutellum transverse, almost heart-shaped, about one tenth width of elytra at base; prosternal spine clear middle region. Elytra twice as long than wide (♀ length 14.61-17.73 mm; width 3.79-4.95 mm), slightly widened in basal part base; almost parallel sided behind callosities to mid-length, outer surface of elytra with shaped cavities, mid dorsal line straight. Membranous

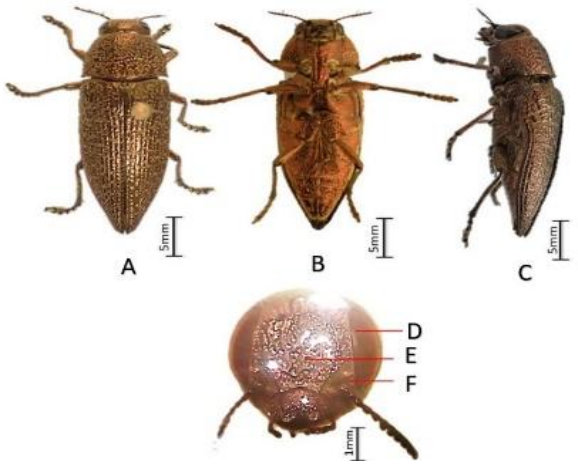

Fig. 1. Female of *L. mimosae*; A. Dorsal view; B. Ventral view; C. Lateral view; D. compound eye; E. carving face; F. antennal cavites

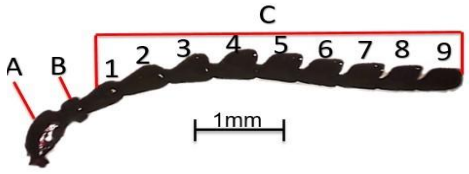

Fig. 2. Anntenna of *L. mimosae*

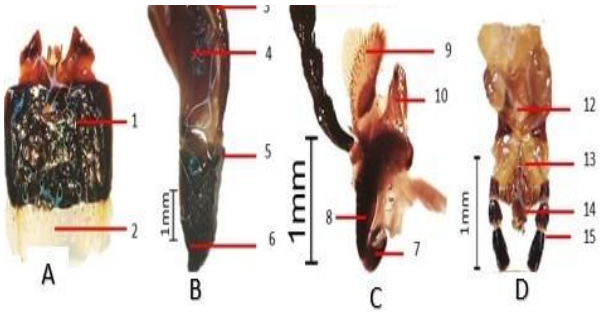

Fig. 3. Mouthparts of *L. mimosae*; A. Labrum, 1 carving face; 2 bristles; B. Mandible; 3 abductor. 4 adductor, 5 condyle, 6 teeth; C. Maxilla, 7 cardo, 8 stipes, 9 galea,10 lacinia,11 maxillary palpus; D. Labium, 12 prementum, 13 glossa, 14 paraglossa, 15 labial palpus

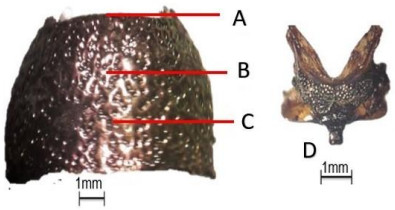

Fig. 4. Dorsal view of pronotum in *L. mimosae;* A. anterior margin; B. Carving pattern; C. Posterior margin; D. Scutellum. cavities

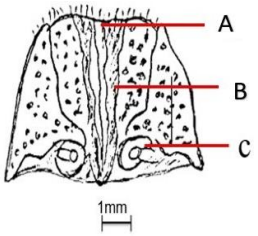

Fig. 5. Prosternum of *L. mimosae* A. Bristles; B. Prosternal spine; C. Fore coxal cavity

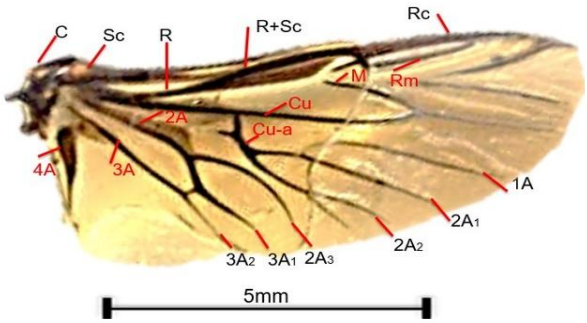

Fig. 6. Membrane wing of *L. mimosae*. C costal vein; SC subcostal; R radial, RC radial cell, M median, RM median radial, Cu cubital, CuA anal cubital, A anal

hind wing with costa short and thick, subcostal vein strong and unbranched, connects with the radial vein at the end of the first third of the wing length, extending apically along the anterior margin; radial cell (RC) formed by fusing the space between the subcosta and the radius (R+SC), and the radio-median cell (RM) is formed in the third anterior apical; medial vein, which is not connected to the radial sector (Rs), extends apically to the beginning of the apical third of the wing; the vein extends from the base of the wing and joins apically with the median (M); anal veins composed of four veins, second and third branched, while the first and fourth unbranched. The naming of veins is according to Fedorenko (2006).

Legs with foreleg 10.02- 11.77 mm long, midleg (12.14- 13.94 mm), hind leg (14.04- 14.50 mm), bronze coloured with intense metallic shine; coxa of forelegs and middle similar, coxal cavity of hind leg

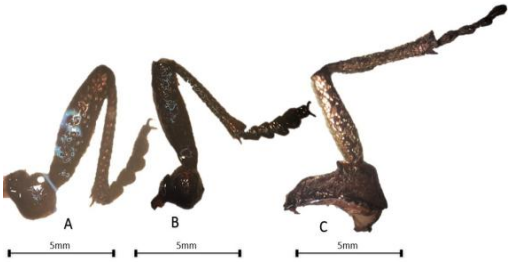

Fig. 7. Legs of *L. mimosae*; A. Foreleg, 1 coxa, 2 trochanter, 3 femur, 4 tibia,; B. midleg, tibia spurs, 6 tarsus, 7 tarsal claw, 8 coxal cavity; C. hindleg

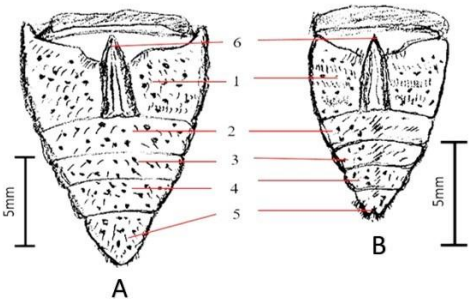

Fig. 8. Ventral view of abdomen in *L. mimosae*; A. Female; B. male, 1 first sternite, 2 second sternite, 3 third sternite, 4 fourth sternite, 5 fifth sternite, 6 first sternite process

large; trochanters exposed and differently sized; femur moderately robust, tibiae and tarsomeres similar in all legs, with femur of hind legs twice as long as wide; hind leg smaller than all, foreleg a little bigger than middle; tibial spur apical, internal in all legs, claws with tarsal pectin process tapered and curved terminally.

Abdomen: In female 15.48- 8.41 mm long, male 09.35- 11.80 mm long, surface densely punctate with abundant small, shallow, confluent punctations, first sternite almost twice as long as second, which about as long as 3 and 4; sternite 5th almost twice as long as fourth, with apex broadly and deeply excised, sternite 5th, cleft in the male and round female, sternite process

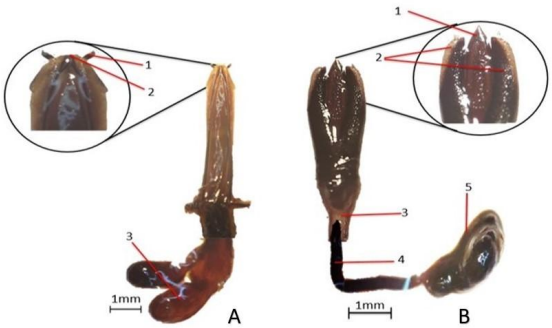

Fig. 9. Dorsal view of genitalia in *L. mimosae*; A. Female genitalia, 1 style, 2 coxito, 3 spermatheca; B. Male genitalia, 1 aedeagus, 2 lateral lobe (claspers), 3 phallobase, 4 vasa dererentia, 5 testis

Fig. 10. A Adult exit site on the *Tamarix pentendra*; B. Adult on the *Eucalyptus* sp.; C. Adult on *Tamarix articulata* trees; D. Adult on *Prosopis jutiflora* tree; E. Damage on the *Ziziphus spina-christi* tree; F. Larvae when attacking the plant stem; G. Trees dying due to injury

spear-shaped and hard. Female genitalia with few bristles located at base, styles tapered and reduced, very few short bristles at apex, spermathecal globose and very flexible; male genitalia, with sides lobes (claspers) well developed, rounded on apical region with punctuations, long bristles and sparse, aedeagus with a tapered apex, phallobase conical, base width almost twice smaller than apex and this with a mid-apical concavity.

Remarks

Hosts include athel tree *Tamarix articulate*, *T pentendra*, jujube *Ziziphus spina-christi*, river-red gum *Eucalyptus sp*. and mesquite *Prosopis jutiflora*. Adults short-lived, surviving for only a few weeks. Their larvae are injurious, develop under the bark, feeds on trunks, branches or twigs, and can severely affect the quality of timber and can make trees susceptible to disease. Adults emerge from their host and feed on its foliage, frequent trees like *Prosopis jutiflora, Eucalyptus* sp., *Tamarix articulata,* and *Ziziphus spina-christi* with peak abundance being around 25th March becoming less by 24th April, with a sex ratio of 1:2.

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USE OF AQUATIC INSECTS TO ASSESS THE BIOLOGICAL STATUS OF A PERENNIAL POND IN ASSAM, NORTHEAST INDIA

Rabindra Hazarika

Post-Graduate Department of Zoology, Darrang College, Tezpur 784001, Assam, India
Email: hazarika.rabindra@gmail.com: ORCID 0000-0003-2024-3635

ABSTRACT

An investigation was carried out on "Hazara Pukhuri", a perennial pond in Sonitpur district, North East India, between July 2019 and June 2020. To assess the health of the waterbody, various biotic and diversity indices were applied, with aquatic and semi-aquatic hemipteran populations functioning as bioindicators. The pond's hemipterans include 17 species from 13 genera and 8 families, including Gerridae, Corixidae, Pleidae, Notonectidae, Nepidae, Belostomatidae, Hydrometridae, and Mesoveliidae. The biotic indices Average Score per Taxon (ASPT), Stream Invertebrate Grade Number-Average Level (SIGNAL-2), and The Biological Monitoring Working Party (BMWP) Score, as well as other diversity indices, were assessed to indicate that the waterbody was unpolluted/ slightly polluted. The presence or lack of littoral vegetation and flooding and drying of nearby shallow water pools and swampy areas were important drivers of the distribution, abundance, and community composition of aquatic and semi-aquatic hemipterans in the studied water body.

Key words: Perennial pond, Assam, Hemiptera, Heteroptera, BMWP, ASPT, abundance, diversity indices, water quality, hydroperiod, population, vegetation

Aquatic insects represent the majority of the functional feeding group, which includes predators, shredders, grazers, filter feeders, gatherers, piercers, and parasites (Mackie, 2001). Hemipterans are true "bugs" (Hemiptera) and its aquatic and semiaquatic members can be found in and around all types of freshwater habitats. These are classified as suborder Heteroptera (Thirumalai, 2007). Hemipterans are important in the ecology of freshwater ecosystems. Thirumalai and Raghunathan (1988) and Ramakrishna (2000) concluded that aquatic bug population dynamics influence the quality of the aquatic environment. Many organisms, including fish, amphibians, waterfowl, and other animals, rely on them for food (Clark, 1992). These insects typically occupy an intermediate position in food chains and are important predators. Certain hemipteran families are useful in the biological control of mosquito larvae (Jenkins, 1964; Bisht and Das, 1981; Ohba and Nakasuji, 2006; Saha et al., 2007). Aquatic Hemiptera can live in an environment that would be extremely stressful for other organisms, as in German mining lakes with a pH <3 (Woolmann, 2001). Thus, these bugs are frequently used to assess the levels of toxins in an environment as they can survive in heavily polluted areas (Papacek 2001; Woolman 2001; Jansson 1987). The diversity and distribution of aquatic Hemiptera in the freshwater ecosystems of the Indian subcontinent have been extensively studied by Thirumalai (2002a, 2002b, 2007), Thirumalai and Suresh Kumar (2006), Thirumalai and Raghunathan (1988), and Bal and Basu (1994a,b, 2000a,b, 2003, 2004). Thirumalai (2002a) found 80 genera and 275 species of aquatic and semiaquatic Hemiptera in India. Chetri et al. (1997), Kalita (2008), Hazarika and Goswami (2010), Gupta and Purkayastha (2012), Gupta and Das (2012), Barman and Baruah (2013, 2015), Barman and Deka (2015), and Barman and Gupta (2015) studied the aquatic and semiaquatic hemipterans of this region previously. These studies overlook the use of aquatic and semiaquatic hemipterans as bioindicators, particularly in the northeastern region of India. The current study, therefore focused on studying the community composition and population dynamics of aquatic and semiaquatic hemipterans in a manmade, perennial fish pond in Sonitpur, Assam.

MATERIALS AND METHODS

At an elevation of 245 feet, Hazara Pukhuri is located within the geographical ranges of $26^0 38/0//N$-$26^0 37/58//N$ and $92^0 46/30//E$-$92^0 46/47//E$. It is the largest perennial pond in Tezpur, Sonitpur District. The pond attracts visitors from all over the world because of its historic significance and its importance as a migratory and resident aquatic bird habitat. The experiment was conducted from July 2019 to June 2020, selecting four sampling sites. Insects from the littoral zones

were collected by netting locations inside the pond's specified sampling sites using simple hand-operated nets of various sizes. The floating and swimming insects were collected using circular nets comprised of coarsely woven cotton cloths and finely woven polyester mosquito curtain cloths. The insects associated with macrophytes were collected using a D-shaped dip net with nylon netting of 500 µm mesh. The net's operation is substantially based on Merritt and Cummins'(1996) descriptions. Insects were sorted and preserved in 70% ethyl alcohol, then identified using standard literature, such as Thirumalai (1999), Bal and Basu (1994a, b), Merritt and Cummins (1996), and Pennak (1996). The adults gathered were used to identify the animals, and preservation was done using wet methods. The taxonomy and biodiversity study laboratory of the Post Graduate Department of Zoology, Darrang College, Tezpur, Assam, houses these voucher specimens. The no. of individuals/ sample (N) and the species per sample (S) were tallied. Diversity Indices such as Shannon diversity index (Ĥ), Index of evenness (e), Simpson index (1-D, where D is the Dominance), Berger-Parker dominance index, Margalef's and Menhinick's richness index, and Fisher's alpha were calculated using the statistical software PAST (version 4.03). Standard methods were used to determine the biotic indices- such as average score/ taxon (ASPT), stream invertebrate grade no.- average level (SIGNAL-2), and the biological monitoring working party (BMWP) ccore (Chessmann, 2001,2003; Hawkes 1998; Jackson, 2009). Based on regional climatological changes, the seasonal fluctuation of aquatic insects was researched by classifying the seasons as pre-monsoon (PRM, March-June), monsoon (MON, July-October), and post-monsoon (POM, November-February).

RESULTS AND DISCUSSION

Members of the families Corixidae, Notonectidae, Pleidae, Nepidae, Belostomatidae, Gerridae, Hydrometridae, and Mesoveliidae contribute to the aquatic and semiaquatic Hemiptera of the pond, with 17 species belonging to 13 genera and 1428 individuals. The seasonal occurrence and abundance of the documented hemipterans are shown in Table 1 and Fig. 1, respectively. The significant diversity of the group in the selected pond ecosystem under Assam's agroclimatic conditions is reflected in the 17 documented species, which is consistent with previous studies. All species found are members of the Heteroptera. At the Deepar beel Ramsar site in Assam, Kalita (2008) identified 9 hemipterans, one

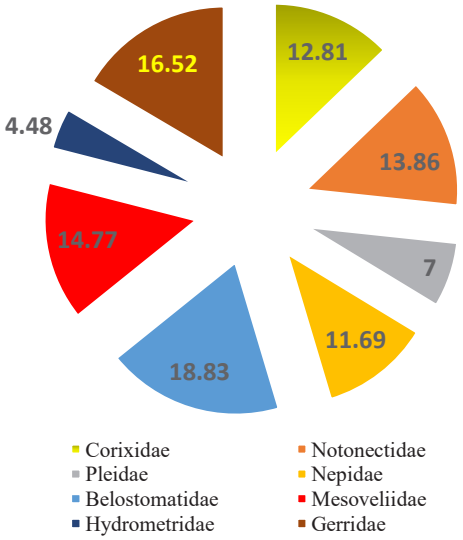

Fig. 1. Relative abundance of aquatic and semi-aquatic Hemiptera- families

of which (*Rhopalosiphum nymphaeae* L.) belongs to the suborder Homoptera. The population density was found often high during the monsoon and pre-monsoon. Among the reported species, 10 species namely *Neogerris parvula* Stal, *Gerris gracilicornis* Horvath, and *Limnogonus nitidus* Mayr (*family* Gerridae); *Diplonychus rusticus* F (Belostomatidae); *Mesovelia vittigera* Horvath (Mesoveliidae); *Hydrometra greeni* Kirkaldy (Hydrometridae); *Ranatra filiformis* F (Nepidae); and *Micronecta scuttellaris scuttellaris* Stal (Corixidae) are the most widely dispersed and dominant species observed. The aquatic macrophytes in the pond, namely, *Eichhornia crassipes (Mart) Solm* and *Hydrilla verticillata* (L.F) Royle, are commonly seen with Belostomatidae and Hydrometridae. Bhattacharya (1998) reported 8 species of aquatic Hemiptera in association with *Eichhornia crassipes* in some freshwater wetlands of West Bengal, while Pal et al. (1998) reported 25 species in association with 39 macrophytes in a freshwater wetland in Southeastern Bengal, supporting the findings of the current study. However, in the littoral section of the pond, species belonging to Gerridae and Mesoveliidae can be found in the open water zone. *On the other hand, Laccotrephes rubber* L, *Laccotrephes griseus* Guerin, *Lethocerus indicus* Lepleiter and Serville, and *Ranatra gracilis* Dallas are uncommon and found in small numbers. *Plea liturata* Fieber and *R. filiformis* while present in significant numbers but not throughout the year. The free-floating *E. crassipes* is associated with most of the insect fauna (8 species), followed by the submerged species *H verticillata* (4 species) and the marginal rooted creeper emergent plant *Jussiaea repens* L (1 species).

Table 1. Diversity, seasonal occurrence, and relative abundance- Hemiptera

Name of the collected species	Seasonal occurrence and abundance				
	PRM	MON	POM	No. of Individuals	Relative abundance (%)
Order: Hemiptera					
Family: Corixidae					
Micronecta scuttellaris scuttellaris Stal	+	+	+	145	10.15%
Micronecta siva Kirkaldy	+	+	-	38	2.66%
Family: Notonectidae					
Nychia marshalli Scott	+	+	+	125	8.75%
Anisops bauvieri Kirkaldy	-	+	+	73	5.11%
Family: Pleidae					
Plea liturata Fieber	-	+	+	100	7.00
Family: Nepidae					
Laccotrephes griseus Guerin-Meneville	-	+	-	9	0.63%
Laccotrephes rubber Linnaeus	+	-	-	14	0.98%
Ranatra filiformis Fabricius	+	+	+	105	7.35%
Ranatra gracilis Dallas	-	+	-	39	2.73%
Family: Belostomatidae					
Diplonychus rusticus Fabricius	+	+	+	207	14.49%
Diplonychus annulatus Fabricius	-	+	+	54	3.78%
Lethocerus indicus Lepleiter and Serv	-	-	+	8	0.56%
Family: Mesoveliidae					
Mesovelia vittigera Horvath	+	+	+	211	14.77%
Family: Hydrometridae					
Hydrometra greeni Kirkaldy	+	+	+	64	4.48%
Family: Gerridae					
Neogerris parvula Stal	+	+	+	130	9.10%
Gerris gracilicornis Horvath	+	+	+	60	4.20%
Limnogonus nitidus Mayr	+	+	+	46	3.22%

+ = Present, - = Absent; PRM= Pre-monsoon; MON= Monsoon; POM= Post monsoon

The majority of freshwater habitats with appropriate water quality and substrate conditions support various macroinvertebrate communities with a well-balanced species distribution among the overall number of individuals present (Sharma et al. 2008). Hydroperiod (wet and dry cycles), habitat complexity (presence or absence of littoral vegetation), hydromedian depth, trophic status (oligotrophy vs. eutrophy), and surface water quality are all factors that influence the distribution, abundance, and community composition of aquatic macroinvertebrates in a freshwater environment (Growns et al., 1992). The most important single influence on insect communities is probably frequent flooding and drying of wetland habitats, and how insects deal with draught is fundamental to their success (Wiggins et al., 1980). Because the pond under study is a perennial water body, hydroperiod is not a limiting factor in the richness and dispersion of the aquatic insect population. However, flooding and drying of the adjacent shallow water pools and swampy areas may partially impact the seasonal population density of aquatic insects, as seen by some species' abrupt population fluctuations (Fig. 2).

Some of the most successful invertebrates in temporary water bodies, according to Batzer and Wissinger (1996), cannot survive drought and instead use fairly predictable migrations between temporary and permanent waters. Freshwater wetlands are known for having a diverse range of plant species that create a mosaic of communities (Bacon, 1988). Vegetation appears to have the greatest influence on macroinvertebrate assemblages (Battle et al., 2001). The examined pond, which is dominated by *Eichhornia crassipes* and has 12 species of aquatic hydrophytes, serves as a unique home for the colonization of rich and diversified insect communities. The presence or absence of littoral vegetation and the hydromedian

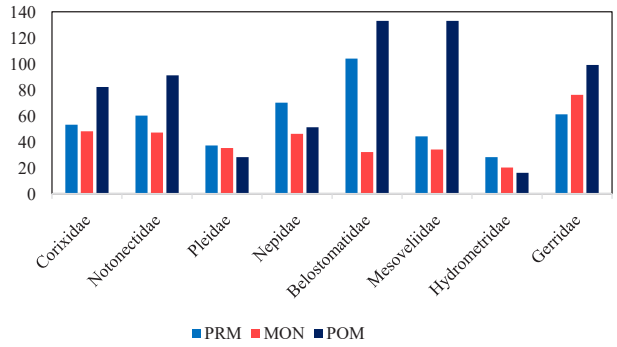

Fig. 2. Seasonal variation of density of Hemiptera- families

depth were found to be the most important parameters influencing the distribution, abundance, and community composition of aquatic and semi-aquatic hemipterans in the investigated water body. Apart from providing habitat, decaying plant material also provides food for aquatic detritivores and increases the availability of shelter, allowing successful avoidance of predation in vegetated areas. The habitat created by the combination of emergent plants and open water is a very prolific area for insect development.

For the aquatic and semi-aquatic hemipteran species inhabiting the analyzed pond, diversity indices such as Shannon Diversity Index ($\hat{H}$), Index of evenness (e), Simpson Index (1-D, where D is the Dominance), Berger-Parker dominance Index, Margalef's richness index and Menhinick's richness index were computed to see the overall trend of population fluctuation during the study period (Table 2). It was discovered that the values of several indices differed depending on their properties. During the inquiry period, the Shannon-Weiner index ranged between 2.231-2.493. Similarly, Simpson's Diversity Index, a measure of diversity that considers both richness and evenness, ranged between 0.860 – 0.909 in the studied water body. Shannon-Weiner index ($\hat{H}$), Simpson's index (1-D), and Index of Evenness (e) of Hemipteran species illustrate no mark fluctuation (Table 2). Maximum abundance is reported in January in the current study, which is due to the higher numerical density of *Mesovelia vittigera*, followed by *Micronecta scuttellaris scuttellaris* and *Diplonychus rusticus* in that month. However, the Shannon-Weiner index ($\hat{H}$) is highest in August (2.493) and lowest (2.231) in January (Table 2), even though the total numerical density of hemipterans is highest in January.

Only *Mesovelia vittigera* had the highest numerical density in that month. Therefore, the maximum abundance of a single species in a population decreases the value of species diversity, corroborating the findings of Roy (1988) on the seasonal fluctuation of aquatic Coleoptera in a freshwater pond at Bhagalpur, India. The migration from the surrounding swamps and pools is thought to be the reason for the highest prevalence of *Mesovelia vittigera* in that month. No rainfall is reported in January, which resulted in drying of the surrounding temporary shallow water bodies. While the species' downward tendency over the next month appears to indicate emigration caused by overcrowding. Julka (1977) discovered this pattern while investigating the Notonectids population in a perennial rainfed pond in Barrackpore, West Bengal, India. The current study on the species diversity and abundance of Hemiptera demonstrates that the pond is not severely contaminated with any form of pollutants as the diversity indices calculated show no significant variations. Pollutants often cause changes in species abundances and community species composition in aquatic ecosystems. However, Margalef's index readings (ranging from 2.50 to 3.02) revealed that the pond's water quality

Table 2. Diversity Indices for the collected aquatic and semiaquatic Hemiptera

Diversity indices	Jul 2019	Aug	Sep	Oct	Nov	Dec	Jan 2020	Feb	Mar	Apr	May	June
Taxa_S	13	14	14	14	14	14	14	14	14	14	14	14
Individuals	73	81	110	74	144	152	180	157	124	131	112	90
Dominance_D	0.103	0.0934	0.09	0.113	0.121	0.137	0.139	0.108	0.1	0.094	0.113	0.098
Simpson_1-D	0.897	0.906	0.909	0.887	0.878	0.862	0.86	0.891	0.899	0.906	0.886	0.901
Shannon_H	2.399	2.493	2.486	2.387	2.333	2.244	2.231	2.396	2.431	2.481	2.378	2.445
Evenness_e^H/S	0.847	0.864	0.858	0.777	0.736	0.673	0.664	0.784	0.812	0.854	0.77	0.823
Menhinick	1.522	1.556	1.335	1.627	1.167	1.136	1.043	1.117	1.257	1.223	1.323	1.476
Margalef	2.797	2.958	2.766	3.02	2.616	2.588	2.503	2.571	2.697	2.667	2.755	2.889
Equitability_J	0.935	0.944	0.942	0.904	0.883	0.85	0.845	0.907	0.921	0.94	0.901	0.926
Fisher_alpha	4.601	4.883	4.255	5.11	3.833	3.759	3.548	3.717	4.055	3.97	4.223	4.644
Berger-Parker	0.164	0.172	0.118	0.229	0.243	0.237	0.261	0.203	0.161	0.168	0.214	0.155

was moderately contaminated during the study period. Margalef's index values > 3 indicate clean water, values <1 indicate severe pollution, and intermediate values indicate moderate pollution of water, according to Lenet et al. (1980).

For determining biological water quality, the selected water body's biotic indexes such as Average Score per Taxon (ASPT), Stream Invertebrate Grade Number-Average Level (SIGNAL-2), and The Biological Monitoring Working Party (BMWP) score were used. The pond's biotic indices score values also show that it is mildly polluted. The system's SIGNAL-2 score was recorded as 2.25. In lotic systems, a SIGNAL-2 score of >5.5 indicates contamination (Chessman 2001). Some of the macroinvertebrate orders with the highest SIGNAL sensitivity scores, such as stoneflies and, to a lesser extent, mayflies and caddisflies, are naturally uncommon in wetlands. As a result, wetlands are more likely to have lower natural scores than streams in the same region (Chessman 2003). In the present study, the low SIGNAL score indicates moderately polluted nature of water. The findings of this study reveal that the pond is not contaminated by any significant contaminants. However, there is still a need for further rigorous inquiry and testing of the effectiveness of the BMWP, ASPT, and SIGNAL-2 scores for usage in ponds in India's northeastern region. The findings also strongly suggest that different biotic and diversity indices be tailored to the geomorphological and environmental characteristics of North East India.

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PEST MANAGEMENT MODULES FOR BASMATI RICE AND FARMER'S PERCEPTION

S Chakravorty, Timmanna[1]*, L Muralikrishnan[2] and Rohit Rana

Centre for Agricultural Technology Assessment and Transfer;
[1]Division of Entomology; [2]Division of Agricultural Extension,
ICAR-Indian Agricultural Research Institute, New Delhi 110012, India
*Email: thimsento@gmail.com (corresponding author): ORCID ID: 0000-0001-9399-4822

ABSTRACT

The experimental trials were conducted to evaluate four IPM modules viz., M1-Integrated pest management, M2-Chemical module, M3-Farmer's practice, and M4-untreated control against major insect pests viz., brown planthopper (BPH) *Nilaparvata lugens* (Stål), white backed planthopper (WBPH) *Sogatella furcifera* (Horvath), yellow stem borer (YSB) *Scirpophaga incertulus* (Walker), leaf folder (LF) *Cnaphalocrocis medinalis* L, in basmati rice in farmer fields at Hapur, Uttar Pradesh. These experiments were conducted in during kharif 2017 and 2018. The observations were made on the mean number of hoppers (plant and leafhoppers), % leaf damage, % dead heart and white earhead. Similarly, occurrence of spiders was also monitored. The results revealed that the M1- IPM module was observed as the best with minimum pest damage, and higher yield. This study concludes that integration of ecofriendly sustainable IPM practices not only minimize insecticide use and other input costs, but also increases the crop yield by safeguarding the natural enemy (spiders). Pre-season skill-oriented extension training programs, field demonstration-based farmer-first participatory approach, as well as regular communication through social media, would enhance their adoption in basmati rice production.

Key words: Basmati rice, insecticide, IPM module, insect pests, *Nilaparvata lugens*, *Sogatella furcifera*, *Scirpophaga incertulus*, *Cnaphalocrocis medinalis*, management, pheromone trap, spiders

Basmati rice has higher demand in the global market, and it is cultivated in a small geographical region of the Indian subcontinent (Sharma, 2017). Currently, India accounts for over 70% of the world's basmati rice production and leading exporter of basmati rice (APEDA, 2019). The subtropical climate of India is suitable for rice cultivation, and also conducive to the survival and proliferation of insects (Rana et al., 2017). More than 100 insect pests are recorded in the rice ecosystem (Heinrichs and Muniappan, 2017). Among these, yellow stem borer (YSB) *Scirpophaga incertulus* Walker, leaf folder (LF) *Cnaphalocrocis medinalis* L, and brown planthopper (BPH) *Nilaparvata lugens* (Stål) are considered major pests (Prakash et al., 2014). Rice yield gets a significant boost by the reduction of insect pests with the use of insecticides (Mishra and Panda, 2004; Dhuyo and Soomro, 2007; Chakraborty, 2010). The wrong use of insecticides has a negative impact on natural enemies (Guan-Soon, 1990; Debach and Rosen, 1991; Raguraman and Karan, 1996). These also invite other problems like insecticide resistance (Khan and Khaliq, 1989), pest resurgence (Kushwaha, 1995), and residues in the harvested produce (Dodan and Roshanlal, 1999; Kaul and Sharma 1999). Due to the maximum pesticide residue limit, a total of 444 import refusals were reported for basmati rice alone by the United States between January 2014 and May 2017 (ICIER, 2021). European Union also declined the basmati rice import as could be seen from 2017-18 to 2019-20 (Nanda, 2021). In this context, there is an urgent need to minimize the usage of pesticides. Therefore, the present study to demonstrate, a commercially viable and ecofriendly safe alternative IPM method for basmati rice in farmer's fields along with evaluation of farmers' attitude orientation towards environmental-friendly IPM.

MATERIALS AND METHODS

Field experiments were conducted to demonstrate and validate the efficacy of pest management modules against insect pests of basmati rice in farmer fields at Peernagar Soodna Hapur (28.72°N, 77.78°E, 213 masl), Uttar Pradesh, for two consecutive years in kharif, 2017 and 2018. The basmati rice (cv Pusa basmati 1121) was grown in farmer fields and all the recommended agronomic practices (except plant protection sprays) were followed for cultivation. Three IPM modules viz., M1(YSB Pheromone traps @ 5/acre, Neem oil 1000ppm @5ml/lit; straw bundles charged with spiders and egg masses @ 10/acre, Bird perches @ 10/acre and need based use of insecticides (Fenobucarb 50% EC@1ml/l;

Cartap hydrochloride 50% SP@1g/l), M2 (Imidacloprid 17.8% SL@0.3ml/l; Fenobucarb 50% EC@1ml/l; Carbosulfan 25% EC@1ml/l; Chlorpyrifos 20% EC@1ml/l based on ETL), M3 (Lambda-cyhalothrin 05% EC@0.5ml/l; Monocrotophos 36% SL@1ml/l; Oxydemeton-methyl 25% EC@1ml/l; Quinalphos 25% EC@1ml/l) routine application, and M4 (Untreated control) were laid in a two-acre area (i.e. 8000 sq m), and divided into five equal replications. Treatments were allotted randomly to the plot in each replication.

Observations were made on % leaf damage by leaf folder at 30 and 40 days after transplanting (DAT), hoppers/hill at 45 and 60 DAT, and % dead hearts and white ears head infestation of yellow stem borer at 60 and 70 DAT. The observations were taken from 20 randomly selected plants from the inner rows in each plot. Observations on spider population were made by visually counting the spiders from hills within 7 to 8-meter radius around each installed bundle in the IPM module and 5 randomly selected spots in other modules at 30, 40 and 60 DAT. The yield of different modules was pooled, and avoidable loss (%) was also calculated with benefit-cost ratio. All the data obtained were subjected to statistical analysis using Analysis of variance (ANOVA) after transformation (Gomez and Gomez,1984) with SPSS software (version 16.0). Further, for the purposive study of sustainable IPM, current modules were assessed for the farmers level perception about their sustainable adoption behaviour. The study assessed the adopter farmers' knowledge and their active participation in acceptance and willingness to implement in their fields level. In this regard, along with the IPM module evaluation the ex post facto research study was carried out after two successful adoption seasons.

Total of 60 IPM adopted farmers and their profile characteristics were analysed with the support of a scheduled based survey through an ex-post-facto research design (Kerlinger, 1978). The study also emphasized the role of farmers' knowledge and attitude orientation towards the adoption of IPM in basmati rice. There were several training and capacity building programmes were conducted for farmers with respect to the IPM in basmati rice. Hence to assess the farmers' knowledge, a standardized modified knowledge test was utilized. To measure the attitude orientation towards adoption of IPM in basmati rice, a modified attitude scale has utilized. The five attributes of innovativeness given by Rogers (1983) have been taken to assess the importance of the attributes of the IPM module for adoption in basmati rice production.

RESULTS AND DISCUSSION

A perusal of data on the insect pests, their infestation, and spiders observed in modules of basmati revealed that the IPM module was significantly superior (Table 1). The leaf folder damage (%) revealed, significant differences in different modules. The leaf damage was found to be minimum in the IPM module (6.97%) at 30 days after transplanting followed by the chemical module (8.11%) and farmer practices (9.45%) as compared to untreated control (12.05%). Whereas at 40 days after transplanting, IPM module (3.61%) and chemical module (4.04%) records were at par with each other, significantly lower than that of farmer's practices (6.33%) while maximum leaf damage was recorded in the untreated control (12.34%). During kharif 2018 also, the chemical (4.65%) and IPM (5.33%) module resulted in the least leaf damage followed by farmers practices (7.34%) at 30 days after transplanting. Considering the overall observations, the IPM module (0.95%) and chemical module (1.04%) were equally effective followed by farmer practices (5.58%) at 40 days after transplanting. These results derive support from previous results on using IPM practices with similar components (Elakkiya et al.,2012; Nayak et al., 2015).

During kharif 2017, data on % deadheart and white earheads of YSB in IPM module (3.43% and 2.67%) and chemical control (3.54% and 3.84%) were statistically at par at 45 and 60 days after transplanting respectively. It was followed by the farmer practice module (7.69% and 5.04%) and the untreated control module (11.96% and 7.53%) at 45 and 60 days after transplanting respectively. However, during the second season (kharif 2018) similar trends were observed in the IPM module (3.75% and 3.13%) and found statistically on par with chemical control (4.19% and 3.46%), followed by farmer practice (6.78% and 5.78%) as compared to untreated control module (10.18% and 8.18%) at 45 and 60 days after transplanting respectively. During kharif 2017, least hopper incidence was recorded in chemical module (3.09 and 1.99/ hill) and IPM module (3.13 and 2.54/ hill) and were on par with each other. Number of hoppers were comparatively less in farmers practice (7.33 and 5.32/ hill) at 45 and 60 DAT, respectively. During kharif 2018, similar results were obtained (Table 1). Kenmore (1997) revealed that significantly minimum hopper incidence in rice was observed with IPM module, and it was also found safe to natural enemies (Rajak et al., 1997; Garg et al., 2008). The present study also revealed the superiority of the IPM module in increasing spiders. These results are in conformity with the previous findings (Pathak and

Table 1. Evaluation of different pest management modules against insect pests of basmati rice

Particulars	% LD leaf folder	No. of hoppers/ hill		%DH YSB	%WEH YSB	Number of spider/ 5 hills			Yield (q/ acre)	C:B ratio
	40DAT	45DAT	60DAT	60DAT	70DAT	30DAT	40DAT	60DAT		
					Kharif 2017					
Integrated pest management module	03.61± 0.30$_{a}$	03.13± 0.31$_{a}$	02.54± 0.12$_{a}$	03.43± 0.19$_{a}$	02.67± 0.61$_{a}$	01.11± 0.09	01.82± 0.33$_{b}$	02.89± 0.05$_{c}$	21.15	1:80
Chemical control	04.04± 0.22$_{a}$	03.09± 0.18$_{a}$	01.99± 0.19$_{a}$	03.54± 0.19$_{a}$	03.84± 0.29$_{a}$	00.57± 0.12	00.98± 0.17$_{a}$	00.81± 0.07$_{a}$	19.78	1:30
Farmers practice	06.33± 0.60$_{b}$	07.33± 0.23$_{b}$	05.32± 0.10$_{b}$	07.69± 0.35$_{b}$	05.04± 0.31$_{b}$	00.85± 0.06	01.20± 0.21$_{ab}$	01.18± 0.13$_{b}$	19.67	1:20
Control	12.34± 1.18$_{c}$	10.56± 0.40$_{c}$	11.90± 0.39$_{c}$	11.96± 1.13$_{c}$	07.53± 0.59$_{c}$	01.22± 0.15	02.12± 0.22$_{c}$	03.26± 0.16$_{d}$	14.78	00
CD (p=0.05)	1.63	0.96	0.65	1.99	1.62	0.32	0.68	0.28		
SE(m)	0.46	0.27	0.18	0.56	0.46	0.09	0.19	0.07		
					Kharif 2018					
Integrated pest management module	00.95± 1.03$_{a}$	03.48± 0.18$_{a}$	00.93± 0.08$_{a}$	03.75± 0.59$_{a}$	03.13± 0.51$_{a}$	01.53± 0.13	02.04± 0.07$_{c}$	03.37± 0.48$_{b}$	20.21	1:90
Farmers practice	05.58± 0.16$_{b}$	08.36± 0.21$_{c}$	05.84± 0.26$_{b}$	06.78± 0.69$_{b}$	05.78± 0.56$_{b}$	0.43± 0.04	00.87± 0.06$_{a}$	00.67± 0.10$_{a}$	18.02	1:33
Chemical control	01.04± 0.57$_{a}$	05.04± 0.15$_{b}$	01.73± 0.13$_{a}$	04.19± 0.14$_{a}$	03.46± 0.64$_{a}$	0.62± 0.05	01.45± 0.08$_{b}$	00.73± 0.13$_{a}$	17.40	1:24
Control	10.22± 0.10$_{c}$	12.11± 0.48$_{d}$	13.04± 0.54$_{c}$	10.18± 1.12$_{c}$	08.18± 0.32$_{c}$	01.50± 0.23	02.51± 0.09$_{d}$	03.95± 0.34$_{b}$	12.95	00
CD (p=0.05)	1.53	1.01	1.05	1.99	2.03	0.53	0.28	1.21		
SE(m)	0.43	0.28	0.29	0.56	0.57	0.15	0.08	0.34		

DAT-Days after transplanting; LD-Leaf damage; DH-Deadhearts; WEH-White ear head

Tiwari, 2006; Ramandeep et al., 2007; Karthikeyan et al. 2010). Data on rice grain yield revealed that all three modules gave statistically significant grain yield and were superior over untreated control; maximum grain yield was obtained with the IPM module followed by chemical control module, and farmer practice. The IPM module ranked 1st with the highest cost-benefit ratio (1:80; 1:90) followed by the chemical module (1:30; 1:33) and farmer's practice (1:2;1.24) (Table 1).

It could be observed from Table 2 that, the majority of the farmers had medium level desired profile characteristics such as training undergone (76.66%), educational status (58.34), contact with an extension agency (53.34%), information-seeking behaviour (48.34%), economic motivation level (45%) and innovativeness (43.33%). With respect to farmers' experience, the majority of the farmers had many years of experience. So, these characters were highly supportive to enhance the adoption of IPM in basmati rice production. At the same time, the lower level of scientific orientation (48.33%) and perception on the environmental conservation (45%) require more attention. In this context, periodical training, and exposure visits with much-needed follow-up activities may be required. More focused training programs related to IPM module and non-formal educational strategies supported the wider adoption of IPM module under field conditions. The training programmes also improved the farmer's analytical skills, eco-friendly crop management skills, knowledge regarding negative externalities of pesticide-use, for continued adoption of IPM module in basmati rice. This finding was supported by the findings of Singh et al. (2008). It was observed that 65% of the farmers belonged to the medium level of knowledge category. With respect to attitude orientation, 53.34% of the farmers belonged to the moderately favourable attitude category. The medium level of knowledge and moderately favourable attitude orientation enhanced their adoption of IPM in basmati rice. Further, the agricultural scientists played important roles in both extension and field level activities. Particularly in the participation in farmer's group and community organization meetings with farmer's field school-related field activities. It gave social learning about the IPM Module in basmati rice to the farmers. Further, it also supported technology-led farmer-to-farmer extension delivery approaches, related to the IPM practice, with effective extension services; the higher frequency of meetings with extension personnel lead to the sustained and continued adoption of IPM practices in basmati rice. These findings were supported by Aggarwal (2015).

Table 2. Farmer's response to the adoption of integrated pest management modules in basmati rice cultivation (n=60)

Profile characteristics of the IPM adopted farmers			
Characteristics	%		
	Low	Medium	High
Educational Status	23.33	58.34	18.33
Farming experience	10.00	21.66	68.34
Economic motivation	13.34	45.00	41.66
Scientific orientation	48.33	30.00	21.67
Information seeking behaviour	35.00	48.34	16.66
Training undergone status	10.00	76.66	13.34
Perception on the environmental conservation	45.00	40.00	15.00
Innovativeness	30.00	43.33	26.67
Contact with extension Agency	36.66	53.34	10.00
Distribution of respondents based on their knowledge and attitude orientation			
Behavioural component	%		
	Low/less favourable	Medium/ moderately favourable	High/ highly favourable
Knowledge	21.67	65.00	13.33
Attitude	18.33	53.34	26.33
Distribution of respondents based on the attributes			
Factors	Respondents	%	
Relative advantage	38	63.34	
Compatibility	25	41.66	
Complexity	19	31.67	
Trialability	42	70.00	
Observability	17	28.34	

* - Multiple responses

It could be observed from Table 2, that the attributes of trialability (70%), relative advantage (63.34%), and compatibility (41.66%) were supported well for the adoption of IPM module. At the same time, other attributes like observability (28.34%) require a certain degree of improvement, and complexity (31.67%) that can be minimized with the enhanced IPM Module adoption process, accessing Information and Communication Technologies (ICTs) and Mass media tools for providing awareness about the IPM module in basmati rice. Establishing farmer's discussion groups in every village and promotion of farm leadership for demonstration of IPM module in basmati rice at the farm field level and organizing pre-season skill-oriented training programmes help to improve the farmer's confidence in the adoption of IPM practice. Thus, development of farming systems-based participatory farmer first extension approach for

successful implementation of the IPM module in basmati rice at the farm field level supports sustainable adoption.

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RECORDS OF ENCYRTIDAE FROM UTTARAKHAND WITH REDESCRIPTION OF *RHYTIDOTHORAX AERISCUTELLUM* (GIRAULT)

Rashmi Nautiyal* and Sudhir Singh[1]

Harsh Vidhya Mandir College, Raisi Haridwar 247671, Uttarakhand, India
[1]Forest Entomology Division, Forest Research Institute, New Forest, Dehradun 248006, Uttarakhand, India
*Email: rashmi.dobhal@gmail.com (corresponding author): ORCID ID: 0000-0001-5944-5213

ABSTRACT

Thirteen known species of Encyrtidae (Hymenoptera: Chalcidoidea) are recorded, including seven new records from Uttarakhand, India. *Rhytidothorax aeriscutellum* (Girault) is redescribed along with its morphometrics based on specimens from Uttarakhand.

Key words: Hymenoptera, Chalcidoidea, Encyrtidae, distribution, new records, host, redescription, biological control, Uttarakhand, India

Encyrtidae are important controlling agents of other insects belonging to the orders Hemiptera, Lepidoptera, Neuroptera and the eggs of ticks (Acarina) and spiders (Hayat, 2006b). Since the encyrtids are economically very important hence, it is essential to identify the different species of Encyrtidae accurately in order to ensure their proper and effective utilization as biological control agents. It is the largest and most abundant family with over 4896 valid species distributed in 506 genera (Noyes, 2022). In India, a total of 157 genera and 1410 species of encyrtids are known and only 99 species in 46 genera are reported so far from Uttarakhand state (Kazmi and Kumar, 2014; Nautiyal and Singh, 2017; Noyes, 2022). Girault (1915) erected the genus *Anusomyia* with *Anusomyia auratiscutum* as its type species and included two species in this genus, namely *A. auratiscutum* and *A. aerscutellum* based on female specimens from Queensland, Australia. The original descriptions of the species *A. aerscutellum* and *A. auratiscutum* were limited. Noyes and Hayat (1984) reviewed the genera of Indo-Pacific Encyrtidae and placed *Anusomyia* as a junior synonym of *Rhytidothorax*. In 1997, Dahms and Gordh reviewed the genera of Australian Encyrtidae described by Girault and accepted *Rhytidothorax* as broadly defined by Noyes and Hayat (1984). Dahms (1997) examined the material determined by Girault along with ten additional specimens but did not give a detailed description of the species. Therefore, in the present paper, a detailed morphometrics and description of *R. aeriscutellum* is given and new distribution records for seven species of Encyrtidae have been documented.

MATERIALS AND METHODS

Encyrtidae were collected from different locations of Doon Valley by host rearing and sweep net methods. The specimens were processed and mounted according to Noyes (1982) and identified using the keys given by Noyes and Hayat (1984; 1994) and Hayat (2006b). Observation and description of *Rhytidothorax aeriscutellum* were done using Olympus SZx16 (Japan) stereozoom microscope. For imaging of dried specimen Olympus SZx16 (Japan) stereozoom microscope with attached AutoMontage Digital Micropublisher Q-Imaging 5.0 RTV camera was used. Automontaged photographs of slide mounted parts were taken with Nikon Digital Sight DS-Fi1using the EDF module of NIS-Br software (Nikon) mounted on Nikon Optiphot compound microscope. Abbreviations and measurements used are according to Noyes and Hayat (1984) and Singh and Agarwal (1993). Body length is given in millimeters (mm), and all other measurements are in micro meter (µm). The specimens are deposited with the National Forest Insect Collection, Entomology Division, Forest Research Institute, Dehradun, India (NFIC-FRI). Following abbreviations are used in the text: M: Male. F: Female. NPCI: National Pusa Collection, Division of Entomology, Indian Agricultural Research Institute, New Delhi, India. USNM: United States National Museum of Natural History, Washington DC, U.S.A. ZSI: Zoological Survey of India, Kolkata, India. BMNH: The Natural History Museum, London. ZDAMU: Department of Zoology, Aligarh Muslim University, Aligarh, India. QMB: Queensland Museum, Brisbane, Australia. NMV: Naturhistorisches Museum,

Vienna, Austria. NFIC-FRI: National Forest Insect Collection, Entomology Division, Forest Research Institute.

RESULTS AND DISCUSSION

A total of 13 species are included, of which seven species are new records from Uttarakhand state and *Rhytidothorax aeriscutellum* is redescribed since its earlier description was inadequate.

1. *Aenasius arizonensis* (Girault)

Chalcaspis arizonensis Girault, 1915: 280, F. USNM, USA- Arizona; *Aenasius arizonensis* (Girault, 1915): Noyes and Woolley, 1994: 1330; *Aenasius bambawalei* Hayat, 2009: 21-25, Holotype, NPC-IARI.

Specimen examined. India: Uttarakhand, Dehradun, Muni ke Reti, 1 Female, 16. vi. 2018, coll. Sudhir Singh (collected by sweeping in nursery).

Distribution. India: Delhi, Haryana, Maharashtra (Hayat, 2006b), Tamil Nadu (Nalini and Manickavasagam, 2011), Andhra Pradesh (Rameshkumar et al., 2011), Puducherry (Manickavasagam and Ramesh Kumar, 2012) and Uttarakhand **(new record)**; Elsewhere: China, Pakistan, Turkey, USA.

2. *Anagyrus alami* Hayat

Anagyrus alami Hayat, 1970: 112, F. Holotype F: India, Nasik (ZSI).

Specimens examined. India: Uttarakhand, Dehradun, New Forest (*bambusetum*), 9 females, 3 males, 6.vii.2018, ex. indet. Scale on *Bamboo tulda*, coll. R. Nautiyal.

Distribution. India: Karnataka, Maharashtra (Hayat, 2006b) and Uttarakhand **(new record)**.

3. *Adelencyrtus coxalis* Hayat, Alam and Agarwal

Adelencyrtus coxalis Hayat, Alam and Agarwal, 1975: 77, 78-80, F, M. Holotype F: India, Guntur (BMNH)

Specimens examined. India: Uttarakhand, Dehradun, New Forest, 26 females, 1 male, 06. iii. 2018, ex. inted. Scale on *Toona cilliata*, coll. R. Nautiyal.

Distribution. India: Andhra Pradesh (Hayat, 2006b), Delhi, Puducherry, Tamil Nadu (Manickavasagam and Rameshkumar, 2012) and Uttarakhand **(new record)**; Elsewhere: China.

4. *Adelencyrtus mayurai* (Subba Rao)

Anabrolepis mayurai Subba Rao, 1957: 380-382, F, M. Holotype, F: India, New Delhi (NPCI); *Adelencyrtus mayurai* (Subba Rao): Noyes and Hayat, 1984: 224, tax.

Specimens examined. India: Uttarakhand, Dehradun, New Forest (*bambusetum*), 3 females, 1 male, 06.vii.2018, ex. indet. Scale on *Bamboo tulda*, coll. R. Nautiyal; New Forest (near Trevor gate), 4 females, 20.iv.2018, ex. indet. pseudococcid sp on *Alstonia scholaris*, coll. R. Nautiyal.

Distribution. India: Delhi, Gujarat, Karnataka, Tamil Nadu, Uttar Pradesh (Hayat, 2006b), Puducherry (Manickavasagam and Rameshkumar, 2012) and Uttarakhand (Nautiyal and Singh, 2017); Elsewhere: Mauritania.

5. *Homalotylus albiclavatus* (Agarwal)

Neoaenasioidea albiclavatus Agarwal, 1970: 27, F. Holotype F: India, Aligarh (ZDAMU); *Neoaenasioidea albiscutellaris* Khan, 1976: 180, F. Holotype F: India, Aligarh (ZDAMU); synonymy by Hayat, 1981: 21, F, tax.; *Homalotylus albiclavatus* (Agarwal): Hayat, Alam and Agarwal, 1975: 69, F, M, key, hosts, distrib.; *Echthroplexis albiclavatus* (Agarwal): Shafee and Fatma, 1984: 371, tax., hosts; *Echthroplexis albiscutellaris* (Khan): Shafee and Fatma, 1984: 373.

Specimen examined. India: Uttarakhand, Dehradun, New Forest (near Trevor gate), 1 female, 11.v.2018, ex. indet. pseudococcid sp. on *Alstonia scholaris*, coll. R. Nautiyal.

Distribution. India: Himachal Pradesh, Jharkhand, Karnataka, Kerala, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal (Hayat, 2006b) and Uttarakhand (Nautiyal and Singh, 2017); Elsewhere: Iran.

6. *Microterys kerrichi* Shafee, Alam and Agarwal

Microterys kerrichi Shafee, Alam and Agarwal, 1975: 66, 69-71, F, M. Holotype F: India, T. Nadu, Arkonam (ZDAMU; lost?)

Specimens examined. India: Uttarakhand, Dehradun, Panditwari, 1 female, 1 male, 31.iii.2018, ex indet. pseudococcids on *Psidium guajava*, coll. R. Nautiyal.

Distribution. India: Tamil Nadu (Hayat, 2006b) and Uttarakhand **(new record)**.

7. *Microterys newcombi* (Girault)

Microterys newcombi Girault, 1915: 91, F. Australia, N.S.W., Sydney (QMB)

Microterys newcombi (Girault): Rosen, 1973: 250.

Specimens examined. India: Uttarakhand, Dehradun, Gorakhpur, 6 females, 10 males, 6. iii. 2018, ex. indet. Coccidson *Citrus maxima* leaves, coll. R. Nautiyal.

Distribution. India: Assam (Hayat, 2006b) and Uttarakhand **(new record)**; Elsewhere: Australia, Malaysia.

8. *Ooencyrtus aethes* Hayat

Ooencyrtus aethes Hayat, 2006a: 307-308, F. Holotype F: India, Aligarh (NPCI).

Specimen examined. India: Uttarakhand, Dehradun, Phondoowala ramgarh range, 1 female, 31. iii. 2018, ex. unidentified eggs on *Murraya koenigii*, coll. R. Nautiyal.

Distribution. India: Uttar Pradesh (Hayat, 2006b) and Uttarakhand (Nautiyal and Singh, 2017).

9. *Prochiloneurus testaceus* (Agarwal)

Achrysopophagus testaceus Agarwal, 1965: 66, 68-69, F. Holotype F: India, Aligarh (ZDAMU); *Prochiloneurus hayati* Shafee, Alam and Agarwal, 1975: 49, 53-55, F. Holotype F: India, Nabha (ZDAMU), synonymy by Hayat, 1999: 391; *Prochiloneurus testaceus* (Agarwal): Shafee, Alam and Agarwal, 1975: 49, 53-55, F, key.

Specimen examined. India: Uttarakhand, Dehradun, Gorakhpur, 1 female, 4.iii.2018, ex. indet pseudococcid on *Psidium guajava*, coll. R. Nautiyal.

Distribution. India: Andaman and Nicobar Island, Andhra Pradesh, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh (Hayat, 2006b) and Uttarakhand (**new record**).

10. *Psyllaephagus macrohomotomae* Singh and Agarwal

Psyllaephagus macrohomotomae Singh and Agarwal, 1993: 73, 81-84, F, M. Holotype F: India, North Lakhimpur (FRI, examined).

Specimens examined. India: Uttarakhand, Dehradun, Kalsi, 4 female, 8 males, 17.iii.2018, ex. indet. psyllid on *Ficus ramphii*, coll. R. Nautiyal.

Distribution. India: Assam, Mizoram (Hayat, 2006b) and Uttarakhand (Nautiyal & Singh, 2017).

11. *Trechnite manaliensis* Hayat, Alam and Agarwal

Trechnite manaliensis Hayat, Alam and Agarwal, 1975: 87-88, 90-92, F, M. Holotype F: India, Aligarh (BMNH).

Specimens examined. India: Uttarakhand, Dehradun, New Forest, 8 female, 4 males, 15. vii. 2018, ex. indet. psyllid on *Terminalia tomentosa*, coll. R. Nautiyal.

Distribution. India: Himachal Pradesh, Karnataka (Rameshkumar et al., 2016) and Uttarakhand (**new record**); Elsewhere: China, Africa.

12. *Zaomma lambinus* (Walker)

Encyrtus lambinus Walker, 1838: 422, F. Lectotype F [designated by Graham, 1969: 271]: England. (BMNH). [As synonym of *Apterencyrtus microphagus* by Graham, 1969: 270];

Chiloneurus microphagus Mayr, 1876: 745, 746, F. syntypes (NMV), synonymy with *lambinus*, implied by Gordh and Trjapitzin, 1979: 37; *Chiloneurus microphagus* (Mayr): Mercet, 1921: 646. *Apterencyrtus microphagus* (Mayr): Hayat, Agarwal and Alam, 1975: 57-60, F, M.; *Zaomma lambinus* (Walker): Gordh and Trjapitzin, 1979: 35, 37, tax.

Specimens examined. India: Uttarakhand, Dehradun, New Forest, 3 females, 1 male, 7. ii. 2018, ex indet. Scaleon *Toona cilliata*, coll. R. Nautiyal.

Distribution. India: Andaman and Nicobar Island, Kerala, Uttar Pradesh (Hayat, 2006b) Odisha, West Bengal (Hayat and Khan 2008) and Uttarakhand (Nautiyal & Singh, 2017); Elsewhere: Algeria, Argentina, Armenia, Austria, Azerbaijan, Brazil, Bulgaria, Canada, Croatia, Czech Republic, Czechoslovakia, Denmark, Finland, France, Georgia, Germany, Hawaii, Hungary, Indonesia, Iran, Italy, Japan, Korea, Mauritius, Moldova, Montenegro, Netherlands, New Zealand, Norway, China, Peru, Philippines, Poland, Romania, Russia, Spain, Sweden, Switzerland, United Kingdom, United States of America, USSR.

13. *Rhytidothorax aeriscutellum* (Girault) (Figs. 1-9)

Anusomyia aeriscutellum Girault, 1915: 164 (original description)

Rhytidothorax aeriscutellum (Girault): Noyes and Hayat, 1984: 333 (generic transfer).

Fig. 1-4. *Rhytidothorax aeriscutellum*. female: 1. body in dorsal view; 2. body in lateral view; 3. head in frontal view; 4. head in lateral view

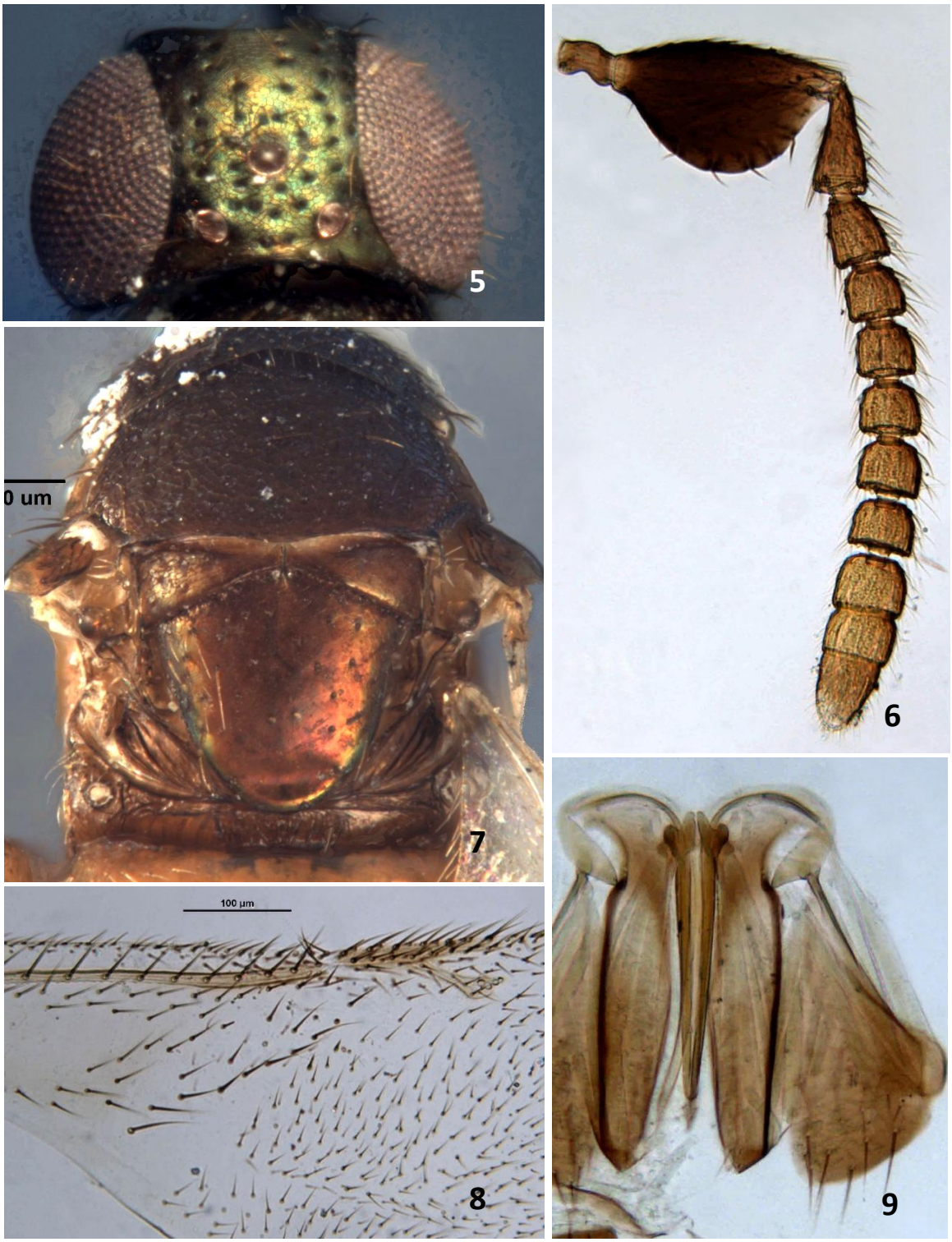

Fig. 5-9. *Rhytidothorax aeriscutellum*. female: 5. head in dorsal view; 6. antenna; 7. mesosoma in dorsal view; 8. part of fore wing showing venation; 9. ovipositor

Redescription

Female length 1.48 mm. Body with head and mesosoma dark brown to black. Head in frontal view with mild blue-green reflection; frontovertex with metallic green reflection; ocelli reddish brown; eyes bronzy reaching sharp occipital margin with gray setae; mandibles with teeth brown, palpi pale; antenna brown, scape flattened dark brown, funicle segments and clava with light brown. Mesosoma dark brown. Wings hyaline. All legs testaceous yellow except mid coxa basal half dark brown. Metasoma light brown with alternate white line at each tergite.

Head, in frontal view (Fig. 3) 1.16x wider than long; inner eye margins smoothly curved; eye 1.84x as long as wide; antennal toruli located much above the mouth margin; inter antennal prominence convex, with long dark setae and raised reticulation; toruli 1.34x as long as wide; distance between toruli 1.23x, distance between torulus and eye margin 1.1x, torulo-mouth margin distance 0.58x shorter than torular length (78: 70: 37: 63); scrobes broadly U-shaped with margins rounded, reaching 0.55x between torulus and median ocellus. Head, in dorsal view (Fig. 5) with anterior and posterior margins slightly concave and convex respectively; 1.62x as wide as long, 2.34x as wide as frontovertex width at level of median ocellus; frontovertex with reticulate sculpture, becoming elongate towards margin of scrobal area; ocellar area with small setigerous punctures, about half diameter of median ocellus; ocelli in right angle triangle; POL 2.29x, OCL 0.58x and OOL about 0.51x the diameter of middle ocellus (94: 24: 21: 41); eye about 1.91x as long as wide. Head, in profile (Fig. 4) 4.5x as high as malar space length; eye 1.27x as long as wide; malar sulcus present. Antenna (Fig. 6) with scape expanded ventrally, 1.67x as long as wide; pedicle long conical, 2.08x as long as broad; all funicle segments with fine and long setae; clava three segmented with rounded apex; except F1, quadrate to broader than long; F1 0.6x smaller than pedicel, 1.22x as long as wide, F2 0.94x, F3 0.96x, F4 0.9x, F5 0.94x, F6 0.83x, clava 2.54x as long as broad. Mandible with two acute teeth, ventral tooth shorter than dorsal.

Mesosoma slightly narrow than head, 0.9x head width. Pronotum visible in dorsal view with around 12 long strong setae along collar; mesoscutum squamiform reticulate sculpture with long brown setae, anterior margin convex, axillae meeting at the middle, axillae 3.26x wider than long; rounded on sides; scutellum mild sculpture with long brown setae, narrow distally, 1.08x as long as wide; propodeum narrow medially, distad of spiracles with light setae, 10x as wide as long. Fore wing proximad of lineacalva with a row of long setae, 2.42x as long as wide; marginal 1.28x and stigmal vein 0.8x longer than postmarginal (103: 64: 80). Midtibial spur 1.2x longer than basitarsus. Metasoma. Metasoma 1.18x longer than mesosoma, 1.35x as long as wide, cercal plates situated almost at anterior half of metasoma; hypopygium extending 0.83x along metasoma length; ovipositor 0.69x smaller than the mid tibia length. Third valvula distinctly articulated with second valvifer (Fig. 9).

Male. Unknown.

Host. Unknown.

Specimens examined. 2f (1f, on a card, with one antenna and one pair of wing, mounted on the slide; 1f completely dissected on a slide under 8 cover slips) India: Uttarakhand: Dehradun, Kalsi; 30. xi. 2018; Coll. R. Nautiyal (by sweeping bamboo bushes).

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INSECT POLLINATOR ASSEMBLAGE ON TEMPERATE FRUIT CROPS IN KUMAUN HIMALAYA

Manoj Kumar Arya* and Aarti Badoni

Insect Biodiversity Laboratory, Department of Zoology, D S B Campus,
Kumaun University, Nainital 263002, Uttarakhand, India
*Email: dr.manojkumar19@rediffmail.com (corresponding author)

ABSTRACT

Kumaun Himalaya harbors a number of temperate fruits crops such as apple, peach, apricot, plum, pear and kiwi that support the fruit growers of the Uttarakhand state. The present study was conducted in temperate fruit orchards located in hills of Nainital district of Kumaun Himalayan region of Uttarakhand state. Information on the distribution of insect pollinators led to many important details. A total of 92 species insect pollinators under 59 genera of 25 families and four orders were recorded. Lepidoptera was the most dominant order whereas Coleoptera was the least dominant. The results revealed that *Apis cerana* F. was the most abundant species. As per Margalef's index, species richness of pollinators was observed to be maximum in apple.

Key words: Temperate fruits, apple, peach, apricot, plum, pear, kiwi, insects, pollinators, species diversity, richness, dominance, Lepidoptera, Coleoptera

Pollination is an important ecosystem service for the maintenance and conservation of biodiversity. Wind, water, and gravity as abiotic, and insects, birds, bats and small mammals as biotic agents provide this service (Sharma and Mitra, 2012; Mattu and Bhagat, 2015). The pollination is declining due to reduction in pollinators (Moisset and Buchmann, 2011; Bhattacharyya and Chakraborty, 2014). Pollination is prerequisite for the efficiency of the vast majority of the yields in agrarian and horticultural ecosystems. This is carried out mostly by insects which are the prime agents of pollination (Riaz et al., 2018). Diversity of pollinators benefit society by improving living conditions and increasing food security. The relationship between flowering plants and the flower visiting insects is essential for the conservation of terrestrial ecosystem. Any loss of biodiversity is a matter of public concern, but pollinator losses, especially insects, may be disturbing due to potential impacts on flowering plant reproduction of and hence on food security (Khan and Khan, 2004; Solar et al., 2009; Mattu and Nirala, 2016). Many insects are of prime significance in the pollination of horticultural and agricultural crops- these include Hymenoptera (bees, ants and wasps), Diptera (flies, mosquitoes etc.), Lepidoptera (butterflies and moths), Coleoptera (beetles and weevils) and Thysanoptera (thrips). Of these Hymenoptera are the most important and abundant (Mattu and Bhagat, 2015). Honeybees form major proportion of insect pollinators on different temperate fruit crops (McGregor, 1976; Mishra et al., 1976; Verma and Chauhan, 1985; Verma, 1990; Free, 1993; Mattu and Mattu, 2010; Joshi and Joshi, 2010a&b; Raj et al., 2012; Sharma et al., 2013; Mattu and Bhagat, 2016). Variation in abundance, density and diversity of insect pollinators in the temperate fruit orchards of India and forest ecosystems of the different parts of world have been explored (Verma and Chauhan, 1985; Larsan et al., 2001; Mishra et al., 2004; Joshi and Joshi, 2010a&b; Takur and Mattu, 2010; Mattu et al., 2012; Raj et al., 2012; Ganie et al. 2013; Pandey et al., 2013; Raj and Mattu, 2014; Arya, 2015; Mattu and Bhagat, 2015; Sathe and Gophane, 2015; Mattu and Nirala, 2016; Garibaldi et al., 2016; Kapkoti et al., 2016; Dar et al., 2017; Altaf et al., 2017; Arya et al., 2018; Riaz et al., 2018). However, no attempts have so far been made to study the species composition, abundance, distribution, and diversity of insect pollinators in temperate fruit crops of the Kumaun hills of Uttarakhand. The present study provides details on species composition, abundance, distribution, and diversity of insect pollinators in temperate fruit crops of Kumaun hills, Western Himalaya, Uttarakhand, India.

MATERIALS AND METHODS

The study was conducted in blooming seasons of selected fruit crops (apricot, apple, kiwi, peach, plum, pear) in the hilly region of the Nainital district of Uttarakhand during 2019. Eight fruit orchards, namely

Ramgarh, Mukteshwar, Dhanachuli, and Paharpani, each with two orchards were focused. Ramgarh (29°26.642′N,79°36.235′E, 2305 masl) is bounded by fruit orchards on terraces cut into hilly sides surrounded by oak and coniferous forests. The vegetation of the surroundings is enriched by the presence of *Quercus leucotricophora*, followed by *Cedrus deodara*, *Rhododendron arboreum*, *Acer oblongum* with scattered *Eucalyptus regnans*, *Berberis asiatica*, *Berbaris vulgare, Berberis chitria, Artimesia anua, Berbaris chitria, Dhatura fatuosa, Anaphalis triplinens, Rosa lasiocarpus, Erigeron* sp. and *Cynadon dactylon* as the understory and ground flora. Five fruits crops apples, peaches, pears, apricots, and plum were selected from here, situated in the Satbunga and Khabrar village. Mukteshwar (29°27′ N, 79°39′ E, 2286 masl) has a variety of flora dominated by *Quercus incana*, *Pinus roxburghii*, *C. deodara*, *R. arboreum* as the canopy; *Pyracantha enulata*, *Rubus ellipticus*, *R. lasiocarpus*, *Pyrus pashia*, *Berberis aristata*, *B. asiatica*, *B. vulgare, R.lasiocarpus, Indigofera gerardiana,* and *Desmodium* sp. as the understory; whereas species of *A.triplinens, Anaphalis* sp., *Leucas*, *Senecio*, *Dicliptera*, *Valeriana*, *Viola*, *Bergenia*, *Erigeron* sp. *Cynadon dactylon,* and various other grasses form the ground flora. Apples, peaches, pears, apricots, cherry, plum, walnut, and citrus on terraces cut into the hillsides are the crops here.

The two fruit orchards selected are located inside the Central Institute of Temperate Horticulture, Regional station, Mukteshwar. Apples, peaches, pears, apricots and plum were selected (29°23.802′ N, 79°39.443′ E, 2115 masl); here agriculture mainly consists of potato mixed with seasonal vegetables and is bounded by temperate fruit tree orchards. A large portion of the land is converted into orchards for growing apples, peaches, pears, apricots, plum, walnut and citrus on terraces cut into the hillsides. The area has a spare cover of *C. deodara*, *Q.incana*, *R. arboreum*, *A. oblongum*, *Aesculus indica*, *Myrica esculenta, P. roxburghii*, *Juglens regia,* and *R.ellipticus Berberis asiatica*, *B.vulgare, R.lasiocarpus, A.anua, Berbaris chitria, Dhatura fatuosa, Anaphalis triplinens, Erigeron* sp. as the understory and ground flora. Six fruit crops like apples, peaches, pears, apricots, plum and Kiwi were selected in the Dhanachuli village. Paharpani (29°38'N, 79°52'E, 1900-1950 masl) from here is the best known location of temperate fruit orchards of apple, plum, peach, pear, plum, apricot, walnut, citrus and kiwi; and here area is surrounded by thick dense forest characterized by four major tree associations of oak forest, oak-pine mixed forest, oak scrub and chir-pine mixed forest. The vegetation is mainly dominated by Banj (*Quercus leucotricophora*, *Q. lanata* and *Q. glauca*), *P. roxburghii*, *C.deodara*, *A.indica*, *R.arboreum*, *Lyonia ovalifolia*, *Myrica nagi, J. regia* and *P.pashia*. Among the shrubs and herbs, *Rubus biflorus*, *R. ellipticus*, *Berberis asiatica*, *B. vulgans, Pyracantha crenulata*, *Lantana camara, A. anua, Indigofera* sp., *Desmodium* sp., *A. triplinens, R.lasiocarpus, D. fatuosa, Erigeron* sp. and *C. dactylon* are common. Six fruits crops like apples, peaches, pears, apricots, plum, and kiwi were selected in this Paharpani area.

Observations of insect pollinators (direct sighting) were carried out in the selected blocks between 8:00 to 16:00 hours during February- May, 2019 when the orchards were in full bloom. The collected samples of insect pollinators were then confirmed by the literature available. The identification of sampled insects was done with literature and insect guides available in the Department of Zoology, D S B Campus, Kumaun University, Nainital. The insect specimens which could not get identified in the laboratory were identified by scientists in the Entomological Section, Forest Research Institute, Dehradun and Northern Regional Station, Zoological Survey of India, Dehradun. Various diversity indices were calculated using the software program PAST version 3.4. Bray-Curtis cluster analysis (quantitative analysis) was performed to find out the similarity of insects using the software program Biodiversity Pro (McAleece et al., 1997).

RESULTS AND DISCUSSION

A total of 2488 individuals of insect pollinators belonging to 92 species of 59 genera under 25 families and four orders were recorded (Table 1). Fig. 1 provides the variation in the number of species and individuals; Lepidoptera was the most dominant with 53 species accounting for 57.60%; followed by Hymenoptera

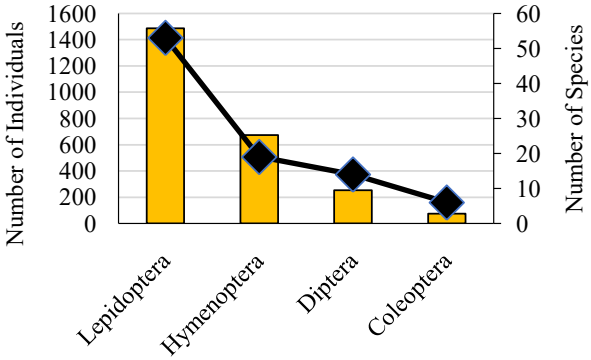

Fig. 1. Species richness/ individuals of pollinator insects of insect orders

Table 1. Species composition, distribution, and relative abundance of insect pollinators

S. No.	Species	Apple	Peach	Pear	Apricot	Plum	Kiwi	Relative Abundance
	Lepidoptera							
	Nymphalidae							
1.	*Acraea issoria* (Hubner)	-	-	-	-	+	-	0.60
2.	*Aglias caschmirensis* (Kollar)	+	+	+	+	+	+	4.42
3.	*Argynnis hyperbius* (L.)	+	-	-	-	-	-	2.41
4.	*Aulocera swaha* (Kollar)	-	-	-	+	+	+	1.60
5.	*Danaus chrysippus* (L.)	-	-	-	+	-	-	0.80
6.	*Danaus genutia* (Cramer)	+	+	-	-	+	-	0.60
7.	*Issoria lathonia* (L.)	+	+	+	+	+	+	1.60
8.	*Euploea core* (Cramer)	-	-	-	-	+	-	0.60
9.	*Euthalia aconthea* (Cramer)	-	-	-	-	-	+	0.40
10.	*Lasiommata schakra* (Kollar)	-	-	-	-	-	+	0.20
11.	*Neptis sankara* (Kollar)	+	-	-	-	-	-	1.00
12.	*Symbrenthia lilaea* Moore	-	+	-	-	-	-	0.20
13.	*Venessa cardui* (L.)	+	+	+	+	+	+	3.01
14.	*Venessa indica* (Herbst)	+	+	+	-	+	+	2.00
15.	*Ypthima nareda* (Kollar)	-	-	+	-	-	-	1.00
	Family: Pieridae							
16.	*Aporia agathon* (Gray)	+	+	+	-	-	-	1.60
17.	*Catopsilia pomona* F.	+	+	-	+	-	-	2.00
18.	*Catopsilia pyranthe* (L.)	+	-	-	-	-	-	1.60
19.	*Colias electo fieldii* Menetries	-	+	-	-	-	-	2.00
20.	*Colias erate* (Esper)	+	-	-	-	-	-	1.00
21.	*Delias belladonna* (F.)	+	+	+	-	-	-	1.00
22.	*Delias sanaca* (Moore)	-	-	-	-	+	-	0.80
23.	*Eurema andersoni* (Moore)	+	-	-	-	-	-	0.60
24.	*Eurema blanda* (Boisduval)	-	+	-	-	-	-	0.60
25.	*Eurema brigata* (Stoll)	-	-	+	+	-	-	0.40
26.	*Eurema lata* (Boisduval)	-	-	-	+	-	-	0.20
27.	*Gonepteryx mahaguru* Gistel	+	-	+	-	+	-	1.60
28.	*Gonepteryx rhamni* (L.)	+	+	-	+	-	-	2.41
29.	*Pieris brassicae* (L.)	+	+	+	+	+	+	4.74
30.	*Pieris canidia* (Sparrman)	+	+	+	+	+	+	4.01
31.	*Pontia daplidice* (L.)	+	-	-	-	-	-	0.20
	Papilionidae							
32.	*Atrophaneura aidoneus* Doubleday	-	-	+	-	-	-	1.20
33.	*Byasa polyeuctes* (Doubleday)	-	-	-	+	-	-	0.60
34.	*Graphium eurous* (Leech)	-	+	-	-	-	-	1.00
35.	*Graphium nomius* (Esper)	+	-	-	-	-	-	0.40
36.	*Papilio bianor* Cramer	-	-	-	-	+	-	0.20
37.	*Papilio demoleus* L.*	-	-	-	-	-	+	0.40
38.	*Papilio machon* L.	+	+	+	+	+	-	0.60
39.	*Papilio polyctor* Boisduval	-	+	-	-	-	-	0.40
40.	*Papilio polytes* L.*	-	-	-	-	-	+	0.36
	Lycaenidae							
41.	*Heliophorus sena* (Kollar)	-	-	-	-	-	+	1.60
42.	*Lampides boeticus* (L.)	-	-	-	-	+	-	1.20
43.	*Lycaena pavana* (Kollar)	+	+	-	-	-	-	0.80
44.	*Lycaena phlaeas* (L.)		+	-	-	-	-	0.60
45.	*Udara albocaeruleus* (Moore)	+	-	-	-	+	-	0.20
46.	*Talicada nyseus* (Guerin-Meneville)	-	-	-	-	-	+	0.28
	Riodinidae							
47.	*Abisara bifasciata* Moore	-	+	-	-	-	-	0.48
48.	*Dodona durga* (Kollar & Redtenbacher)	+	-	-	+	-	-	0.73
	Family: Sphingidae							
49.	*Daphnis nerii* (L.)	-	-	-	+	-	-	0.20
50.	*Macroglossum affictitia* Butler	+	+	-	-	-	-	1.28
51.	*Macroglossum nycteris* Kollar	+	+	-	-	-	-	1.00
	Saturnidae							
52.	*Actias selene* Hubner	-	-	-	-	-	+	0.40

(contd.)

(Table 1 contd...)

	Family: Erebidae							
53.	*Syntomoides imaon* Cramer	+	-	-	-	-	-	0.48
	Hymenoptera							
	Apidae							
54.	*Apis cerana* F.	+	+	+	+	+	+	5.62
55.	*Apis dorsata* F.	+	+	+	+	+	-	4.01
56.	*Apis mellifera* L.	+	+	+	+	+	+	2.81
57.	*Apis laboriosa* Smith	+	-	-	-	-	-	1.20
58.	*Xylocopa bentoni* Cockerell	+	-	-	-	-	-	1.00
59.	*Xylocopa auripennis* Lepeletier	-	+	-	-	-	-	1.00
60.	*Bombus haemorrhoidalis* Smith	+	+	+	+	+	-	0.72
61.	*Bombus* sp.	+	+	+	-	-	-	0.40
	Vespidae							
62.	*Eumenes petiolata* F.	+	-	-	-	-	-	1.60
63.	*Polistes rufolineatus* Cameron	+	-	-	-	-	-	2.41
64.	*Polistes maculipennis* Saussure	-	+	-	-	-	-	1.40
65.	*Vespa basalis* Smith	+	+	-	-	-	-	0.60
	Scoliidae							
66.	*Capsomeris* sp.	+	+	-	-	-	+	1.44
67.	*Scolia affinis* Guerin	-	-	+	-	-	-	0.80
68.	*Scolia venustata* Smith	+	-	-	-	-	-	0.40
	Formicidae							
69.	*Componotus* sp.	-	+	+	+	-	-	0.28
70.	*Camponotus compressus* (F.)	+	-	-	-	-	-	0.12
	Family: Halictidae							
71.	*Halictus spp.*	-	-	+	-	+	-	0.40
	Sphecidae							
72.	*Ammophila atripes* Smith	-	-	-	+	-	-	0.80
	Diptera							
	Syrphidae							
73.	*Eristalis cerealis* F.	-	-	+	+	-	-	1.40
74.	*Eristalis himalayensis* Brunetti	+	-	-	-	-	-	0.36
75.	*Eristalis tenax* (L.)	+	+	+	+	+	+	0.80
76.	*Episyrphus balteatus* (De Geer)	+	-	+	-	+	-	1.00
77.	*Syrphus fulvifacies* Brunetti	+	+	+	+	+	+	1.60
	Tachinidae							
78.	*Gonia rufitibialis* Walker	-	+	-	-	-	-	1.80
79.	*Gonia* sp.	+	-	-	-	-	-	0.24
	Tabanidae							
80.	*Phililiche longirostris* (Hardwicke)	-	+	-	-	-	-	0.12
81.	*Tabanus orientis* Walker	+	-	-	-	+	-	0.28
82.	*Hybomitra* sp.	-	-	-	-	+	-	0.16
	Calliphoridae							
83.	*Lucilia sericata* Meigen	+	-	-	-	+	-	0.64
	Muscidae							
84.	*Musca domestica* L.	+	-	+	-	-	-	0.48
	Sarcophagidae							
85.	*Sarcophaga* sp.	+	+	-	-	-	-	0.40
	Tipulidae							
86.	*Tipula* sp.	-	-	-	-	+	-	0.80
	Coleoptera							
	Scarabaeidae							
87.	*Cetonia bensoni* (Westwood)	-	+	-	-	-	-	1.04
	Coccinellidae							
88.	*Coccinella septempunctata* (L.)	+	+	+	-	+	-	0.40
89.	*Coccinella transversalis* (F.)	-	-	-	+	-	-	0.24
	Chrysomelidae							
90.	*Altica cyanea* (Weber)	+	-	-	-	-	-	0.72
	Meloidae							
91.	*Mylabris cichorii* L.	+	+	-	-	+	-	0.40
92.	*Mylabris pustulata* (Thunberg)	-	-	+	-	-	-	0.16
	Total	51	40	28	25	30	19	

(Abbreviations used: + = species present; - = species absent; * = insect species also act as pest)

with 19 species (20.65 %), *Apis cerana* F. was the most abundant (5.62 %). *Philoliche longirostris, Componotus compressus, Hybomitra* species, and *Mylabris pustulata* were found to be the least abundant. Families of insect pollinators are as given in Fig. 2. Across the four major temperate fruit growing belts studied, maximum number of species were observed from the Dhanachuli region (81 species) followed by others. Data in Table 2 reveals that apple flowers were visited by 935 individuals, 51 species under 20 families of four orders. Of these, Lepidoptera was the most dominant order with 26 species. The flowers of apple, peach, plum, and pear were visited by 51 species (20 families), 40 species (17 families), 30 species (14 families), and 11 species (12 families) of insect pollinators, respectively. Likewise, apricot and kiwi flowers were visited by 25 species (9 families) and 19 species (8 families); peach flowers by 534 individuals under 40 species and 17 families, with

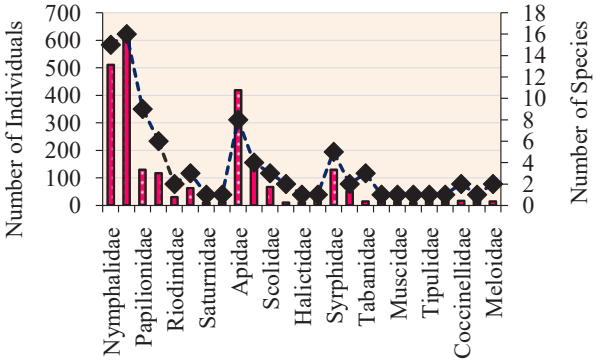

Fig. 2. Species/ individuals of families of insect pollinators

Lepidoptera being the most dominant, and with the family, Pieridae represented by 8 species. Plum flowers were visited by 278 individuals under 30 species and 14 families and of these, Lepidoptera was the most dominant; and pear was visited by 304 individuals under 28 species and 11 families, with Lepidoptera being the most dominant. Apricot flowers were visited by 360 individuals under 25 species and 9 families with Lepidoptera again being the most dominant order with 15 species. Kiwi flowers were visited by 168 individuals under 19 species and 8 families, and Lepidoptera was the most dominant.

Table 3 provides details of richness of insect pollinators across fruit crops as calculated with Margalef's index- maximum value was in apple (7.309), followed by peach (6.193), plum (5.153), pear (4.723), apricot (4.316) and kiwi (3.513) respectively. The calculated values of the evenness were 0.847, 0.766.765, 0.750, 0.746, and 0.720 for apricot, apple, kiwi, plum, pear, and peach, respectively. Shannon-Weiner index were found to be- for apple (3.665), peach (3.361), plum (3.114), apricot (3.053), pear (3.040), and kiwi (2.677). Thus, maximum diversity was recorded in apple, peach, and pear crops. The single linkage Bray- Curtis cluster analysis of species richness showed the % of similarity of insect pollinators (Fig. 3)- showing two major clusters, first cluster being kiwi, plum, apricot, and pear, while the second cluster being of apple and peach. Thus, the 92 species of insect pollinators fall under 25 families with maximum species belonging to the orders

Table 2. Relative number of individuals/ species of pollinators of fruit crops

Orders	Apple	Peach	Pear	Apricot	Plum	Kiwi	No. of individuals/ species
Lepidoptera	527/26	308/22	173/13	166/15	179/16	135/14	1488/53
Hymenoptera	309/12	145/10	78/8	66/6	50/5	26/3	674/19
Diptera	73/10	59/5	45/5	22/3	46/7	7/2	252/14
Coleoptera	26/3	31/3	8/2	6/1	32/2	--	74/6
Total (Indv./Sp.)	935/51	543/40	304/28	260/25	278/30	168/19	2488/92

Table 3. Diversity indices of insect pollinators of fruit crops

Diversity indices	Apple	Peach	Pear	Apricot	Plum	Kiwi	Total
Taxa_S	51	40	28	25	30	19	92
Individuals	935	543	304	260	278	168	2488
Dominance_D	0.031	0.043	0.057	0.052	0.053	0.094	0.021
Simpson_1-D	0.969	0.956	0.942	0.947	0.946	0.905	0.978
Shannon_H	3.665	3.361	3.040	3.053	3.114	2.677	4.153
Evenness_e^H/S	0.766	0.720	0.746	0.847	0.750	0.765	0.691
Margalef's	7.309	6.193	4.723	4.316	5.153	3.513	11.64

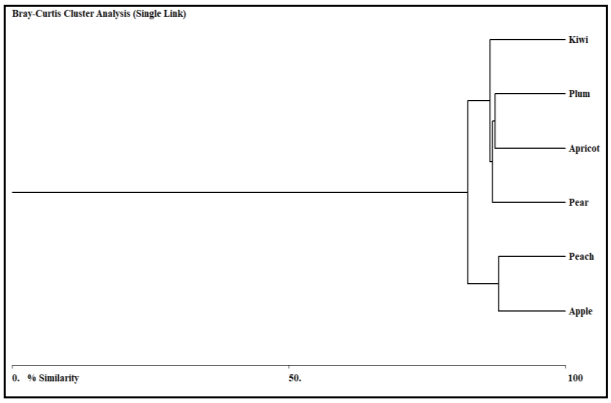

Fig. 3. Bray-Curtis Cluster Analysis of pollinators in fruit crops

Lepidoptera, Hymenoptera, Diptera and Coleoptera. Relative abundance reveals that *Apis cerana*, *Pieris brassicae*, *Aglis caschmirensis*, *Pieris canidia*, *Vanessa cardui*, *Apis melifera*, *Vanessa indica*, *Issoria lathonia, Syrphus fulvifacies,* and *Eristalis tenax* were the most abundant. Maximum diversity was observed in apple, followed by peach, pear, plum, apricot and kiwi.

In North Korea, 88 species of insect pollinators were found on the flowers of apple, pear, and peach (Hong et al., 1989). Joshi and Joshi (2010b) in the orchards of apple, peach, pear, and citrus in the Mukteshwar area of district Nainital reported 122 species under 31 families. Lepidoptera was the most dominant order followed by Hymenoptera, Coleoptera, Diptera, Odonata, Hemiptera, and Heteroptera. Sharma and Mitra (2012) on insect pollinators of temperate fruit crops in Himachal Pradesh revealed Hymenoptera as the most dominant. Maximum number of insect pollinators were observed from *Malus* sp. Raj and Mattu (2014) with apple, pear, peach, plum, almond, and cherry in Himachal Himalaya, revealed the presence of 70 insect pollinators under 27 families and six orders. Mattu and Bhagat (2015) in twenty orchards showed that apple flowers were visited by 44 species of insect pollinators corresponding to six orders and 18 families. *Apis cerana* was found the most abundant. Mattu and Nirala (2016) with apple crop in Shimla hills revealed 41 species of insect pollinators with Hymenoptera as the most dominant. *Apis cerana*, *Pieris brassicae*, *Aglis caschmirensis*, *Pieris canidia*, *Vanessa cardui*, *Apis melifera* were realtively more abundant and these results are in conformity with those of others (Mishra et al., 1976; Verma and Chauhan, 1985; Verma, 1990; Mattu and Mattu, 2010; Joshi and Joshi, 2010a; Raj et al., 2012; Sharma et al., 2013; Mattu and Bhagat, 2016). Likewise, McGregor (1976) and Free (1993) observed that honey bees were the important and dominant pollinators in the United States and Europe. The dominance of bees, syrphids, butterflies, and beetles in apple crops in the Himalayan region had been reported (Raj et al., 2012; Mattu, 2014). *Apis cerana* enhances apple production in the Nainital district of Uttarakhand (Sharma et al., 2012). Unfortunately, the bees that pollinate the wild plants are seldom paid any scientific attention (Bhattacharyya and Chakraborty, 2014). Sathe and Gophane (2015) from Kolhapur region, India, observed 30 pollinating insects belonging to the order Lepidoptera, Hymenoptera, Diptera, Coleoptera, and Thysanoptera; *Apis dorsata* was the most abundant. Dar et al. (2017) observed 45 pollinators from Srinagar, Budgam, and Pulwama region of Kashmir valley, India. Kapkoti et al. (2016) studied the variations in the abundance and diversity of insects in different apple orchards of Kumaun, Western Himalaya, India, and reported the important insect groups like bees, wasps, hoverflies, and dragonflies. Arya et al. (2018) conducted a systematic survey of anthophilous insect fauna and reported a total of 53 species of insects under 18 families in Binsar Wildlife Sanctuary, Western Himalaya, India.

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TOXICITY OF ACEPHATE TO LIVER AND KIDNEY OF FEMALE WISTAR RATS

Ekta Jain and Nisha Vashishat*

Department of Zoology, Punjab Agricultural University, Ludhiana141004, Punjab, India
*Email: nisha.vashishat@pau.edu (corresponding author)

ABSTRACT

Acephate is a broad spectrum insecticide used against pests of vegetables, cotton and ornamental plants. In the present study, acephate was orally administered to female wistar rats to examine its toxic effects, if any, at dose level of 1/50th, 1/25th and 1/10th of LD_{50} value along with a control group for 45 days. Results revealed a remarkable decrease in the feed intake of 1/10th acephate treated rats during 5th and 6th week of treatment. The net body weights and liver weight decreased non-significantly to a small extent over 45 days of treatment. The weight of kidney and content of total soluble protein decreased significantly in a dose dependent manner in treated rats. The significant alterations in the activity of antioxidative enzymes i.e. glutathione peroxidase, glutathione-S-transferase, glutathione reductase, superoxide dismutase, catalase and lipid peroxidation levels were observed. The appearance of comet in 1/10th dosed rats indicated DNA damage. Further, no formation of concentric rings in treated rats indicated the absence or low concentration of antibodies in the serum.

Key words: Acephate, antibodies, antioxidative enzymes, DNA damage, genotoxic, immunological, lipid peroxidation, LD_{50}, organophosphates, oxidative stress, *Rattus norvegicus*

Organophosphate (OP) pesticides have been used worldwide during past few decades in agricultural and household practices for crop protection and pest control. As a result of their widespread use these chemicals ultimately enter into the environment and affect the life there in. World Health Organization has reported approximately three million cases of organophosphate poisoning/ year accounting for about 300,000 deaths (Robb and Baker, 2019). The toxic effects of OPs on non target species include many neurotoxic, immunological, mutagenic, teratogenic, carcinogenic and reproductive effects (Mostafalou and Abdollahi, 2017). Though the main target of organophosphates is central and peripheral nervous system attributed to inactivation of enzyme acetylcholinesterase (AChE) (Ndonwi et al., 2019) but acute and subchronic toxicity of OPs is also due to disturbance in redox reactions resulting into oxidative stress. The disturbance in the balance between the generation and removal of free radicals within body by OPs leads to oxidative stress by production of free radicals such as reactive oxygen species (ROS). The major biomolecules such as proteins, lipids and nucleic acids are attacked by ROS, but lipids are targeted the most and hence lipid peroxidation of cell membranes takes place.

Acephate (O, S-dimethyl acetyl phosphoramid-othioate) is one of the top ten organophosphate insecticides used in agriculture (Ribeiro et al., 2016). It is used as foliar treatment in several vegetables, cotton and ornamental plants for the control of many biting and sucking insects. Acephate and its primary metabolite, methamidophos are toxic to both target as well as non target organisms (Lin et al., 2020). Studies conducted on effects of acephate on different organisms have pinpointed its potential cytotoxic, neurotoxic, mutagenic and carcinogenic effects (Bhadaniya et al., 2015) along with suppression of the immune system which results into more susceptibility to infectious diseases. Sankhala et al. (2012) reported suppression of humoral immune response in acephate treated rats. The administration of acephate resulted into genotoxicity and cytotoxicity and was also believed to affect sperm structure in rats (Dhanushka et al., 2017). Liver and kidney are the major organs responsible for drug metabolism and excretion, respectively. The assessment of oxidative stress biomarkers in these organs may give an account of the toxicity of acephate. The adverse effects of pesticides cannot be ignored and are a serious public health issue because a large portion of the population is indulged in agricultural and related activities which involve their high scale chronic exposure to the pesticides. The ability of acephate to produce ROS like other OPs (Dhanushka et al., 2017) highlighted the need to carry out present study to investigate the toxic effects of acephate in liver and kidney along with genotoxic and immunological effects in female wistar rats.

MATERIALS AND METHODS

All chemicals used were acquired from SD Fine-Chemical Ltd. and Sissco Research Laboratories Pvt. Ltd., Mumbai, India. Standard pelleted feed for rats was obtained from Ashirwad Industries, S A S Nagar, India. Acephate (Starthene 75 SP) was procured from Modern Pesticides, Ludhiana. The study was conducted on sexually mature female wistar rats, *Rattus norvegicus* (Berkenhout) weighing 130-200 gm procured from Central animal facility, NIPER, S A S Nagar. Before treatment, rats were acclimatized for 15 days and then divided into four groups (3 treatments and 1 control) containing six rats each. The rats were kept in standard laboratory conditions (22°C for 45 days) and were provided with standard pelleted diet and water ad libitum. The experiment was approved by the Committee for the Purpose of Control and Supervision of Experiments on Animals (CPCSEA) vide Memo no. IAEC/2019/63-97 and the protocol given by National guidelines on the proper care and use of animals in the laboratory research were followed. The exposure of commercial formulation of acephate (Starthene 75 SP) was given to female rats by mixing it in olive oil to increase its acceptability to the rats. The first group served as control and received olive oil only without pesticide. Acephate treatment was given to the other three groups of rats @ 1/50th, 1/25th and 1/10th of LD_{50} i.e. 866 mg/ kg of body weight (Gupta and Moretto, 2005) for 6 weeks by oral intubation. After pesticide treatment, they were examined for three to five hours for symptoms like, excessive salivation, hyperactivity and mortality. The feed intake of the acephate treated and control rats was measured and expressed as gm/100 gm b.wt at weekly intervals. Weighing of rats was done before starting the experiment and at weekly intervals for 6 weeks. Following formula was used to calculate the difference in body weight

$$\text{Difference in body weight (g/100 g b.wt/day)} = \frac{\text{Current body weight (g)- Previous body weight (g)}}{\text{Previous body weight (g) x number of days}}$$

After six weeks of treatment, rats were fasted overnight and sacrificed by cervical dislocation. After dissection, blood sample from each rat was collected directly from heart in EDTA coated vials and centrifuged at 2300 r.p.m. for 15 min. Supernatant was collected as plasma and stored for antioxidant activity. The liver and kidney were excised out, cleaned in saline and weighed. After weighing of organs, 0.5 gm each of kidney and liver were homogenized in 2 ml of 0.1 M phosphate buffer saline (PBS, pH 7.4). The homogenate formed was centrifuged at 3000 rpm for 10 min and supernatant collected was stored for estimation of oxidative stress biomarkers. The antioxidative activity (AOA) in blood plasma was estimated by the method of Koracevic and Koracevic (2001). The liver and kidney supernatant was used for estimation of total soluble proteins, Superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), glutathione-S-transferase (GST) and glutathione reductase (GR) and lipid peroxidase (LPO) by the standardized methods- Lowry et al. (1951), Marklund and Marklund (1974), Aebi (1983), Hafeman et al. (1984), Habig et al. (1974), Carlberg and Mannervik (1985) and Stocks and Dormandy (1971), respectively. To assess genotoxicity bone marrow was extracted from femur of the rat with syringe and needle. The comet assay was performed as described by Singh et al. (1988). Slides were viewed under a fluorescent microscope Nikon Eclipse 80i for analyzing the presence of comet tail (DNA strand breaks) within 20 min of staining. Blood was collected from orbital socket by retro-orbital bleeding of rats before the treatment and after six weeks of treatment. Serum was obtained from blood and quantitative determination of serum immunoglobulins was done by observing the antibody-antigen reaction on the agarose coated slides through radial immunodiffusion as per Fahey and Mackelvey (1965). The data were subjected to ANOVA (p=0.05).

RESULTS AND DISCUSSION

No mortality was seen in acephate treated rats but other symptoms such as increase in sleep duration, cloudy eyes, red spots on thoracic region, itching were seen along with loss of body hair. There was no significant change in food consumption in the low dosed rats however a remarkable decrease was observed in the feed intake of 1/10th acephate treated rats during 5th and 6th week of treatment. Excessive salivation and decrease in feed intake was recorded in high dose acephate treated rats (Bhadaniya et al., 2015). The decrease in food intake may be due to disturbance in hormone level or direct cytogenetic effect of pesticide. The net body weights decreased to a small extent over 45 days of treatment while no such effects were observed in the control rats. The decrease in body weight of the organophosphate treated rats was reported by many workers and reduction in the food consumption can be the reason behind the reduced body weight of the treated rats which is a direct effect of application of organophosphate (Mokhtar et al., 2013). The liver of

treated rats showed non-significant decrease in weight (3.12± 0.01 gm/100 gm b.wt.) as compared to that of the control rats (3.25± 0.01 gm/100 gm b.wt.) however, the kidney weight decreased significantly in the treated rats (0.22± 0.006 gm/ 100 gm b.wt.) in dose dependent manner as compared to the control rats (0.37± 0.006 gm/ 100 gm b.wt.).

The AOA of plasma in control rats was determined to be 1.70± 0.10 mmol/ ml. The activity showed a significantly decreasing trend in plasma of 1/50th, 1/25th and1/10th of LD_{50} acephate treated rats with the values 1.43± 0.08, 1.19± 0.04 and 0.86± 0.02 mmol/ ml respectively (Fig. 1). The amount of total soluble proteins significantly decreased to half of its original value in the liver of acephate treated rats and to a significant extent in kidneys as well (Table 1). The disintegration of the structural proteins could be the reason for protein exhaustion. Protein content showed a declining trend in chlorpyrifos treated albino rats (Ubaidur Rahman et al., 2021). There was a significant reduction in SOD and CAT activity in kidney and liver of 1/10th acephate treated rats as compared to control. Non significant change was seen in the glutathione peroxidase activity in both the organs of treated rats as compared to control rats. The present study showed a significant increase in the GST activity in liver and kidney of the treated rats. There was significant decrease in the GR activity in liver but non-significant change in kidney of treated rats. In a study conducted by Arab et al. (2018), malathion increased MDA level and reduced GSH content compared with the control group in rat ovarian tissue. Muhammad et al. (2019) revealed that GPx levels decreased in fipronil treated rats. The biochemical studies in the rat liver demonstrated significant perturbations in the levels of glutathione-S-transferase (Gupta et al., 2019).

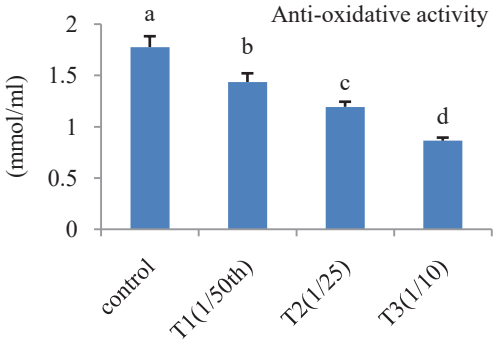

Fig. 1. Effect of acephate on antioxidant activity (mmol/ml) of plasma of wistar rats

A significant increase in level of LPO was observed in both the organs of treated rats. An increase in levels of reactive oxygen species causes oxidative stress and lipid peroxidation (Selmi et al., 2018). Lipid peroxidation and tissue damage is the result of induction of oxidative stress due to excessive generation of free radicals and ROS by the toxicity of pesticides. The mechanism of generation of oxidative stress is related to pesticide biotransformation as in the case of chlorpyrifos (Ndonwi et al., 2019). It further may induce developmental and behavioral abnormalities, hematological malignancies, histopathological alterations, oxidative stress, genotoxicity and immunotoxicity as evidenced by animal modeling (Ubaidur Rahman et al., 2021). According to recent studies conducted by Upadhyay et al. (2019), acephate exposure caused changes in biomarker responses like total protein and total cholesterol in female wistar rats. Liver and kidney collectively play an important role in metabolization process by transformation of thiono organophosphates accompanied by elimination process and act as main sites where maximum effects of pesticide by generation of oxidative stress can be seen. Rats treated with 200

Table 1. Effect of acephate on oxidative stress biomarkers in liver and kidney tissues of female wistar rats

Para-meters	Treatment							
	Liver				Kidney			
	Control	1/50th	1/25th	1/10th	Control	1/50th	1/25th	1/10th
Protein	7.29±0.10^{a}	6.61±0.10^{b}	5.91±0.10^{c}	4.11±0.20^{d}	9.55±0.10^{a}	9.01 0.02^{a}	8.63±0.20^{b}	8.39±0.03^{c}
SOD	0.68±0.20^{a}	0.57±0.006^{b}	0.52±0.009^{b}	0.41±0.11^{c}	0.70±0.00^{a}	0.55±0.007^{b}	0.40±0.009^{b}	0.30±0.00^{b}
CAT	0.82±0.01^{a}	0.75±0.02^{b}	0.69±0.006^{b}	0.57±0.004^{c}	1.87±0.004^{a}	1.65±0.03^{b}	1.44±0.6^{b}	1.03±0.007^{a}
GPx	0.57±0.02^{a}	0.57±0.03^{a}	0.42±0.01^{a}	0.30±0.004^{b}	0.54±0.007^{a}	0.45±0.02^{a}	0.44±0.02^{a}	0.43±0.008^{a}
GST	2.35±0.013^{a}	4.99±0.011^{b}	6.68±0.04^{c}	7.68±0.04^{d}	0.56±0.009^{a}	0.69±0.034^{b}	0.74±0.013^{c}	0.83±0.004^{d}
GR	4.77±0.008^{a}	3.47±0.026^{b}	2.48±0.04^{b}	1.97±0.08^{b}	4.76±0.03^{a}	4.58±0.02^{a}	4.37±0.011^{a}	3.95±0.017^{b}
LPO	0.57±0.004^{a}	0.69±0.006^{a}	0.75±0.02^{a}	0.82±0.01^{b}	1.03±0.007^{a}	1.44±0.6^{a}	1.65±0.03^{a}	1.87±0.004^{b}

Values expressed as mean± SE; ^{abcd} represents significant difference between treatments for different organs at p≤0.05 as compared to control. Units: Protein (mg/ gm wet weight of tissue), SOD (U/mg protein), CAT (µmole of H_2O_2 decomposed/min/mg protein), GPx(U/ mg protein), GST (µmoles of GSH-CDNB conjugate formed/min/mg protein), GR (µmoles of NADPH oxidized/min/mg protein), Lipid peroxidation (nmol MDA/100 mg tissue)

mg/ kg b.w. of malathion showed oxidative alterations and many histopathological lesions in the liver and kidney tissues (Selmi et al., 2018); severe damage was observed in hepatic tissue including prominent enlargement of sinusoids, infiltration of mononuclear cell, dilation, hemorrhage and necrosis, while it was degeneration of glomeruli, Bowman's capsules and associated tubules structure in kidney. Londhe et al. (2020) reported degeneration in liver and kidney of $1/20^{th}$ of LD_{50} of acephate treated female rats.

Slides of bone marrow cells showed orange-coloured cells of control rats which indicated healthy DNA. In $1/50^{th}$ and $1/25^{th}$ acephate treated cells, DNA strands were seen which were yellow in colour. It indicated incomplete damage of DNA i.e. only unwinding of the DNA strands whereas in $1/10^{th}$ acephate treated rats which was the highest dose, a proper comet tail was observed which showed DNA damage (Fig. 2,3). Exposure of rat lymphocytes to commonly used organophosphate pesticides i.e. chlorpyriphos, methyl parathion and malathion caused significantly marked increase in DNA damage (Ojha and Gupta, 2015). The DNA damage in acephate treated rats may be due to the production of ROS as well as electrophilic free-radical metabolites which interacts with DNA to induce DNA strand breaks. According to Goldoni et al. (2019), the appearance of tail in DNA strand is dose dependent. A significant increase in DNA damage was observed by Aranha et al. (2020) in peripubertal male rats exposed

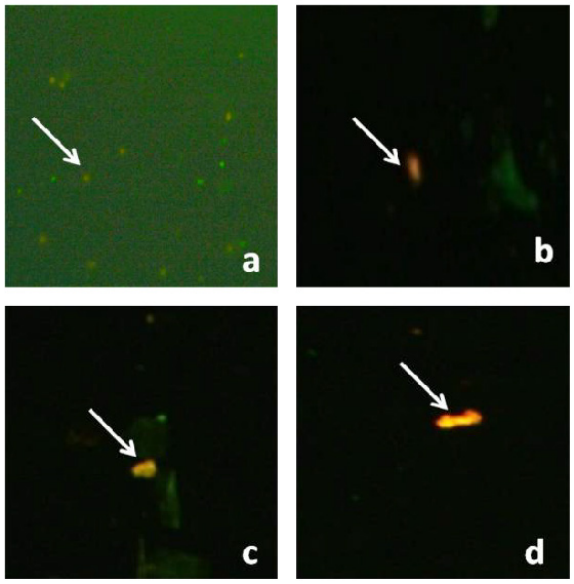

Fig. 2. Comet assay showing a) normal cells with no DNA damage in control rats, b) small comet tail in $1/50^{th}$ of LD50 of acephate treated rats, c) medium comet tail in $1/25^{th}$ of LD50 of acephate treated rats and d) large comet tail in $1/10^{th}$ of LD50 of acephate treated rats

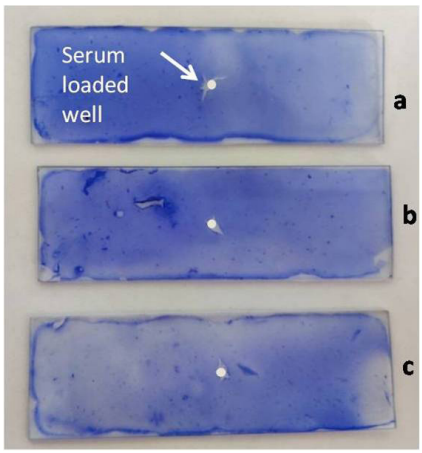

Fig. 3. Agar-coated slides a) $1/50^{th}$, b) $1/25^{th}$, c) $1/10^{th}$ of LD_{50} value of acephate treated rats showing no antibody-antigen reaction thus no concentric rings formed

to acephate in combination with other agrochemicals. In Radial immunodiffusion assay, there was no formation of concentric rings in the acephate treated slides which indicated the absence or low concentration of antibodies in the serum as compared to control. This may be due to lesser production of antibodies by the plasma cells. The chlorpyrifos treated rats showed a significant decrease in the IgG level in the 2^{nd} week of treatment (8368± 1192 mg/ l) when compared to control animals (10252± 555 mg/ l) (Elelaimy et al., 2012).

It can be concluded that acephate showed effects in female wistar rats at both the organ and cellular level. DNA strand breakage and absence of concentric rings in RIA highlighted the genotoxic and immunomodulatory potential of acephate in the exposed organisms. Liver and kidney both the organs were found to be affected in terms of acephate induced oxidative stress by elevation of pro-oxidants markers and depletion of antioxidant enzymes markers in female wistar rats in dose dependent manner.

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CONFLICT OF INTEREST

The authors declare no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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RELATIVE SUSCEPTIBILITY OF LIFE STAGES OF COTTON WHITEFLY *BEMISIA TABACI* (GENN.) TO PYRIPROXYFEN

Kelageri S S, Mahapatro G K[1]*, Subramanian S, Chitra Srivastava and Rajna S

Division of Entomology, ICAR-Indian Agricultural Research Institute (IARI), New Delhi 110012, India
[1]IARI Regional Station, Pune 411067, Maharashtra, India
*Email: gagan_gk@rediffmail.com (corresponding author)

ABSTRACT

The relative susceptibility of lifestages of seven *Bemisia tabaci* (Genn.) populations from major cotton growing regions in India to pyriproxyfen has been studied. The results revealed that adults were unaffected at significantly high concentration ie., 200 mg/ l (field recommended dose, <10% mortality), hence adult bioassay was not done. Indore and Amravati populations were the most and least susceptible ones for both egg and nymphal stages; and all the populations were found susceptible to pyriproxyfen with RR ratio of <5, except for Amravati one, revealing low level of resistance with RR ratio (5.04- egg; 5.09- nymph) computed deploying the LC_{90} and LC_{50} values.

Key words: *Bemisia tabaci*, pyriproxyfen, bioassay, $LC_{90,}$ LC_{50}, adults, egg, nymph, juvenile hormone analogue, relative resistance ratio

The cotton whitefly *Bemisia tabaci* (Gennadius) is a pest of global significance affecting wide range of crops including field, vegetable, fruit and ornamental crops (Kanakala and Ghanim 2019; Horowitz et al., 2020). Indirectly *B. tabaci* affects crops through vectoring more than 114 virus species (Simon, 2003). Use of insecticides is the major control measure against *B. tabaci,* although the rapid development of insecticide resistance by *B. tabaci* has resulted in frequent pest outbreaks. It has evolved resistance to most of the commonly used insecticides (Basit 2019, Horowitz et al., 2020; Mota-Sanchez and Wise, 2019). Involvement of biorational insecticides in the spray schedule reduces selection pressure and encourages natural enemies. Juvenile hormone analogues (JHAs) are the synthetic analogues of juvenile hormone, and these are considered to be effective and environment friendly (Mohandass et al., 2006). Pyriproxyfen is a pyridine based juvenile hormone analogue ie., 4-phenoxyphenyl (RS)-2-(2-pyridyloxy) propyl ether, it targets JH binding site receptors in insects by mimicking the action of juvenile hormone and thus keeping it in the immature stage (Sullivan and Goh, 2008). Pyriproxyfen has been proven as an effective molecule for managing *B. tabaci* with strong ovicidal action, inhibiting adult emergence and translaminar activity against eggs; and the egg hatchability of the treated female gets suppressed (Ishaaya and Horowitz, 1992). In this study the relative susceptibility of seven *B. tabaci* populations from cotton growing regions of India to pyriproxyfen has been evaluated.

MATERIALS AND METHODS

Bemisia tabaci populations were collected from seven cotton growing locations and reared on cotton (*Gossypium hirsutum* L.) in the Insect Proof Climate Control Chamber, Division of Entomology, IARI (27±2^{0}C, 60-70% RH, and photoperiod 14:10- L:D). The whiteflies collected from *Leucaena leucocephala* from Pusa campus, reared under laboratory condition, served as the susceptible check. The details of populations are- Amravati (21.02°N 77.48°E), Guntur (16.22°N,80.30°E), Hisar (29.09°N, 75.87°E), Indore (22.8°N,75.73°E), Ludhiana (30.54°N, 75.48°E), New Delhi (28.64°N,77.17°E), Sriganganagar (29.54°N,73.54°E), and susceptible (laboratory- 28.38°N 77.09°E) one. Commercial formulation of pyriproxyfen 10 EC (Lano®, Sumitomo Chemical India) procured from the market was diluted with deionized water to make 1% stock solution for use in bioassay. Seven concentrations with three replications were set and studies carried out following the modified Insecticide Resistance Action Committee (IRAC) protocols (https://irac-online.org/). All the important lifestages viz., egg, nymph (N2) and adults were used; lethal effects in egg and nymphal stage (2nd instar) were tested following the IRAC method No. 016 (formally method No 12c) (https://irac-online.org/), whereas adults were tested with leaf dip bioassay- modified IRAC method by Naveen et al. (2017). The estimates of lethal concentrations and 95% confidence intervals

were determined by log–dose probit analysis using PoloPlus 2.0 (LeOra Software, Petaluma, CA). Relative resistance ratios were computed to classify these- 5.0 < RR ≤ 10.0, as low level of resistance; (10.0 < RR ≤ 40.0) as moderate level; and RR ≥40.0 as a high level of resistance (Liu et al., 2010). Correlation coefficient was worked out to understand the relationship between RR and slope of the equation.

RESULTS AND DISCUSSION

The susceptibility studies were carried out keeping the laboratory susceptible population as the baseline. Pyriproxyfen did not cause significant mortality in adults even at very high concentration i.e. < 10 % mortality at 200 mg/ l (maximum field recommended dose) with the laboratory susceptible populations; hence, adult bioassay was not undertaken for the field populations. The LC_5 against egg and nymph given in Table 1 reveal that control mortalities in all the bioassays were <7%, and the LC_{50} and LC_{90} values for the susceptible population was 0.018 and 0.083 mg/ l. The RR ratio for egg was maximum for the populations from Amravati and Sriganganagar. There was no significant difference between the LC_{50} and LC_{90} value of laboratory susceptible population and field populations except for Sriganganagar and Hisar ones considering the overlap of 95% fiducial limits. The results suggest a high amount of homogeneity in the response of populations to pyriproxyfen at egg stage. In nymphal bioassay the control mortalities were <9%, and LC_{50} and LC_{90} values for the susceptible population were 0.054 and 0.176 mg/ l. The RR ratio for egg stage was maximum for Amravati population followed by Ludhiana one. There was a significant difference between the LC_{50} value of laboratory susceptible and field populations except for Indore one; similarly there was significant difference between the LC_{90} value of laboratory susceptible and field populations except for Indore, New Delhi and Guntur populations; and the overlap of 95% fiducial limits suggest the existence of heterogeneity in the response of these to pyriproxyfen at nymphal stage. Correlation coefficients indicate non-significant values between slope and RR values for both egg (n=8, r=–0.265, p=0.526) and nymph (n=8, r=0.502, p=205) stages at p=0.05, indicating the heterogeneous response across individuals of the samples. According to the resistance level classification given by Liu et al. (2010), the populations studies were found to be susceptible to pyriproxyfen at both egg and nymphal stages except for Amravati population at egg stage.

Pyriproxyfen showed limited efficacy against adults of *B. tabaci*, but maintaining the insect in its immature stage, with suppression of embryogenesis and adult formation (Ishaaya and Horowitz 1992). Pyriproxyfen is known to cause the external deformities in emerged adults such as twisted wings and legs in case of *Plodia interpunctella* (Ghasemi et al., 2010), apart from external deformities pyriproxyfen reduces the size of ovaries due to the reduction in the synthesis and supply of lipid and protein (Ghasemi et al., 2010). There are many reports of pyriproxyfen resistance in *B. tabaci*- Egg bioassays by Devine et al. (1999) reported very high level of resistance (6500-fold) among Israeli populations; low to moderate level of resistance (11-fold) in Chinese populations (Luo et al., 2010); moderate resistance from Alhassa Oasis (Saudi Arabia) (Hajjar et al., 2019); and high resistance (89.71-folds) from cotton field populations of Arizona (Ma et al., 2010) and Australian (96.9 fold) (Hopkinson et al., 2019). Similarly with nymphal bio assay studies, Basit et al. (2013) reported low level of resistance from Pakistan; moderate level of resistance (30.08-fold) from West Bengal, India was observed (Roy et al., 2019); and very high level of resistance (1100-fold) in Israeli populations (Devine et al., 1999). Pyriproxyfen resistance in *B. tabaci* might be a case of metabolic resistance involving cytochrome P450 monooxygenases (P450s) and glutathione S-transferases (GSTs) (Ma et al., 2010; Ghanim et al., 2007; Nauen et al., 2015).

The present results are in contrast with the resistance development data available from other parts of the world, as it has been observed that the Indian populations are highly susceptible to the pyriproxyfen at both egg and nymphal stages. This might be due to the less selection pressure exerted as pyriproxyfen is not among the mainstream insecticides. Another factor is the dominance of B biotype of *B. tabaci* in the Indian subcontinent, as confirmed by the earlier studies (Ellango et al., 2015; Mandali et al., 2016). It was observed that cases of strong resistance to pyriproxyfen have been associated with the Q rather than the B biotype (Dennehy et al., 2005; Horowitz and Ishaaya, 2014). This fact derives support from the data that in Israel considerable reduction in pyriproxyfen resistance was observed since 2009. Since then studies had shown a significant shift in the biotype ratios i.e. the B biotype has become predominate over the Q (Crowder et al., 2011; Horowitz and Ishaaya, 2014). Recent studies involving the *B. tabaci* populations from major cotton growing regions of India revealed the LC_{50} values of 52 to 956 and 26 to 194 mg/ l for imidacloprid and

Table 1. Log dose probit mortality data for pyriproxyfen against egg stage of different *Bemisia tabaci* populations

S. No.	Population	df	Slope± SE	$\chi 2$	LC_{50} value mg/ l (CI 95%)	Fiducial limit for LC_{50} (mg/ l)	RR for LC_{50}	LC_{90} value mg/ l (CI 95%)	Fiducial limit for LC_{90} (mg/ l)	RR for LC_{90}
Lab Susceptible		3	1.929± 0.104	2.764	0.018	0.010 to 0.031 (a)	1.00	0.083	0.042 to 1.538(a)	1.00
1	Amravati	3	2.171± 0.095	1.261	0.064	0.026 to 0.115(a)	3.56	0.418	0.188 to 16.826(a)	5.04
2	Guntur	3	1.552± 0.089	3.150	0.038	0.031 to 0.045(a)	2.11	0.253	0.178 to 0.426(a)	3.05
3	Hisar	3	1.850± 0.095	1.146	0.052	0.043 to 0.063(b)	2.89	0.258	0.181 to 0.458(a)	3.11
4	Indore	4	2.566± 0.085	2.175	0.020	0.010 to 0.040 (a)	1.11	0.135	0.057 to 6.133(a)	1.63
5	Ludhiana	3	1.623± 0.082	1.781	0.049	0.027 to 0.083(a)	2.72	0.303	0.145 to 3.328(a)	3.65
6	New Delhi	3	1.556± 0.079	3.134	0.030	0.023 to 0.039(a)	1.67	0.201	0.123 to 0.484(a)	2.42
7	Sriganganagar	3	1.555± 0.087	2.112	0.056	0.035 to 0.089(b)	3.11	0.371	0.179 to 3.038(a)	4.47

Log dose probit mortality data for pyriproxyfen against nymphal stage (2^{nd} instar) of different *Bemisia tabaci* populations

S. No.	Population	df	Slope± SE	$\chi 2$	LC_{50} value mg/ l (CI 95%)	Fiducial limit for LC_{50} (mg/ l)	RR for LC_{50}	LC_{90} value mg/ l (CI 95%)	Fiducial limit for LC_{90} (mg/ l)	RR for LC_{90}
Lab Susceptible		3	1.565± 0.269	2.824	0.054	0.041 to 0.073(a)	1.00	0.176	0.105 to 0.316(a)	1.00
1	Amravati	3	2.543± 0.416	0.874	0.275	0.193 to 0.396(c)	5.09	0.878	0.540 to 4.244(b)	4.99
2	Guntur	4	3.562± 0.541	2.863	0.155	0.136 to 0.176(b)	2.87	0.355	0.285 to 0.517(a)	2.02
3	Hisar	4	3.603± 0.589	0.985	0.173	0.151 to 0.195(b)	3.20	0.393	0.318 to 0.575(b)	2.23
4	Indore	3	2.362± 0.397	0.485	0.079	0.065 to 0.095(a)	1.46	0.275	0.206 to 1.024(a)	1.56
5	Ludhiana	4	3.236± 0.569	2.142	0.191	0.169 to 0.216(c)	3.54	0.424	0.340 to 0.634(b)	2.41
6	New Delhi	3	2.949± 0.488	0.062	0.137	0.117 to 0.159(b)	2.54	0.373	0.285 to 0.614(a)	2.12
7	Sriganganagar	3	3.880± 0.599	1.150	0.187	0.166 to 0.210(c)	3.46	0.400	0.327 to 0.568(b)	2.27

Chi-square values non-significant- p=0.05 (table value 3df=7.81, 4df=9.49); Letters in parentheses indicate significant difference in lethal concentrations

thiamethoxam; while pyrethroids viz., cypermethrin and deltamethrin showed LC_{50} values of 10 to 1362 and 10 to 760 mg/ l respectively. Similarly OP insecticides triazophos, monocrotophos and chlopyriphos showed LC_{50} values ranging from 53 to 1429, 88 to 3934, 12 to 220 mg/ l, respectively (Naveen et al., 2017). Novel insecticides fipronil and flonicamid showed LC_{50} values of 6.56 to 20.80 and 23.35 to 749.91 mg/ l (Romila et al., 2019) and for cyantraniliprole it was 1.80 to 4.57 mg/ l (Rajna et al., 2021). Comparison of these LC_{50} values with those of pyriproxyfen from the present study viz., 0.018 to 0.064 mg/ l for egg and 0.054 to 0.275 mg/l for nymph reveal the supremacy of the pyriproxyfen, suggesting that it can be used as a stage specific insecticide in IRM programmes.

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AUTHOR CONTRIBUTION STATEMENT

CS, MGK, and SS conceived and designed research, KSS and RS conducted experiments and analyzed data, KSS wrote manuscript and MGK corrected manuscript.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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DIVERSITY OF APHIDS AND THEIR PREDATORY COCCINELLIDS FROM WEST BENGAL

Atanu Maji, Suprakash Pal[1*], Biwash Gurung[2], Moulita Chatterjee and Shyamal Kumar Sahoo

Department of Entomology; [1]Directorate of Research (RRS-TZ), Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar 736165, West Bengal, India
[2]School of Agriculture, ITM University, Gwalior 474001, Madhya Pradesh, India
*Email: palsento@gmail.com (corresponding author)

ABSTRACT

The terai agroclimatic region of West Bengal has been surveyed in this study for the diversity of aphids and their predatory coccinellids during 2017-19. The collected specimens were studied in the laboratory of Department of Entomology, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar. A total of 29 plant hosts were observed which revealed that *Brevicoryne brassicae* (L), *Myzus persicae* (Sulzer), *Lipaphis erysimi* (Kalt), *Aphis gossypii* (Glover) and *Sitobion avenae* (F) are the important species. Many coccinellids were observed predating on these, of which the dominant ones were *Coccinella septempunctata* (L), *C. transversalis* (F), *Micraspis discolor* (F), and *Cheilomenes sexmaculata* (F)

Key words: Aphids, species diversity, agri-horticultural crops, Aphidoidea, Hemiptera, Coccinellidae, Coleoptera, major species, predators, Terai region, *Coccinella septempunctata*

The economic importance of aphids has been widely accepted since they suck the plant sap, affect the growth of the plant, transmit several viral diseases and cause serious production losses in agricultural, horticultural, forest and other all types of plants. Biodiversity, in the recent years, has acquired significant importance as focal point of discussion like some other international issues. For the sustainable management of aphids on different crops it is pertinent to have information of its species composition. The entomophagous arthropods that attack the aphid species can be broadly grouped as specialists and generalists. Generalist aphidophagous predators like coccinellids (Coleoptera, Coccinellidae) play a great role to check the population of the aphid species (Müller and Godfray, 1999). The knowledge of the diversity of coccinellids forms a prerequisite for their successful conservation in the agroecosystems. The purpose of this study was to enlist the economically important aphid species associated with the agricultural, horticultural, forestry and other plants along with their predatory coccinellid fauna. These observations can enable conservation biological control of aphid pests of crops by exploiting the predatory efficiency of native coccinellids.

MATERIALS AND METHODS

The aphids were inspected on different crops like cereals, pulses, vegetables, oilseeds, medicinal and ornamental plants, grasses and weeds in different locations of terai region in different seasons and the aphids were collected from different plant parts by cutting the infested part and placed in a plastic bag and tightened with a rubber band and then brought back to the laboratory. Then, some aphids were transferred into the small vials with 70% ethanol and sent for taxonomic studies. Aphids were identified and confirmed by Dr Sunil Joshi, ICAR-NBAIR (National Bureau of Agricultural Insects Resource), Bangalore, India. Those insect pests which occurred on the crop till harvest, after their first appearance was designated as 'regular', while those insect pests whose population occurred intermittently or otherwise disappear before harvest was categorized as 'sporadic'. The insects which were merely recorded and whose population occurred after a considerable time lag were designated as a stray. The coccinellid specimens were collected by hand netting and hand picking from different plants. The specimens were transfixed by the insect pins passing through the right elytra. But the very small specimens were mounted on the card point and pinned. Each specimen was properly labeled with, the place of collection, date of collection, collector name and host plant. The specimens were identified with the samples preserved at the department identified earlier by Dr J Poorani, ICAR-NRC for Banana, Tiruchirapalli, India.

RESULTS AND DISCUSSION

Twenty species of aphids were recorded infesting 29 plant species from terai region of West Bengal. The aphid species with their host, host family, season

Table 1. Aphid diversity in the agroecosystems of Terai region, West Bengal

S. No.	Common name	Aphid species	Host plant	Family/ group	Season	Pest status	Intensity of infestation
1.	Cabbage aphid	*Brevicoryne brassicae* (Linn)	*Brassica oleracea var capitata* (Cabbage)	Brassica	January- March	Regular	Medium
2.	The mango aphid	*Aphis* (*Toxoptera*) *odinae* (Van der Goot)	*Mangifera indica* (Mango)	Cashews	January- March	Sporadic	Medium
3.	The mango aphid	*Aphis* (*Toxoptera*) *odinae* (Van der Goot)	*Neolamarckia cadamba* (Burflower tree)	Rubiaceae	January- April	Sporadic	Medium
4.	Chrysanthemum aphid	*Macrosiphoniella sanborni* (Gillette)	*Chrysanthemum indicum* (Chrysanths)	Asteraceae	December- April	Regular	High
5.	Aphid	*Cervaphis rappardi indica* (Basu)	*Cajanus cajan* (Pigeon pea)	Legumes	January- May	Sporadic	Medium
6.	Green peach aphid	*Myzus persicae* (Sulzer)	*Solanum tuberosum* (Potato)	Solanaceae	January- March	Regular	Medium
7.	Green peach aphid	*Myzus persicae* (Sulzer)	*Helianthus annus* (Sunflower)	Asteraceae	December- February	Sporadic	Low
8.	Aphid	*Sitobion* sp.	*Zea mays* (Maize)	Poaceae	February - April	Sporadic	Low
9.	English grain aphid	*Sitobion avenae* (Fitch)	*Triticum aestivum* (Wheat)	Poaceae	February- April	Regular	High
10.	Cowpea aphid	*Aphis craccivora* (Koch)	*Vigna radiate* (Mung bean)	Legumes	December- March	Regular	Medium
11.	Cowpea aphid	*Aphis craccivora* (Koch)	*Mussaenda acuminate* (Mussaenda)	Rubiaceae	January-March	Sporadic	Medium
12.	Aphid	*Aiceona* sp.	*Persea bombycina* (Som plant)	Lauraceae	January-April	Sporadic	High
13.	Chenopodium aphid	*Hayhurstia atriplicis* (L)	*Chenopodium album* (White Goosefoot)	Amaranthaceae	March	Stray	Low
14.	Mustard aphid	*Lipaphis erysimi* (Kalt)	*Brassica Campestris* (Mustard)	Brassica	January-March	Regular	High
15.	Pea aphid	*Acyrthosiphon pisum* (Harris)	*Pisum sativum* (Pea)	Legumes	January-March	Regular	Medium
16.	Cotton aphid	*Aphis gossypii* (Glover)	*Abelmoschus esculentus* (Ladies finger)	Malvaceae	May	Sporadic	Medium
17.	Cotton aphid	*Aphis gossypii* (Glover)	*Momordica charantia* (Bitter gourd)	Cucurbitaceae	March-April	Regular	Medium
18.	Cotton aphid	*Aphis gossypii* (Glover)	*Gossypium hirsutum* (Cotton)	Malvaceae	December-March	Regular	High
19.	Cotton aphid	*Aphis gossypii* (Glover)	*Capsicum annuum* (Chili)	Solanaceae	January-March	Regular	Medium
20.	Cotton aphid	*Aphis gossypii* (Glover)	*Ocimum tenuiflorum* (Tulsi)	Lamiaceae	December-February	Sporadic	Low

(contd.)

Table 1 (contd.)

21.	Sugarcane woolly aphid	*Ceratovacuna lanigera* (Zehnter)	*Saccharum officinarum* (Sugarcane)	Poaceae	September-February	Sporadic	Medium
22.	Oriental citrus aphid	*Toxoptera citricida* (Kirkaldy)	*Citrus limon* (Lemon)	Rutaceae	January-March	Regular	Medium
23.	Corn leaf aphid	*Rhopalosiphum maidis* (Fitch)	*Zea mays* (Maize)	poaceae	March- April	Sporadic	Medium
24.	Brown citrus aphid	*Toxoptera aurantii* (Boyer de Fonscolombe)	*Phlogacanthus thyrsiformis* (Ram Basak)	Acanthaceae	December- February	Sporadic	High
25.	Coriander aphid	*Hyadaphis coriandri* (Das)	*Coriandrum sativum* (Coriander)	Apiaceae	February- March	Sporadic	High
26.	Aphid	*Aphis* (*Toxoptera*) sp.	*Litchi chinensis* (Litchi)	Sapindaceae	January- February	Sporadic	Medium
27.	Bean aphid	*Aphis fabae*	*Solanum nigrum* (Blackberry nightshade)	Solanaceae	February- March	Sporadic	Medium
28.	Cotton aphid	*Aphis gossypii* (Glover)	*Lantana camara* (Lantana)	Verbenaceae	January	Stray	Low
29.	Cotton aphid	*Aphis gossypii* (Glover)	*Ismelia carinata* (Annual Chrysanthemum)	Asteraceae	February- April	Regular	High
30.	Pomegranate aphid	*Aphis punicae*	*Punica granatum* (Pomegranate)	Punicaceae	February	Sporadic	Low

of occurrence, pest status and intensity of infestation are listed in Table 1 while their predatory coccinellids are in Table 2. Among the aphids, *Aphis gossypii* (Glover) was the most dominant and it infested five host plants. Ghosh (1974) observed that *A. gossypii* causing severe damage to vegetable crops like okra, chilli, bitter gourd etc. Ebert et al. (1997) observed that cotton (*Gossypium hirsutum*) is one of the economically important cash crops which is highly susceptible to cotton aphid. The other dominant aphids observed include *Myzus persicae* (Sulzer) and *Aphis craccivora* (Koch). Nikolakakis et al. (2003) noticed that *M. persicae* can attack potato until harvest, especially high population being found at young leaves stage. Ghosh (1975) observed that *A. craccivora* is an important cosmopolitan and polyphagous species causing heavy damage on mungbean and remains active throughout the year. The grain aphid *Sitobion avenae* (F) was found to occur regularly during February-April; Deol (1990) observed it causing serious damage on cereal crops and reducing the yield. Woolly aphid *Ceratovacuna lanigera* (Zehnter) on sugarcane and *Lipaphis erysimi* (Kalt) on mustard are the others. In 1995, Gupta and Goswami reported that heavy infestation of *C. lanigera* causing reduction in the yield and up to 15% reduction in sugar content. Pal et al. (2013) observed the mustard aphid *L. erysimi* as one of the most important pests in the Terai region of West Bengal. Among the predaceous coccinellids, *Micraspis discolor* (F.) was the most dominant species in rice, wheat and linseed whereas, *Coccinella transversalis* (F.) was the most abundant in maize and mustard followed by *M. discolor* (Gurung et al., 2019). The Sub-Himalayan Terai region of Northern West Bengal, thus inhabits many aphids and predaceous coccinellids. The potential of exercising a natural check on the population buildup of aphids thus exists with their conservation.

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Table 2. Diversity of predatory coccinellids on aphids in the agroecosystems of Terai region, West Bengal

S. No.	Aphid species	Crop	Natural enemies observed associated with the aphid species in the field	Status of the N.E.
1.	*Brevicoryne brassicae* (Linn)	*Brassica oleracea* var *capitata* (Cabbage)	*Micraspis discolor* (F)	High
			Coccinella septempunctata (L)	Medium
			Coccinella transversalis (F)	High
2.	*Aphis* (*Toxoptera*) *odinae* (Van der Goot)	*Mangifera indica* (Mango)	*Micraspis discolor* (F)	High
			Cheilomenes sexmaculata (F)	Low
3.	*Aphis* (*Toxoptera*) *odinae* (Van der Goot)	*Neolamarckia Cadamba* (Burflower tree)	*Synonychimorpha chittagoni* (Vazirani)	Medium
			Coccinella transversalis(F)	Medium
4.	*Macrosiphoniella sanborni* (Gillette)	*Chrysanthemum indicum* (Chrysanths)	*Cheilomenes sexmaculata* (F)	Medium
			Propylea dissecta (Mulsant)	Low
5.	*Cervaphis rappardi indica* (Basu)	*Cajanus cajan* (Pigeon pea)	*Micraspis discolor* (F)	High
			Cheilomenes sexmaculata (F)	Low
6.	*Myzus persicae* (Sulzer)	*Solanum tuberosum* (Potato)	*Coccinella septempunctata* (L)	Medium
			Micraspis discolor (F)	High
7.	*Myzus persicae* (Sulzer)	*Helianthus annus* (Sunflower)	*Micraspis discolor* (F)	Medium
			Coccinella transversalis (F)	Medium
8.	*Sitobion* sp. and *Rhopalosiphum maidis* (Fitch)	*Zea mays* (Maize)	*Micraspis discolor* (F)	Medium
			Cheilomenes sexmaculata (F)	Low
			Coccinella transversalis (F)	Medium
9.	*Sitobion avenae* (F)	*Triticum aestivum* (Wheat)	*Micraspis discolor* (F)	High
			Brumoides suturalis (F)	Low
			Cheilomenes sexmaculata(F)	Medium
			Coccinella septempunctata (L)	Medium
			Illeis indica (F)	Medium
10.	*Aphis craccivora* (Koch)	*Vigna radiate* (Mung bean)	*Micraspis discolor* (F)	High
			Coccinella septempunctata (L)	Medium
11.	*Aphis craccivora* (Koch)	*Mussaenda acuminate* (Mussaenda)	*Cheilomenes sexmaculata* (F)	Low
			Micraspis discolor (F)	Medium
12.	*Aiceona* sp.	*Persea bombycina* (Som plant)	*Anisolemnia dilatata* (F)	Medium
			Harmonia dimidiata (F)	Medium
13.	*Hayhurstia atriplicis* (L)	*Chenopodium album* (White Goosefoot)	*Micraspis discolor* (F)	Low
14.	*Lipaphis erysimi* (Kalt)	*Brassica Campestris* (Mustard)	*Coccinella septempunctata* (L)	Medium
			Coccinella transversalis (F)	High
			Micraspis discolor (F)	Medium
15.	*Acyrthosiphon pisum* (Harris)	*Pisum sativum* (Pea)	*Coccinella transversalis* (F)	Medium
			Cheilomenes sexmaculata (F)	Low
			Micraspis discolor (F)	Medium
16.	*Aphis gossypii* (Glover)	*Abelmoschus esculentus* (Ladies finger)	*Micraspis discolor* (F)	Medium
			Coccinella transversalis (F)	High
			Brumoides suturalis (F)	Medium
17.	*Aphis gossypii* (Glover)	*Momordica charantia* (Bitter gourd)	*Coccinella transversalis* (F)	Medium
			Micraspis discolor (F)	Low
18.	*Aphis gossypii* (Glover)	*Gossypium hirsutum* (Cotton)	*Cheilomenes sexmaculata* (F)	Medium
			Micraspis discolor (F)	High
			Cheilomenes sexmaculata (F)	Medium
19.	*Aphis gossypii* (Glover)	*Capsicum annuum* (Chili)	*Anegleis cardoni* (Weise)	Low
			Coccinella transversalis(F)	High
			Coccinella septempunctata (L)	Medium

(contd.)

Table 2 (contd.)

20.	*Aphis gossypii* (Glover)	*Ocimum tenuiflorum* (Tulsi)	*Cheilomenes sexmaculata* (F)	Medium
			Coccinella transversalis (F)	High
21.	*Ceratovacuna lanigera* (Zehnter)	*Saccharum officinarum* (Sugarcane)	*Cheilomenes sexmaculata* (F)	Medium
			Propylea dissecta (Mulsant)	High
			Micrasps yasumatsui (Sasaji)	Medium
			Coccinella septempunctata (L)	Medium
22.	*Toxoptera citricida* (Kirkaldy)	*Citrus limon* (Lemon)	*Cryptogonus bimaculatus* (Kapur)	Low
			Micraspis discolor (F)	Medium
23.	*Toxoptera aurantii* (Boyer de Fonscolombe)	*Phlogacanthus thyrsiformis* (Ram Basak)	*Cheilomenes sexmaculata* (F)	Medium
			Coccinella transversalis (F)	High
24.	*Hyadaphis coriandri* (Das)	*Coriandrum sativum* (Coriander)	*Micraspis discolor* (F)	Medium
			Cheilomenes sexmaculata (F)	Low
			Coccinella transversalis (F)	Medium
25.	*Aphis* (Toxoptera) sp.	Litchi chinensis (Litchi)	-	-
26.	*Aphis fabae*	*Solanum nigrum* (Blackberry nightshade)	*Coccinella transversalis* (F)	Low
			Coccinella septempunctata (L).	Medium
27.	*Aphis gossypii* (Glover)	*Lantana camara* (Lantana)	-	-
28	*Aphis gossypii* (Glover)	*Ismelia carinata* (Annual Chrysanthemum)	*Coccinella transversalis* (F)	Medium
29.	*Aphis punicae*	*Punica granatum* (Pomegranate)	*Micraspis discolor* (F)	Low

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ESTIMATION OF RESIDUES OF FLUBENDIAMIDE AND DELTAMETHRIN IN CHICKPEA

Neeraj Sharma*, Kousik Mandal, Gagan Jyot and Balwinder Singh

Department of Entomology, Punjab Agricultural University, Ludhiana 141004, Punjab, India
*Email: neerajmenon01@gmail.com (corresponding author)

ABSTRACT

Persistence and residue study of flubendiamide and deltamethrin on chickpea pods and soil was carried out following foliar application of flubendiamide 90 + deltamethrin 60: 150 SC (W/V) @ 22.5 g a.i. ha^{-1} and @ 15.0 g a.i. ha^{-1}. In foliar application the initial residue of flubendiamide was found to be 0.61 and 1.35 mg kg^{-1} and deltamethrin to be 1.01 and 2.00 mg kg^{-1} at recommended and double the recommended dose, respectively. The residue dissipated below the limit of quantification at 7 and 10 for flubendiamide, 10 and 15 days for deltamethrin at recommended and double the recommended dose, respectively. The residue was below 0.05 mg kg^{-1} in chickpea pods and soil samples collected after 20 days of last application. Study of risk assessment revealed that the dose sprayed is completely safe, and waiting period of one day is to be observed.

Key words: Flubendiamide 90 + deltamethrin 60: 150 SC (W/V), dissipation, residue, pods, soil, GLC, half-life, HPLC, persistence, risk assessment, waiting period

Chickpea is a valued dietary crop (Wood and Grusak, 2007), and its nutritional value is well known as infant formula meeting the WHO/FAO requirements (Malunga et al., 2014). India is the single largest producer of chickpea with 65% share but it lacks behind in terms of productivity which is only 935.34 kg ha^{-1} (Merga and Haji, 2019). The productivity can be increased by diminishing the crop losses caused by insect pests. Major pests of the crop in India are the gram pod borer *Helicoverpa armigera* (Hubner), semilooper *Autographa nigrisigna* Walker, cut worm *Agrotis ipsilon* Hufnagel, termite *Odontotermes obesus* Rambor *Microtermes obesi* Holmgren, black bean aphid *Aphis fabae* Scopoli, white grub *Phyllopha gaimplicita* Horn, and tobacco caterpillar *Spodoptera litura* (F.) (Chandrashekhar et al., 2014). To prevent the damage, pesticide mixtures provide a promising option, and these broaden the activity spectrum overcoming pest resistance to single pesticide (Das, 2014). One such pesticide mixture is flubendiamide and deltamethrin.

The present study analyses the persistence, dissipation and risk assessment of flubendiamide and deltamethrin in chickpea. Flubendiamide is a novel systemic insecticide, highly effective for controlling lepidopteran pests (Nauen et al., 2007; Das, 2014; Ebbinghaus-Kintscher et al., 2007). A toxicologically important plant metabolite of flubendiamide is des-iodo flubendiamide which is formed as a result of loss of iodine present at 3-position of the phthalic acid moiety of the flubendiamide (EFSA 2013). Deltamethrin is type II pyrethroid with an α-cyano group, and it is a broad-spectrum insecticide (Tomlin 2006). Its mode of action is on the sodium ion channel (WHO Environmental Health Criteria, 1990), and it is registered for use on various crops including cereals, cotton, vegetables and field crops for pests such as aphids, mites, weevils, and beetles (Toxicological Profile for Pyrethrins and Pyrethroids, 2007). There are many reports regarding the residue studies of flubendiamide and deltamethrin present separately as single pesticide on many crops. Dissipation studies of flubendiamide were done by Mohapattra et al. (2010) in cabbage, Das et al. (2012) in okra and Takkar et al. (2013) in brinjal. Similarly for deltamethrin, dissipation studies were done by Kaur et al. (2011) in brinjal, Pandher et al. (2012) in chilli and Reddy and Reddy (2011) in cabbage. A few reports on combination formulations are also available. For eg., dissipation of flubendiamide and thiacloprid on tomato (Kooner et al., 2010), flubendiamide and thiacloprid residues in chilli (Parmar et al., 2012). But no literature is available on the combination formulation of flubendiamide and deltamethrin in chickpea. This study estimates the residues of flubendiamide and deltamethrin when applied as a mixed formulation of flubendiamide 90 + deltamethrin60 :150 SC (W/V) @ 22.5 g a.i. ha^{-1} and @15.0 g a.i. ha^{-1}.

MATERIALS AND METHODS

The certified reference standard of flubendiamide (purity 98.1 %), des-iodo flubendiamide (purity 99.8

%), and deltamethrin (purity 99.6 %) were procured from Bayer Mumbai. Solvents like acetone, chloroform, HPLC grade acetonitrile, sodium chloride were obtained from Merck. Anhydrous sodium sulfate and charcoal were taken from S D Fine Chemicals. Redistillation of various solvents was done using glass apparatus and reagent blanks were injected to check the purity of solvents and various other chemicals used during the processing. Flubendiamide and des-iodo flubendiamide standards of 1 mg ml^{-1} were prepared in acetonitrile and deltamethrin of 1 mg kg^{-1} was prepared in acetone: hexane mixture (1:1) and stored at 4°C. Intermediate working standard solution of 100 µg ml^{-1} was prepared and was used to prepare working standard solutions of various concentrations of flubendiamide, des-iodo flubendiamide and deltamethrin in respective solvents needed to construct a calibration curve (Fig. 1). The residues of flubendiamide and its metabolite des-iodo flubendiamide were quantified by HPLC (Shimadzu Company) having reversed-phase C_{18} column, photo diode array (PDA) detector and dual pump. HPLC operating conditions were as follows: Mobile phase: Acetonitrile: water: 70:30; flow rate of solvent: 0.3 ml min^{1} and wavelength of the PDA was 254 nm. By operating under these conditions, retention time of the flubendiamide and des-iodo flubendiamide were found to be 24.301 and 17.509 min. Analysis of the deltamethrin residues was done using gas liquid chromatograph (GLC- (Shimadzu Model GC-2010). A capillary column (30 mx 0.25 mm i.d) was used with the temperature programming of 280^{0}C for 5 min, followed by a rate of change of 5^{0}C min^{-1} to 230^{o}C for 20 min. The injector and detector were maintained at 280°C and 300°C, respectively. Carrier gas (N_2) flow was maintained @ 0.61 ml min^{-1}. The retention time of deltamethrin was 11.69 min.

Chickpea (variety PBG 5) was planted at Entomological Research Farm, PAU, Ludhiana, India. Field experiment was conducted using a randomized block design with three treatments pertaining to the residues of flubendiamide, des-iodo flubendiamide and deltamethrin in chickpea pods and soil. The treatment T_0 (control), T_1 (recommended dose (22.5 + 15 g a.i. ha^{-1}), and treatment T_2 (double the recommended dose (45 + 30g a.i. ha^{-1}) of the combination product (flubendiamide 90% + deltamethrin 60%), were made by applying 150 SC formulation @ 250 and 500 ml ha^{-1} in water (500 l ha^{-1}). The mixed formulation was sprayed thrice following good agricultural practices (GAP). The first spray was done at pod formation stage and subsequent ones at seven days interval as per the retreatment interval suggested for the field trials. Knapsack sprayer fitted with hollow cone nozzle was used for spraying. About half kg of chickpea pod samples were gathered

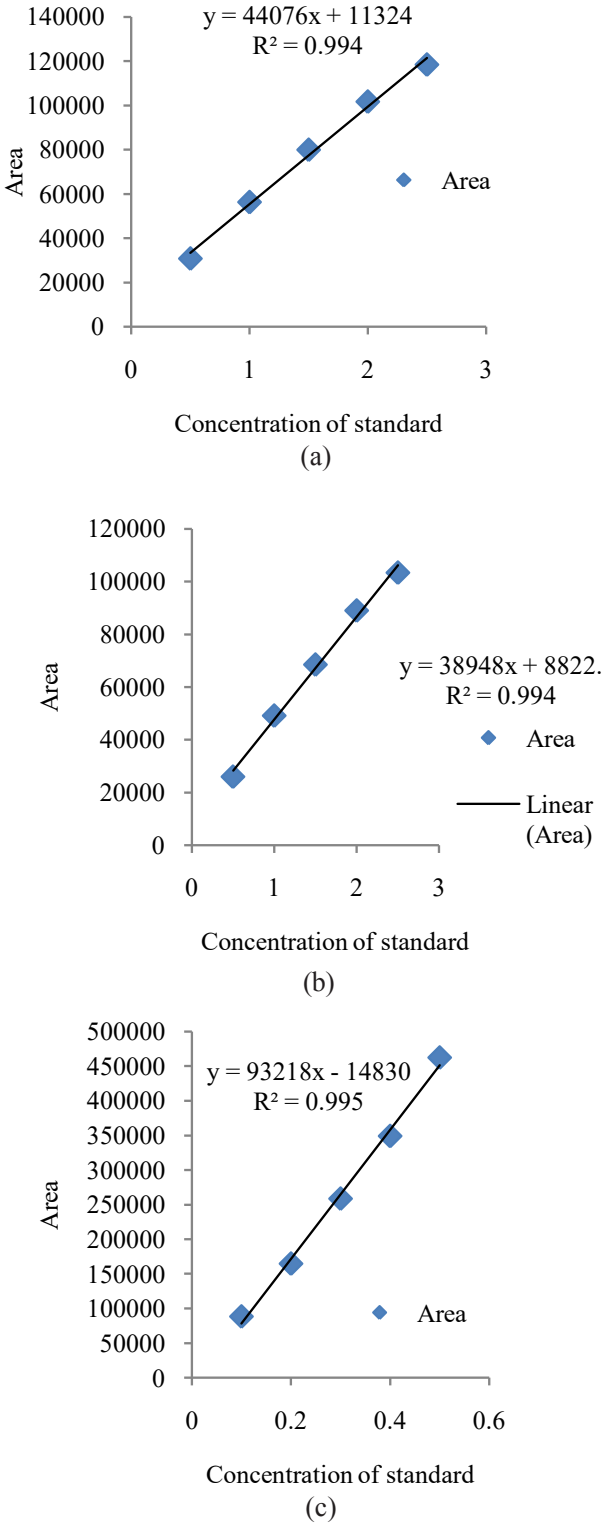


Fig. 1. Calibration curve of a) flubendiamide b) des-iodoflubendiamide c) deltamethrin

randomly from each treatment at 0 (2 hours), 1, 3, 5, 7, 10 and 15 days after third application. Mature seeds and soil samples were collected 20 days after third application. The chickpea pod samples from each treatment plot were mixed and sent to the laboratory where a representative sample of 50 g each was processed. Soil samples were taken from a depth of around 0-15 cm from 10 locales of each treated plot by using tube auger. After mixing and drying, the samples were sieved to remove any unwanted material. Moisture content of the soil samples was analyzed to get its dry weight for further calculations.

For extraction and clean-up of samples, methodology of Luke et al. (1975) was followed with few modifications. The methodology of partitioning was followed against QuEChERS methodology to achieve low limit of quantification value for the estimation of flubendiamide residues on HPLC. There were two setups for the extraction of residues. This is due to the different solubilities of flubendiamide and deltamethrin in different solvents. Flubendiamide and its metabolite dissolves in acetonitrile and deltamethrin in acetone. For flubendiamide- chickpea pods and soil (50 g each) were dipped separately into 100 ml acetonitrile and were kept overnight. The extract was filtered with the filter paper into a separatory funnel. It was further diluted with 600 mL brine solution, and then partitioned thrice with 100, 50 and 50 ml chloroform. The consolidated organic layers were passed through anhydrous sodium sulphate bolstered on glass wool in a filtering funnel. The extract obtained was concentrated to 25 ml in a rotary evaporator at 35°C. It was then treated with 500 mg activated charcoal powder and kept on a shaker for 2 hr. The clear extract was then filtered and concentrated and the last volume was made in acetonitrile. For deltamethrin, chickpea pods and soil (50g each) were dipped separately into 100 ml acetone and were kept overnight. The extract was filtered with the filter paper into a separatory funnel. It was further diluted with 600 ml brine solution, and then partitioned twice with 75 ml dichloromethane and twice with 75 ml hexane. Both the dichloromethane and hexane fractions were combined. The consolidated organic layers were passed through anhydrous sodium sulphate bolstered on glass wool in a filtering funnel. The extract obtained was concentrated to 3 ml in a rotary evaporator at 35°C. The extract was cleaned up using activated silica gel. A glass column was packed with 15 g of activated silica gel and mixed with 1.0 g of charcoal, in between two layers of anhydrous sodium sulphate supported on glass wool. The column was pre-washed with dichloromethane, and the concentrated extract was poured over it. The extract was eluted with a freshly prepared solvent mixture of dichloromethane and acetone (2:1, v/v). The clear extract was then filtered and concentrated to 2 ml in acetone.

RESULTS AND DISCUSSION

The instrumentation method used for the determination of residues of flubendiamide and its metabolite, des-iodo flubendiamide on HPLC and deltamethrin on GLC was validated in terms of its selectivity, linearity, precision in terms of repeatability and reproducibility and its limit of detection and quantification as per the SANTE guidelines (2015). Comparison of six control samples was made with that of six samples spiked at limit of quantification (0.05 µg ml^{-1}). No peak was found at the retention time of standard concerned in case of control samples. Hence, the selectivity of the method was checked. The matrix matched calibration curves of flubendiamide, des-iodo flubendiamide and deltamethrin were prepared to study the effect of matrix on the response of the analyte. Each produced a linear relationship with correlation coefficient (R^2) values above 0.990. The recovery studies were done at least three levels of fortification with LOQ as the lowest level of fortification. The acceptability criterion is the recovery range between 70-120%. Chickpea pods and soil samples were spiked with flubendiamide, de-iodo flubendiamide and deltamethrin at three levels of 0.05, 0.25 and 0.5 mg kg^{-1} and analysed as per the methodology described above. Recovery was >80 % in all the cases (Table 1). Therefore no correction factor was applied on the results obtained. Precision in terms of repeatability (RSD_r) of the method was determined by doing three replications of each fortification level. The acceptance criteria for RSD_r values is $\leq \pm$ 20 %. The RSD_r values are summarized in Table 1. Precision in terms of reproducibility (RSD_R) was checked by analyzing samples at LOQ level of 0.05 mg kg^{-1} for all the three pesticides under different set of conditions i.e. on different days or by different analysts. The acceptance criteria for RSD_R values is $\leq \pm$ 20 %. The RSD_R values are summarized in Table 1. The sensitivity of the detector for the analyte was calculated from limit of detection and limit of quantification values. For LOD calculations, the signal to noise (S/N) ratio was 3 and for LOQ the S/N value was 10.The limit of detection (LOD) and limit of quantification (LOQ) were worked out to be 0.016 and 0.05 mg kg^{-1} for all the three pesticides.

Dissipation trend of flubendiamide (mg kg^{-1}) on chickpea pods at various time intervals after the

Table 1. Recovery and RSD_r of flubendiamide, des-iodoflubendiamide and deltamethrin

Substrate	Level of fortification (mg kg^{-1})	Flubendiamide		Des-iodoflubendiamide		Deltamethrin	
		*Recovery (%)	RSD_r %	*Recovery (%)	RSD_r, %	*Recovery (%)	RSD_r, %
Chickpea pods	0.05	85.16± 2.48	2.91	86.37± 3.16	3.66	89.15± 2.18	2.45
	0.25	88.19± 2.38	2.70	88.49± 2.72	3.07	92.74± 3.65	3.94
	0.50	90.12± 3.15	3.50	89.61± 3.41	3.81	89.90± 3.18	3.54
Soil	0.05	92.17± 2.06	2.24	94.27± 2.15	2.28	92.32± 3.05	3.30
	0.25	94.36± 2.49	2.64	89.19± 2.65	2.97	95.08± 2.83	2.98
	0.50	90.75± 2.61	2.88	93.92± 2.39	2.54	89.71± 2.79	3.11

at 0.05 mg kg^{-1} level

Substrate	Day	Flubendiamide			Des-iodoflubendiamide			Deltamethrin		
		*Recovery (%)	RSD_r %	RSD_R %	*Recovery (%)	RSD_r, %	RSD_R %	*Recovery (%)	RSD_r %	RSD_R %
Chickpea pods	1	85.16± 2.48	2.91	3.04	86.37± 3.16	3.66	3.34	89.15± 2.18	2.45	2.93
	2	89.62± 2.79	3.11		92.08± 2.67	2.90		85.97± 1.94	2.26	
	3	90.27± 1.84	2.04		91.15± 2.23	2.45		85.06± 2.49	2.93	
Soil	1	92.17± 2.06	2.24	2.63	94.27± 2.15	2.28	3.06	92.32± 3.05	3.30	3.01
	2	90.16± 1.98	2.20		91.09± 3.76	4.13		89.43± 1.96	2.19	
	3	95.67± 2.76	2.88		91.46± 1.87	2.04		96.72± 3.38	3.49	

*Mean ± S.D. of three determinations

Residues of flubendiamide and deltamethrin (mg kg^{-1}) on chickpea pods and soil after foliar application of flubendiamide 90 + deltamethrin 60 :150 SC (W/V) @ 250 and 500 ml ha^{-1}.

Days after application	Flubendiamide				Deltamethrin			
	@ 22.5 g a.i. ha^{-1}		@ 45 g a.i. ha^{-1}		@ 15 g a.i. ha^{-1}		@ 30 g a.i. ha^{-1}	
	Mean± S.D.	% Dissipation	Mean± S.D.	% Dissipation	Mean± S.D.	% Dissipation	Mean± S.D.	% Dissipation
				Chickpea pods				
Before application	< LOQ		< LOQ		< LOQ		< LOQ	
0 (2 hrs after application)	0.61± 0.03	-	1.35 ± 0.03	-	1.01± 0.02	-	2.00 ± 0.03	-
1	0.52± 0.01	14.75	0.83 ± 0.04	38.52	0.85± 0.03	15.84	1.41 ± 0.17	29.50
3	0.29± 0.04	50.81	0.70 ± 0.02	48.15	0.65 ± 0.05	35.64	0.90 ± 0.02	55.00
5	0.23± 0.01	62.29	0.74 ± 0.04	74.07	0.44± 0.02	56.44	0.74± 0.04	63.00
7	< LOQ	-	0.43± 0.04	91.11	0.15± 0.04	85.15	0.43± 0.04	78.50
10	< LOQ	-	< LOQ	-	< LOQ	-	0.13± 0.03	93.50
15	< LOQ	-	< LOQ	-	< LOQ	-	< LOQ	-
				Mature pods				
20	< LOQ	-	< LOQ	-	< LOQ	-	< LOQ	-
				Soil				
20	< LOQ	-	< LOQ	-	< LOQ	-	< LOQ	-
$T_{1/2}$	2.87		3.14		3.38		2.61	

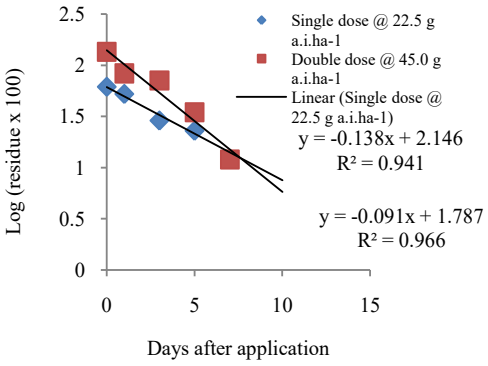
Maximum permissible intake (MPI) and theoretical maximum residue contribution (TMRC) of flubendiamide and deltamethrin in chickpea pods

Interval (days)	MPI (ug person^{-1} day^{-1})	Flubendiamide				MPI (ug person^{-1} day^{-1})	Deltamethrin			
		@22.5 g a.i. ha^{-1}		@45.0 g a.i. ha^{-1}			@15.0 g a.i. ha^{-1}		@30.0 g a.i. ha^{-1}	
		Residues (ug g^{-1})	TMRC (ug person^{-1} day^{-1})	Residues (ug g^{-1}	TMRC (ug person^{-1} day^{-1})		Residues (ug g^{-1})	TMRC (ug person^{-1} day^{-1})	Residues (ug g^{-1}	TMRC (ug person^{-1} day^{-1})
0	1200	0.61	0.73	1.35	1.62	1800	0.85	1.02	2.00	2.4
1	1200	0.52	0.62	0.83	1.00	1800	0.65	0.78	1.41	1.69
3	1200	0.29	0.35	0.70	0.84	1800	0.44	0.53	0.90	1.08
5	1200	0.23	0.28	0.35	0.42	1800	0.15	0.18	0.74	0.89
7	1200	<LOQ	-	0.12	0.14	1800	< LOQ	-	0.43	0.52
10	1200	<LOQ	-	<LOQ	-	1800	<LOQ	-	0.13	0.16
15	1200	<LOQ	-	<LOQ	-	1800	<LOQ	-	< LOQ	-

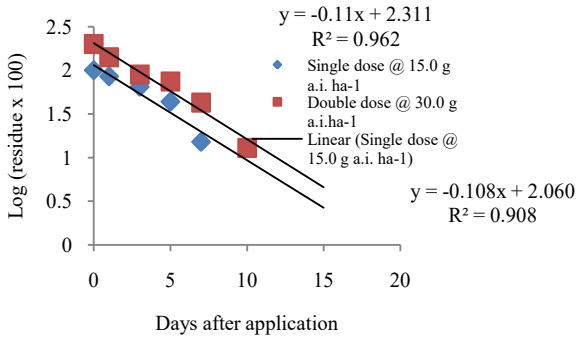
Limit of Quantification (LOQ) =0.05 mg kg^{-1}

application of the combined formulation @250 and 500 ml ha^{-1} representing recommended and double the recommended dose of 22.5 g a.i. ha^{-1}and 45 g a.i. ha^{-1} respectively, are presented in Table 1; initial deposits of flubendiamide on chickpea pods were calculated to be 0.61 mg kg^{-1}and 1.35 mg kg^{-1} at recommended and double the recommended dose, respectively. Residues dissipated to >50 % in both the dosages after 5 days. Residues of declined below the limit of quantification i.e. < 0.05 mg kg^{-1} at 7 and 10 days in two dosages. At harvest time of 20 days, none of the mature seeds and soil samples were detected for the presence of any residues. No residues of its metabolite des-iodo flubendiamide were found at LOQ level of 0.05 mg kg-1. The dissipation graph follows first-order kinetics (Fig. 2a). Half-life ($T_{1/2}$) were calculated as 2.87 and 3.14 at recommended and double the recommended dose, respectively. Dissipation trend of deltamethrin (mg kg^{-1}) on chickpea pods at various time intervals after the application of the combined formulation @250 and 500 ml ha^{-1} representing recommended dose of 15.0 g a.i. ha^{-1} and double the recommended dose of 30.0 g a.i. ha^{-1}, are presented in Table 1. Initial deposits were calculated to be 1.01 mg kg^{-1} at recommended dose and 2.00 mg kg^{-1} at double the recommended dose. Residues dissipated to more than 50 % after 5 days and declined below limit of quantification i.e. < 0.05 mg kg^{-1} at 10 and 15 days in both the dosages. At harvest time of 20 days, none of the mature seeds and soil samples were detected for residues. Half-life ($T_{1/2}$) of deltamethrin were calculated as 3.38 and 2.61, at recommended and double the recommended dose, respectively. Mukherjee et al (2015) calculated the dissipation trend of deltamethrin in a ready mix formulation of three pesticides on two crops i.e. tomato and egg plant when sprayed with 0.75% and1% deltamethrin at recommended and double the recommended dose of 1.0 and 2.0 l/ ha. Deltamethrin persisted till 5 days. Dissipation of deltamethrin followed first-order kinetics with half-life values ranged from 2.6 to 4.7 for tomato and egg plant, respectively (Fig. 2 b).

The consumption of food crops with pesticide residues may pose health hazards to the consumers if the residue levels in food commodity exceeds the maximum residue limit. MRL values are not available for the flubendiamide and deltamethrin in chickpea. Therefore theoretical maximum residues contribution (TMRC) were calculated and compared with maximum permissible intake (MPI) to evaluate the risk posed on consumer. Acceptable daily intake (ADI) is the amount



(a)



(b)

Fig. 2. Semi-logarithmic graph showing dissipation behaviour of a) Flubendiamide b) deltamethrin

of pesticide present in the daily diet of a person up to which it is safe and does not cause any health hazard upon consumption. ADI values for Flubendiamide and deltamethrin are 0.02 and 0.03 mg/ kg bw/ day, respectively. MPI was calculated as the product of average human weight (60 kg) and ADI. As per the National Sample Survey (Anonymous 2014), in rural areas, an average of 0.033 kg chickpea is consumed in 'other pulses' category in 30 days as compared to 0.036 kg/ 30 days in the urban area. Considering the bigger figure of 0.036 kg/ 30 days (1.2 g/ day) with the assumption that the entire commodity was contaminated with maximum amount of the pesticide residues. TMRC is obtained as the product of average daily consumption (g) and the residue levels of pesticide (ug g^{-1}) analysed a commodity. Table 1 depicts the comparison of the TMRC values with MPI in flubendiamide and deltamethrin, respectively. It was observed that TMRC values are far below the high values of MPI for both flubendiamide and deltamethrin. Study of risk assessment revealed that the dose sprayed is completely safe as even the highest residues detected for both the pesticides in 0 day are far below the maximum permissible intake (MPI). Therefore, following guidelines of good agricultural practices, waiting period of one day will be observed.

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IMIDACLOPRID INDUCED REPRODUCTIVE TOXICITY IN FEMALE ALBINO RATS

Prerna Sood

Department of Zoology, Punjab Agricultural University, Ludhiana 141004, Punjab, India
Email: prernasood@pau.edu (corresponding Author)

ABSTRACT

Imidacloprid a systemic neonicotinoid, mainly used for controlling insects and pests in agricultural sector. Two doses of imidacloprid (10 and 20 mg/ kg/ day) were selected based on LD_{50} and given through oral intubation to female rats for 60 days. Disturbed cyclicity with significant ($P<0.05$) decrease in the number of estrous cycle days and increased diestrous index was observed at high dose. Serial sections of ovary were studied for atretic follicles in imidacloprid treated rats. Number of healthy follicles was significantly ($P<0.05$) decreased with increased number of atretic follicles at high dose of imidacloprid. The histopathology of ovary also revealed more atretic follicles at high dose of imidacloprid. Decreased body weight and ovary weight in imidacloprid treated rats was dose dependent. Based on the observed effects, it can be concluded that imidacloprid produced more significant effects on female reproduction at high dose (20 mg/ kgbw/ day) as compared to low dose (10 mg/ kgbw/ day).

Key words: Imidacloprid, albino rats, ovary, growth, follicles, high dose, low dose, body weight, ovary weight, atretic follicles, healthy follicles, reproduction, cyclicity

Pesticides are used in agricultural sector to control insect pests and these raises a number of environmental distresses (Bretveld et al., 2006). Pesticide remnants can move into food web and after a permissible limit the hazards due to pesticide usage is of great concern (McLachlan, 2001). Pesticide poisoning is a major threat to the developing countries, leading to death of many people each year (Dawson et al., 2010). The pesticide usage has increased with the increased awareness of their utility among people (Muthviveganandavel et al., 2008). Imidacloprid (IM), a chloro-nicotinyl is a broadly used neonicotinoid for crop safety throughout the world (Chao and Casida, 1997). Because of its high pesticidal activity at a very small amount (Broznil et al., 2008) it is commonly used to control the pests of various crops throughout the world (Proenca et al., 2005). Metabolism of imidacloprid is done by human cytochrome P_{450} isozymes by hydroxylation and reduction reactions (Schulz et al., 2002). Various toxicity studies in animals and humans evidenced or suggested that these insecticides may cause various brain disorders, tumors growth, reproductive and respiratory disorders (Holmstrup et al., 2010; Yang et al., 2008, Whitehorn et al., 2012). Based on LD_{50} of imidacloprid that is 450 mgkg/ day it is classified as moderate toxic insecticide by Environment Protection Agency (EPA) (Bhardwaj et al., 2010; Brunet et al., 2010)

A number of studies indicated the toxic effect of imidacloprid as immonotoxic, genotoxic, neurotoxic and developmental effects of imidacloprid (Lonare et al., 2014; Gawade et al., 2013). Some studies reported that pesticide exposure can affect the reproduction by interferring with neural transmission and reproductive endocrinology which may alter the functioning of reproductive organs (Gill et al., 2011). From the past few studies a number of evidences have been reported which showed the toxic effects of pesticides or environmental contaminants on male and female reproductive system (Aitken et al., 2016). Similar studies on pesticides and insecticides proved the effect of these pesticides on female reproduction and folliculogenesis (Ding et al., 2020; Gonsioroski et al., 2020). Despite a lot of information on imidacloprid toxicity studies, very scarce or no information is available on the effect of imidacloprid on follicular development in the ovary. The present study mainly aims at finding out the toxic effect of 10 mg/ kgbw/ day (low dose) and 20 mg/ kgbw/ day of imidacloprid (high dose) treatment on estrous cyclicity, ovarian weight and damage in ovarian follicles of female albino rats.

MATERIALS AND METHODS

The experiment was done in Animal Physiology Laboratory of Department of Zoology, Punjab Agricultural University, Ludhiana. Technical grade of imidacloprid was purchased from Ludhiana, India. For this study, female albino rats, aged 3 months, weighing between 100–150 g procured from Guru

Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana. The rats were kept in cages and were given free access to pelleted food and water ad libitum. The rats were given temperature (22± 2°C) and humidity (30–70%) and lightning schedule with 12 hr light and dark cycle. The protocol for this experiment follows the guidelines for proper caring and use of animals in the laboratory research and got approved by Institutional Animal Ethics Committee. Test concentrations were achieved by dilutions of imidacloprid with corn oil. Active ingredients (% age) of formulation of imidacloprid was used to calculate the test concentrations. Dose of imidacloprid was selected based on its LD_{50} which is 450 mg/ kg body weight (Bomann, 1989). Group I -control, Group II (T1) -10 mg/ kg/ day of imidacloprid (low dose), Group III (T2) - 20 mg/ kg/ day of imidacloprid (high dose). The estrous cyclicity of control and treated rats was checked by examining the vaginal smears every morning. Rats were sacrificed after the treatment of 60 days.

For histopathology, ovaries were excised from control and treated rats and fixed in 10% formalin. Then each tissue was processed and dehydrated, paraffin sections of 5 µm were cut and staining of tissues was done with haematoxylin-eosin stain and examined under microscope. Serial sections of control and treated ovary were studied for various interpretations like total number of healthy follicles, number of atretic follicles, corpus luteum (Kaur and Guraya, 2003). From the serial section of ovary, the follicle number in every developmental stage was counted. The follicles were divided into six groups according to Cooper et al., (1993) and Pederson and Peters (1968) i.e. primordial, primary, secondary, tertiary, early antral, antral follicles and corpus luteum. Primordial follicle consists of an ovum or oocyte surrounded by granulosa layer of cells having squamous shape. Primary follicle consists of large oocyte surrounded by two layers of granulosa cells having cuboidal shape. Secondary follicle consists of oocyte surrounded by more than two or two to three granulosa cell layers having cuboidal shape. Early antral follicle consists of oocyte surrounded by three or more granulosa cell layers with no cavity (antrum). Antral follicle consists of an oocyte surrounded by many granulosa cells layers having antrum. Ovary weight, estrous cyclicity, number of follicles were analysed using Graph Pad Prism. Statistical analysis was done by analysis of variance (ANOVA) between control and treated group of rats followed by Dunnet's test.

RESULTS AND DISCUSSION

High dose (20 mg/ kgbw/ day) of imidacloprid treated rats showed decreased ovarian weight and body weight. This decrease in body weight and ovary weight was not significant at 10 mg/ kgbw/ day as shown in Table 1. Decreased body weight may be due to decreased feed intake. Decrease in weight of ovary may be due to toxic effect of imidacloprid on ovary (Yavasoglu et al., 2006). Similar results have also been shown after treatment with organophosphates (methyl parathion) that there was decrease in the ovarian weights (Kaur and Dhanju, 2005). Vohra and Khera (2016) also showed similar decrease in ovary weight after exposure of imidacloprid to female rats in three generation study. The present study showed that control rats have normal 4-5 days estrous cycle while high dose (20mg / kgbw/ day) treated females showed significant decrease in estrous cycle days with significant increase in diestrous phase. There was increase in diestrous index in both the doses of imidacloprid treated rats as shown in Table 1. This disturbed cyclicity was due to disrupted reproductive endocrinology (Bretveld et al., 2006). Borgeest et al., (2002) also reported significant increase in estrous phase and decrease in number of estrous cycle days after treatment with methoxychlor in mice. Vohra and Khera (2018) also reported disruption in estrouscyclicity after exposure of high and low dose of imidacloprid to female wistar rats in two generational study. Similar results have also been shown by Baligar and Kaliwal (2002) when rats were treated with

Table 1. Imidacloprid induced changes in estrous cyclicity, relative ovary weight and net body gain weight of female rats

	Control	T1	T2
No. of cycles	5.6±0.22	4.2±0.20*	4.31±0.31*
Diestrous index	40.67	51.23	63.45
Ovary weight	0.03 ±0.002	0.029 ±0.001	0.02±0.001*
Body weight gain(g/ 100g bw)	45 ± 4.47	35 ± 6.32	42.5 ± 5.12

Values represent mean± SE of 6 animals in each group. *Significant difference (p= 0.05)
Diestrus index =Days with clear diestrus smear/ 60 days (duration of treatment) x 100.

carbofuran showed decrease in number of estrous cycle days and increase in diestrous phase. Another study has also showed similar results after treatment with organophosphate pesticides (fenthion, dimethoate and methyl parathion) to female rats (Budreau and Singh, 1973; Soratur and Kaliwal, 2000; Maths, 1998). Since imidacloprid is a neonicotinoid insecticide, it may act on hypothalamus in the brain which has effect on ovary and can affect the estrous cyclicity and follicle formation. It can also be due to imbalancing of reproductive hormones after the imidacloprid treatment (Radhika and Kaliwal, 2002).

The kinetics of follicles in the ovaries of treated and control rats were studied under light microscope in present study as shown in Fig. 1 and 2. Control group showed higher number of healthy follicles while high dose of imidacloprid treated rats showed decreased number of healthy follicles in the ovaries. Basic functional unit of mammalian ovary is the follicles. Assessment of number of follicles is an indicator of normal and damaged follicles in the ovary. Two important hormones involved in follicular development are the Follicle Stimulating Hormone (FSH) and Luteinising hormone (LH) (Plowchalk et al., 1993). The present study showed the increased number of atretic follicles and decreased number of normal follicles in higher dose (20 mg/ kgbw/ day) of imidacloprid treated group but no significant effect on healthy and atretic follicles was shown in lower dose of imidacloprid treated female rats (Fig. 3). Similar study conducted by scientists after treatment with cypermethrin showed reduction in number of estrous cycle days, increased atretic follicles and decreased healthy follicles in cypermethrin treated groups as compared to control (Nada et al., 2017). Similar results have been reported by some studies on treatment with different carbamates and chlorinated pesticides. These pesticides reduce the healthy follicles as compared to atretic follicles (Martinez and Swartz, 1991; Jadaramkunti and Kaliwal, 2019). One study have reported to inhibit the development of antral follicles and antrum and in turn resulted in increase in number of atretic follicles (Ataya et al., 2008). It has also been reported by Baligar and Kaliwal (2002) that rats treated with mancozeb also showed similar trend of healthy and atretic follicles.

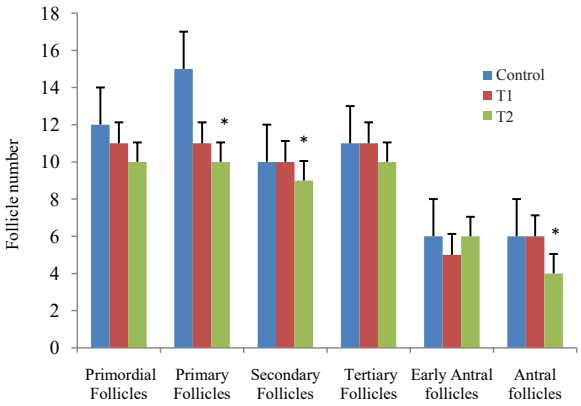

Fig. 1. Effect of imidacloprid on healthy follicles at different stages, at 10 and 20 mg/ kdbw/ day dose. Fig shows the more healthy follicles in control as compared to treated group at $p<0.05$

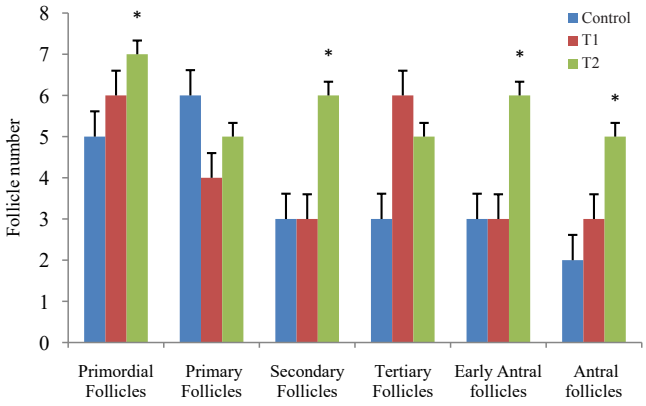

Fig. 2. Effect of imidacloprid on atretic follicles at different stages, at 10 and 20 mg/ kdbw/ day dose. Fig shows the more atretic follicles in high dose of imidacloprid treated rats as compared to treated group at $p<0.05$

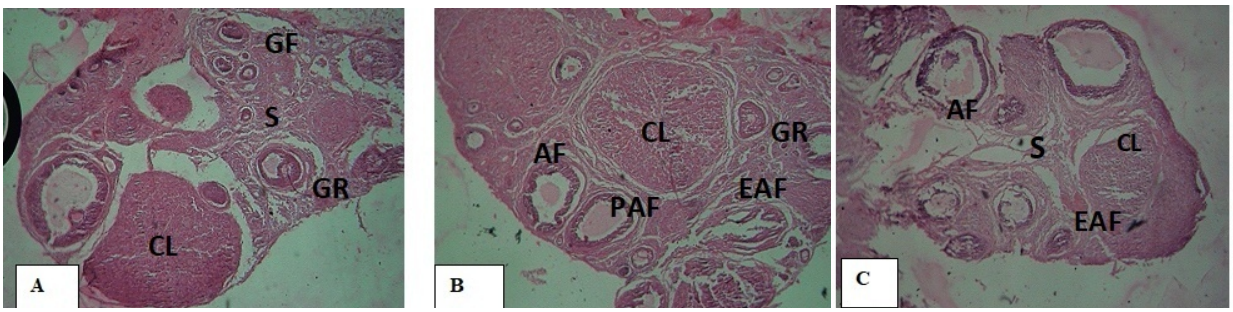

Fig. 3. Ovary section- Control rats (A), T1 (10 mg/ kgbw/ day) (B) and T2 (20 mg/ kgbw/ day) (C) of imidacloprid treated rats: S-Stroma, A-Antral follicles, CL- Corpus luteum, GR- Graffian follicle, GF-Growing follicle, EA-Early antrum, AF-Antral follicle Type, PAF- Pre antral follicle

Similar results have also been observed in mice treating with herbicide atrazine (Pernot et al., 2017)

The histopathological slides of ovaries of control rats showed number of developing follicles i.e. primordial, primary, secondary, tertiary, early antral, antral and atretic follicles. Ovaries from rats treated with 20 mg/ kgbw/ day showed more number of all phases of atretic follicles i.e. antral follicles, corpus luteum, early antrum, antral follicle type and preantral follicle as compared to ovaries of rats treated with 10 mg/ kgbw/ day. Atresia is the breakdown of follicles in the ovary and oxidative stress may also be responsible for increased atretic follicles (Fig. 3). This is authenticated by the findings of Gupta et al., (2006). Similar findings have also been reported by Guneyet al., (2007a, b) after exposure of methidathion to female rats. Similar results have also been reported by Borgeestet al., (2002) when mouse were treated with methoxychlor showed follicular atresia and affects ovarian physiology. Disturbed estrous cyclicity and ovarian follicles is due to direct effect of insecticide on hypothalamic-hypophysial ovarian axis causing reproductive hormone imbalancing. In the present study disruption in estrous cyclicity, decreased number of healthy follicles, increased atretic follicles may be due to damage by the insecticide at hypothalamo-pituitary gonadal axis. Because insecticides or pesticides may destroy reproductive endocrinology (Stoker et al., 2003). Imidacloprid treated rats showed dose dependent toxicity in relation to body weight. In high dose of imidacloprid (20 mg/ kgbw/ day) treated rats significantly decreased body weight gain and decreased ovarian weight was observed in our study as compared to control. In conclusion this study revealed the effectiveness of high dose of imidacloprid (20 mg/ kgbw/ day) to affect estrous cyclicity and atretic follicles as compared to low dose of imidacloprid (10 mg/ kgbw/ day) treated rats.

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CONFLICT OF INTEREST

There is no conflict of interest.

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NEW RECORDS OF *EUHAMITERMES* HOLMGREN FROM SOUTH INDIA

M Ranjith, C M Kalleshwaraswamy*, K J Meghana, Sharanabasappa S Deshmukh, B K Shivanna, K M Satish[1] and B C Dhananjaya[2]

Department of Entomology; [1]Department of Plant Biotechnology; [2]Department of Soil Science and Agricultural Chemistry, College of Agriculture, Keladi Shivappa Nayaka University of Agriculture and Horticultural Sciences, Shivamogga 577204, Karnataka, India
*Email: kalleshwaraswamycm@uahs.edu.in (corresponding author)

ABSTRACT

***Euhamitermes* Holmgren is a soldier rare, soil feeding termite of the Oriental region. Two species of this genus viz., *Euhamitermes lighti* (Snyder) and *Euhamitermes chhotanii* Maiti are hereby first reported from southern Indian states of Karnataka and Kerala, respectively. Record of *E. chhotanii* in Kerala makes an addition of the genus and thus to the termite fauna of Kerala. These two species are redescribed and illustrated based on soldier and workers.**

Key words: *Euhamitermes lighti*, *E. chhotanii*, soil termites, soldier rare group, Kerala, Karnataka, inquiline, distribution, key, illustrations, new records,

Termites are dominant arthropods and as decomposers play a key role in nutrient recycling (Amina et al., 2016). India accounts vast diversity of termites consisting of 295 species under 52 genera and six families; of these, family Termitidae accounts for maximum species diversity with 209 species under 34 genera (Rajmohana et al., 2019). Termite diversity of south India comprises of 132 species (Ranjith and Kalleshwaraswamy, 2021), under 35 genera of five families (Kalleshwaraswamy et al., 2013). Soil feeding termites are one of the diverse groups under the family Termitidae. Of these, *Euhamitermes* Holmgren is one of the rarely collected, soil feeding, soldier-rare genus, endemic to the Oriental region under the subfamily Apicotermitinae Grassé and Noirot. This genus was erected by Holmgren (1912) with *E. hamatus* as its type species, and it is distributed in the Oriental region with 24 species, of which 10 species are from the Indian region (Krishna et al., 2013). As part of taxonomic studies on termites of south India, some *Euhamitermes* samples were collected, and these form the first report of its species from south India and amongst the genera from Kerala.

MATERIALS AND METHODS

Termites were collected as a part of studies undertaken in south India from parts of colonies underneath boulders and walls of termitarium and preserved in 80% ethyl alcohol. Measurements were taken using a stereozoom microscope (ZEISS Stemi508, 10-50x). The images were taken using LEICA M205C stereozoom microscope connected with LEICA DFC450 camera. The specimens were identified following Chhotani (1997) and morphological terminologies; and index of soldiers follow Roonwal and Chhotani (1989) whereas, workers follow Eggleton (2010). The voucher specimens are deposited in the Department of Entomology, College of Agriculture, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India.

RESULTS AND DISCUSSION

A. Redescription

Euhamitermes Holmgren 1912: Subfamily Apicotermitinae Grassé and Noirot 1955

1. *Euhamitermes chhotanii* Maiti, 1983

Type locality: West Bengal: Cooch Behar: Atiamochar Forest

Material examined: India: INDIA, Kerala, Nilambur, Pothukal, 11°24’57”N, 76°13’22”E, 57m, 15.i.2020, Coll. Ranjith, M., *ex*. Mound wall of *Odontotermes* sp.

Diagnostics: Soldier (Fig. 1, Table 1): Head capsule sub rectangular, creamish yellow, densely hairy, sides subparallel, slightly bulged near the base antennae and longer than wide. Y-suture absent. Fontanelle indistinct. Antennae pale yellowish brown with 14 segmented,

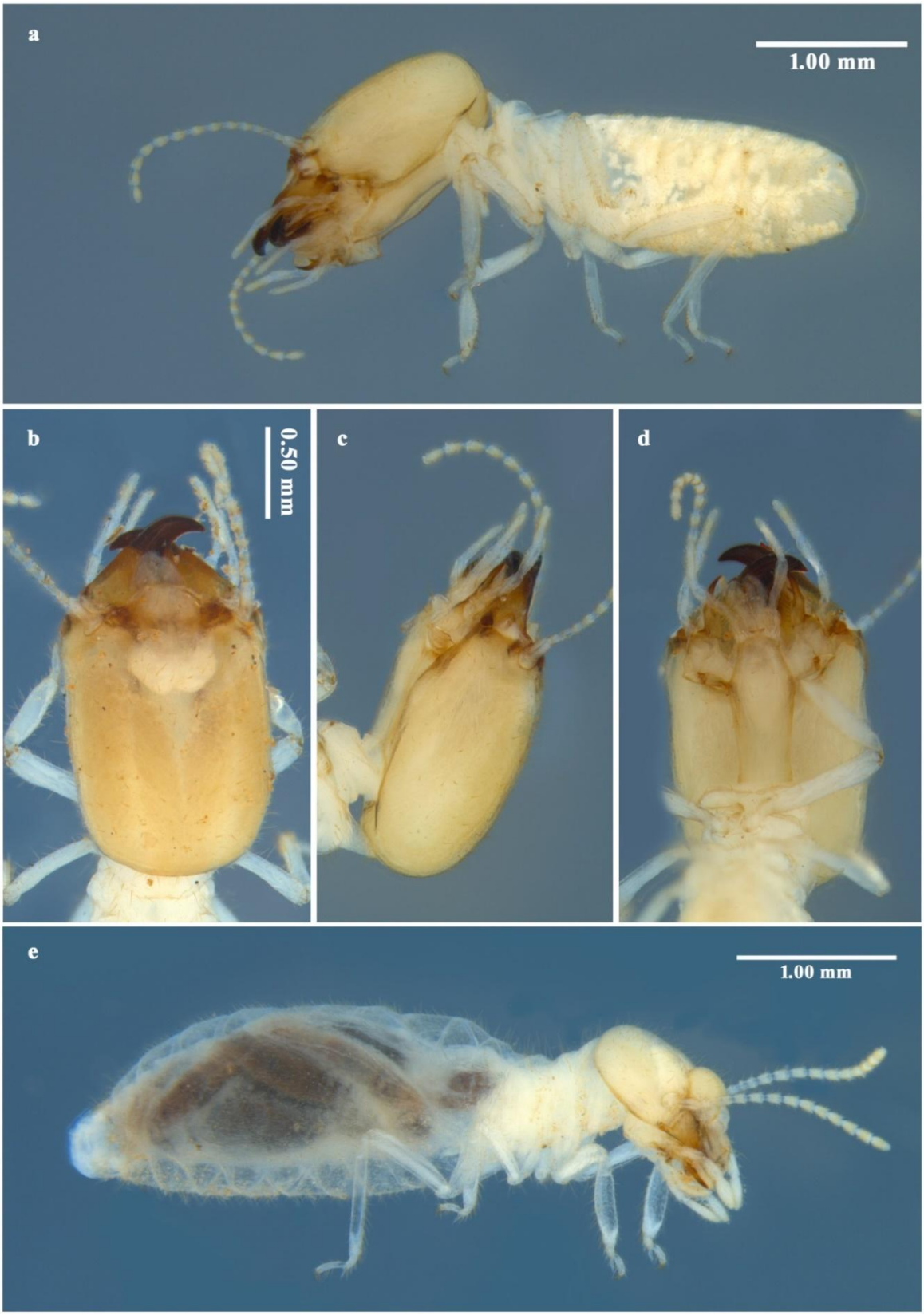

Fig. 1. *E. chhotanii* Maiti, soldier: a. whole body; b. Dorsal view of head;
c. Lateral view of head; d. Ventral view of head; e. Worker

Table 1. Measurements of soldiers of *Euhamitermes* spp. (modified from Chhotani, 1997)

Body parts*	*Euhamitermes chhotanii* Maiti		*Euhamitermes lighti* (Snyder)	
	Soldier	Worker	Soldier	Worker
Head length to the base of mandible	1.38-1.45	0.68-0.70	1.50-1.75	0.70-0.75
Head length to tip of labrum	-	1.10-1.15	-	1.12-1.15
Maximum head width	1.11-1.13	0.80-0.85	1.12-1.30	0.85-0.88
Head index	0.80-0.86	1.19-1.22	0.71-0.81	1.13-1.26
Mandible length	0.69-0.70	-	0.75-0.80	-
Mandible index	0.48-0.50	-	0.50	-
Tooth distance	0.24-0.25	-	0.22	-
Tooth index	0.35-0.36	-	0.29	-
Postclypeus length	-	0.22-0.28	-	0.18-0.22
Postclypeus width	-	0.38-0.42	-	0.35-0.38
Pronotum length	0.30-0.38	0.22-0.25	0.30-0.40	0.25-0.28
Pronotum width	0.60-0.61	0.42-0.48	0.63-0.70	0.48-0.50
Postmentum length	0.80-0.96	-	0.90-1.15	-
Maximum width of postmentum	0.32-0.38	-	0.32-0.48	-
Minimum width of postmentum	0.25-0.30	-	0.20-0.30	-
Postmentum constriction index	0.78	-	0.56-0.70	-
Labrum length	0.20-0.21	-	0.20-0.25	-
Labrum width	0.30-0.32	-	0.30-0.40	-
Total body length	3.90-0.46	3.75-4.30	4.00-5.40	4.15-4.30

*Measurements in mm except indices

with second segment the shortest. Labrum whitish, tongue-shaped, hairy and broader than long. Mandibles sickle-shaped apices strongly bent inwards, distally dark brownish basally paler, short, stout and broad at the base and shorter as compared to head length. Mandibular tooth small and forwardly placed. Postmentum longer, club-shaped, anteriorly wider with a broad waist having sides gradually converging posteriorly. Pronotum paler, strongly saddle-shaped, anterior margin round without any depression posterior margin weakly depressed wider than long. Legs with apical tibial spur 3:2:2. Tarsi four segmented. Abdomen oblong and densely hairy. Cerci short and two segmented. Worker (Fig. 1, Table 1): Head sub-circular, broader, creamish white and densely hairy. Post clypeus swollen, wider and hairy. Labrum tongue-shaped, broad, whitish, and sparsely hairy. Pronotum whitish, saddle-shaped and posterior margin with a weak median depression. Abdominal wall transparent, internal content visible from outside and densely hairy.

Distribution: West Bengal, Kerala

Remarks: This species was collected from the mound wall of *Odontotermes* sp., which indicates they are inquilines. This was reported to be a soil feeder but its inquiline nature is quite surprising. However, the present record makes the first report of the genus from Kerala and species from south India.

2. *Euhamitermes lighti* (Snyder, 1933)

Type locality: Dehra Dun: Uttarakhand (formerly part of Uttar Pradesh)

Material examined: INDIA, Karnataka, Kodagu, AHRS Madikeri, 12°25’33”N, 75°43’45”E, 1113m, 12.x.2020, Coll. Ranjith, M., *ex*. Underneath boulders.

Diagnostics: Soldier (Fig. 2, Table 1): Head capsule sub rectangular, sides sub-parallel and weavy, posterior margin faintly rounded, yellowish brown, modestly hairy, longer than broad. Fontanelle is inconspicuous. Antennae pale yellowish brown with 14 segmented and fourth segment the shortest. Labrum paler, tongue-shaped broader at the base. Mandibles brownish, paler basally, shorter, length nearly half the head length, thick, robust, broader basally, apices weakly bent and each with a small prominent tooth situated anterior one-third of the mandible. Postmentum long, club-shaped, sides slightly converging posteriorly, minimum width lying near posterior margin. Pronotum paler, moderately pilose, strongly saddle-shaped, anterior round, posterior margin substraight, sides rounded, broader than long. Legs with apical tibial spur 3:2:2. Tarsi four segmented. Abdomen elongated and densely hairy. Cerci are short and two segmented. Worker (Fig. 2, Table 1): Head capsule sub-circular, broader, pale yellowish, moderately hairy. Y-shaped suture absent. Fontanelle is indistinct. Antennae paler with 14 segmented, fourth

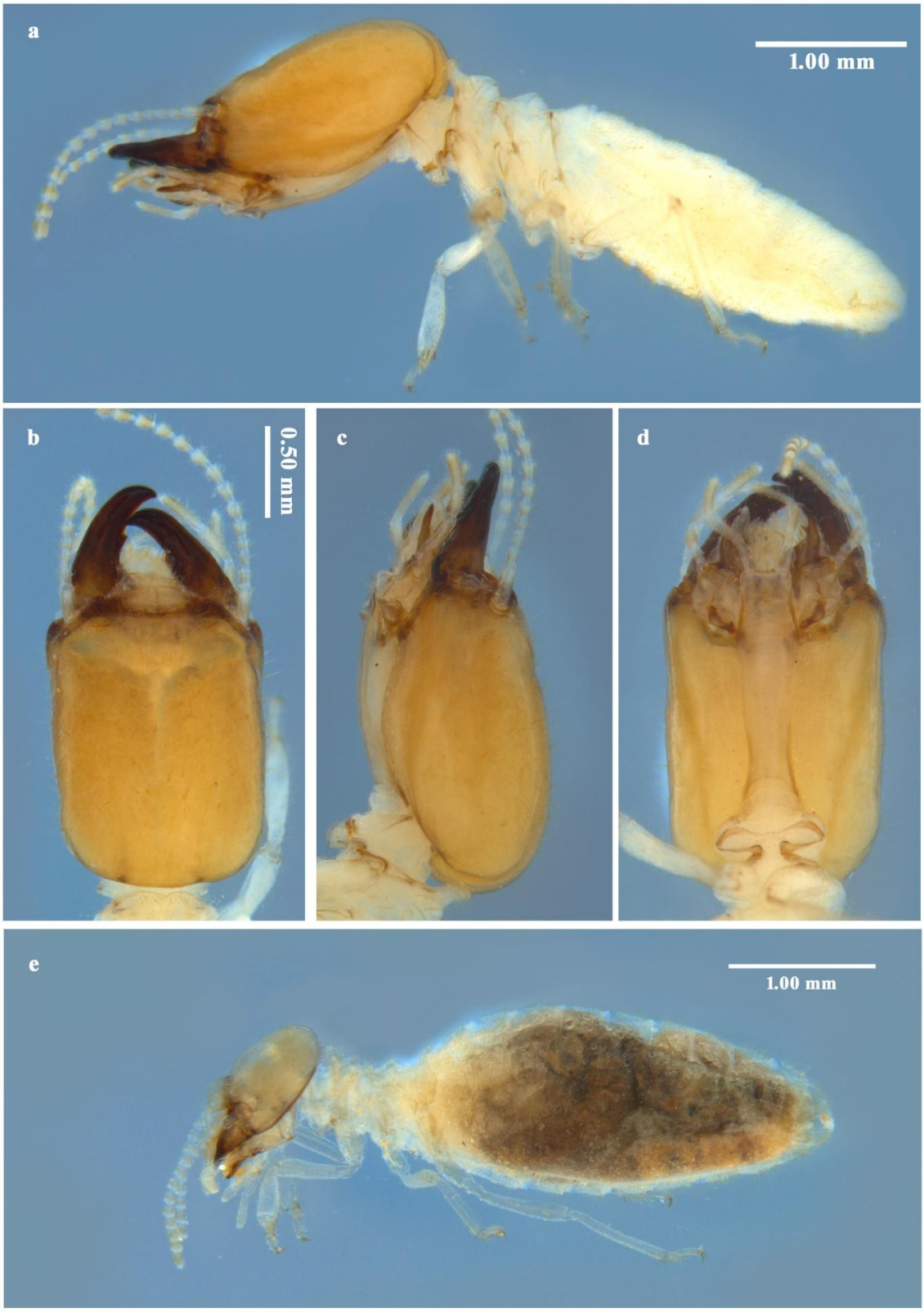

Fig. 2. *E. lighti* (Snyder), soldier: a. Whole body; b. Dorsal view of head; c. Lateral view of head; d. Ventral view of head; e. Worker

segment the shortest. Postclypeus swollen, hairy and wider. Labrum creamish, tongue-shaped and broader. Pronotum paler, saddle-shaped. Abdominal wall transparent, internal content visible from outside and densely hairy.

Distribution: Uttarakhand, Karnataka

Remarks: The species was collected underneath a small boulder, indicate its soil inhabiting and soil feeding nature. The present record of the species from Karnataka makes the first report of the species from south India.

B. Key to the species (soldiers) of *Euhamitermes* from India (modified from Chhotani, 1997) (Soldiers unknown for *E. urbanii* and *E. wittmeri*)

1. Head length to the lateral base of left mandible 1.27 mm and maximum head width 0.97 mm…… ……..……..…..*E. aruni*
2. Head length to the lateral base of left mandible more than 1.38 mm and maximum head width more than 1.07 mm…….....……..2
3. Head length to the lateral base of left mandible 1.90 mm….....*E. indicus*
4. Head length to the lateral base of left mandible less than 1.75 mm…….....……...3
5. Mandibles larger; length of left mandible 0.88 mm…….....….....*E. dentatus*
6. Mandibles shorter; length of left mandible less than 0.80 mm…….....……..4
7. Head length to lateral base of left mandible 1.38-1.45 mm.....*E. chhotanii*
8. Head length to lateral base of left mandible more than 1.44 mm….....……..5
9. Tooth of left mandible small and not prominent…… …….....……...6
10. Tooth of left mandible large and prominent…… ……..…...7
11. Head capsule weakly converging posteriorly…… ……..…….....…….*E. hamatus*
12. Head capsule more or less sub-parallel…… .....*E. lighti*
13. Mandibles comparatively thicker at base, tooth larger.....….....….*E. karnatakensis*
14. Mandibles comparatively thinner at base, tooth smaller..…….....……*E. kanhaensis*

Of the 10 species of *Euhamitermes*, three species have distribution in south India.

Euhamitermes dentatus have distribution in Telangana (formerly part of Andhra Pradesh), *E. indicus* have distribution in Tamil Nadu and *E. karnatakensis* have distribution in Karnataka (Chhotani, 1997). Records of *E. chhotanii* and *E. lighti* make the new additions of the species to the south India. Of the 10 species known from Indian region, *E. urbanii* Roonwal and Chhotani and *E. wittmeri* Roonwal and Chhotani are known only by their imago caste. The two new records of *Euhmaitermes* were earlier recorded only from their type locality, however, these present records further to the southern India instinct to the importance of detailed study of termite fauna of India, especially on the highly diverse soil termites. Recently, many new records of soil termites from Kerala were made by Amina et al. (2016) and Amina and Rajmohana (2021), indicating the intensive surveys and extensive taxonomic works in India are required for better understanding of termite diversity and their distribution.

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ACARICIDE RESISTANCE IN FIELD-COLLECTED TWO-SPOTTED SPIDER MITE *TETRANYCHUS URTICAE* KOCH

Naveena K, Shanthi M*, Chinniah C, Jayaraj J, Ramasubramanian T[1], Mini M L[2] and Renuka R[2]

Department of Agricultural Entomology; [2]Department of Biotechnology
Agricultural College and Research Institute (AC & RI), Tamil Nadu Agricultural University (TNAU),
Madurai 625104, Tamil Nadu, India
[1]ICAR - Sugarcane Breeding Institute, Coimbatore 641007, Tamil Nadu, India
*Email: mshanthiento@tnau.ac.in (corresponding author)

ABSTRACT

Two spotted spider mite *Tetranychus urticae* Koch is an economically serious pest posing threat to major vegetable crops. Roving survey in and around Coimbatore region revealed that farmers do not target mites with acaricides instead they use higher dose of insecticides at frequent intervals which results in development of resistance. The bioassay results revealed that fenpropathrin (2.07 to 6.86-folds) and fenazaquin (2.74 to 7.13-folds) exhibit higher susceptibility, whereas diafenthiuron (5.35 to 12.25-folds) revealed a low to moderate level of resistance. The propargite (43.80 to 60.63-folds) and chlorfenapyr (61.01 to 75.10-folds) exhibited high resistance, followed by spiromesifen (222.28 to 300.26-folds) and buprofezin (382.60 to 417.87-folds), with extremely high level of resistance. The higher specific activity of GST (4.54-folds), MFO (10.06-folds) and CarE (15.06-folds) in Puthupalayam population suggested the role of biochemical resistance. A significant positive correlation was observed between diafenthiuron and CarE activity (r = 0.981*), fenpropathrin and MFO activity (r = 0.964*).

Key words: Fenazaquin, propargite, spiromesifen, buprofezin, fenpropathrin, diafenthiuron, chlorfenapyr, LC_{50}, RR, GST, MFO, CarE, resistance, vegetables.

Two-spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae) is a world-wide pest, mesophyll feeder, and major vegetable crop pest in field and greenhouse conditions (Titiksha and Sood, 2019). It is responsible for 10 to 50% yield loss on tomato and 15.29 to 81.10% fruit loss of brinjal. On depletion of nutrient content, they form ballooning and gets migrated to another plant through the wind (Shukla et al., 2017). Modern agricultural practices viz., dumping of pesticides when the population is below thresholds and monocropping system lead to resistance development. The biological characteristics of *T. urticae* accelerate the development of resistance (Van Leuween et al., 2009); and to date, *T. urticae* has developed resistance to 96 chemicals, and 551 resistance cases have been reported worldwide (Mota-Sanchez and Wise, 2021). The resistance development leads to reduced efficacy and increased costs. Survey in major vegetable growing areas of Coimbatore and Tiruppur districts revealed a insecticide usage pattern requiring evaluation. Since, *T. urticae* was resistant, farmers targeted mites with varied insecticides, and at higher doses at frequent intervals, The farmers were not aware of the acaricides. Hence, the present study with selected insecticides along with standard checks to ascertain the level of resistance and detoxification enzymes associated with them.

MATERIALS AND METHODS

A roving survey was conducted in vegetable growing areas of Coimbatore and Tiruppur regions during August 2019- April 2021, and the populations of *T. urticae* were collected from four locations viz., Puthupalayam (10.9965° N; 76.8542° E), Pichanur (10.8623° N; 76.8727° E), Muthur (11.0449° N; 77.7352° E) and Nallur (11.1014° N; 77.3927° E) covering two districts. In order to obtain uniform aged mites, the collected adults were released on potted bhendi plants (variety: Arka Anamika) in polyhouse at the Department of Horticulture, AC & RI, Madurai, separately and allowed to multiply. The F_1 mites were utilized as a source for bioassay and enzyme assay studies. The initial susceptible culture of *T. urticae* was obtained from All India Network Project (AINP) on Agricultural Acarology, TNAU, Coimbatore and reared under laboratory condition (26± 1°C; 70± 10%RH) in mulberry leaves at the Mass Culture Laboratory, Department of Agricultural Entomology, AC & RI, Madurai till 25th generation to calculate base-line

LC_{50} values. The acaricides selected for assessing the resistance level were fenazaquin 10%EC, propargite 57%EC, spiromesifen 22.9%SC, buprofezin 25%SC, fenpropathrin 10%EC, diafenthiuron 50%W/W and chlorfenapyr 10%SC. The chemicals required for detoxification enzyme assays were purchased from Sigma Aldrich Pvt. Ltd. The IRAC (2009) recommended leaf dip bioassay method (Method No. 004) was used. The fresh mulberry leaf discs (5x 5 cm) were dipped in the test solutions for 30 sec and allowed them to air dry. An untreated control was maintained by dipping leaf discs in distilled water. Twenty F_1 adult female mites were transferred to the treated leaves. The mortality of mites was determined by their inability to walk at least a distance equivalent to their body length when prodded with a brush after 48 hours of acaricide exposure.

The protein content was estimated using a standard, bovine serum albumin (BSA) and the values were expressed as mg g^{-1} (Lowry et al., 1951). The glutathione S transferase (GST) activity was quantified using 1-chloro-2, 4-dinitrobenzene (CDNB) as a substrate and the enzyme extract of 600 adult female mites (15 mg) was prepared with ice-cold Tris-HCl buffer (0.1 M, pH 8.0) containing 10 mM reduced glutathione. To the 100 µl of enzyme extract, 3.824 ml Tris-HCl buffer (0.1 M, pH 8.0) was added and allowed for pre-incubation of 10 min at 25°C. Then, 76 µl of 0.1 M CDNB prepared in acetone was added. The change in absorbance was recorded for 5 mins with every 1 min interval in UV-Vis spectrophotometer at 340 nm and the specific activity of enzyme was expressed as nmoles of CDNB conjugated ml^{-1} min^{-1} mg^{-1} protein (Bose, 2019). The *p*-nitroanisole was used as a substrate to estimate mixed function oxidase (MFO) activity. The enzyme extract of adult mites was prepared with 50 mM ice-cold Tris-HCl buffer containing 1.15 % KCl and 1.0 mM ethylenediamine tetraacetic acid (EDTA) (pH 7.7). The assay mixture containing 1.7 ml Tris-HCl buffer, 1 ml 50 Mm *p*-nitroanisole (in ethanol) and 100 µl enzyme extract was incubated at 34°C for 3 min. Then 200 µl of 10.0 mM nicotinamide adenine dinucleotide phosphate (NADPH) in 0.1 M phosphate buffer at pH 7.8 was added and the reaction mixture was again incubated at 34°C for 30 min. The activity was immediately measured at 405 nm for every 15 sec interval till 10 min against the blank at 34°C and the enzyme activity was expressed as nmoles of *p*-nitrophenol formed ml^{-1} min^{-1} mg^{-1} protein (Sharma, 2017). The carboxyl esterase (CarE) activity was estimated by preparing enzyme source with ice-cold phosphate buffer (0.04 M, pH 7.0). The reaction mixture contained 100 µl of enzyme source, 450 µl of 0.04 M phosphate buffer and 1.80 ml of 0.3 Mm α-naphthyl acetate was taken in a test tube where α-naphthyl acetate was used as a substrate. Then, the reaction was stopped by adding 0.9 ml of mixture containing two parts of 1% fast blue BB salt and five parts of 5% sodium dodecyl sulfate (SDS) and the reaction mixture was incubated at 30°C for 20 min under natural light conditions. The color was allowed to develop at room temperature for 15 min. The absorbance was measured at 600 nm using UV-Vis spectrophotometer and the specific activity was expressed as nmoles of α-naphthol produced ml^{-1} min^{-1} mg^{-1} protein (He, 2003).

The laboratory experiments were conducted at completely randomized design (CRD) with three replications during 2019-2021 in Central Instrumentation Laboratory, AC & RI, Madurai. The detoxification enzyme assay was replicated thrice and a control without enzyme extract was maintained for each replication. The median lethal concentration (LC_{50}) was determined by Finney's Probit analysis (Regupathy and Dhamu, 2001). The resistance ratio (RR) was computed by dividing the LC_{50} of field population with that of susceptible population. The level of resistance was categorized based on the RR values as follows, <10 as low resistance, 10-40 as moderate resistance, 40-160 as high resistance and >160 as extremely high resistance (Kim et al., 2004). The specific activity (SA) of detoxification enzymes was calculated by dividing the mean of OD difference (nm) and total volume of reaction mixture (ml) with extinction coefficient, volume of substrate (ml), incubation time (min) and protein (mg). The final value was multiplied with 1000 to obtain results in nmoles ml^{-1} min^{-1} mg of $protein^{-1}$ where, extinction coefficient of CDNB is 0.0096 μM^{-1} cm^{-1}; extinction coefficient of *p*-nitroanisole is 0.00332 $\mu M^{-1} cm^{-1}$ and extinction coefficient of α-naphthol is 0.00222 μM^{-1} cm^{-1}.

RESULTS AND DISCUSSION

The laboratory population was observed to be highly susceptible to fenazaquin (LC_{50} of 0.11 ppm) followed by fenpropathrin (0.12 ppm), chlorfenapyr (0.15 ppm), diafenthiuron (0.22 ppm), propargite (0.91 ppm), spiromesifen (2.00 ppm) and buprofezin (5.17 ppm), respectively. The highly toxic acaricides with lowest LC_{50} were fenpropathrin (0.26 ppm) and fenazaquin (0.30 ppm) to Muthur and Puthupalayam populations, respectively showing low level of resistance. All the four field populations tested were highly resistant to

Table 1. Toxicity of acaricides against field populations of *Tetranychus urticae*

Locations	N	Slope± SE	χ^2	LC_{50} (ppm) (50% FL)	LC_{95} (ppm) (95% FL)	RR	Class
				Respiration targets			
				Fenazaquin			
Puthupalayam	360	4.91± 0.04	0.69	0.30 (0.24-0.36)	0.65 (0.53-0.79)	2.74	Low
Pichanur	360	9.45± 0.02	0.60	0.51 (0.46-0.57)	0.77 (0.69-0.86)	4.70	Low
Muthur	360	7.29± 0.02	0.09	0.78 (0.69-0.88)	1.32 (1.17-1.49)	7.13	Low
Nallur	360	4.05± 0.04	0.00	0.59 (0.48-0.72)	1.51 (1.23-1.85)	5.40	Low
Susceptible	360	3.56± 0.05	0.67	0.11 (0.08-0.14)	0.32 (0.25-0.42)	-	-
				Propargite			
Puthupalayam	360	24.04± 0.00	0.96	55.23 (53.31-57.22)	64.68 (62.43-67.01)	60.63	High
Pichanur	360	36.93± 0.00	0.90	54.62 (53.31-55.97)	60.54 (59.08-62.03)	59.96	High
Muthur	360	27.82± 0.00	0.97	43.05 (41.68-44.46)	49.24 (47.68-50.85)	47.25	High
Nallur	360	17.54± 0.01	0.96	39.90 (38.02-41.88)	49.53 (47.19-51.99)	43.80	High
Susceptible	360	2.21± 0.08	0.99	0.91 (0.61-1.34)	5.03 (3.41-7.42)	-	-
				Diafenthiuron			
Puthupalayam	360	2.19± 0.09	0.39	2.70 (1.79-4.08)	16.93 (11.22-25.55)	12.25	Moderate
Pichanur	360	3.25± 0.06	0.39	1.18 (0.90-1.55)	3.95 (3.00-5.20)	5.35	Low
Muthur	360	4.30± 0.04	0.65	1.64 (1.34-2.02)	4.04 (3.29-4.97)	7.44	Low
Nallur	360	3.17± 0.06	0.82	2.25 (1.70-2.99)	7.63 (5.75-10.12)	10.21	Low
Susceptible	360	2.87± 0.06	0.83	0.22 (0.16-0.30)	0.85 (0.63-1.16)	-	-
				Chlorfenapyr			
Puthupalayam	360	14.51± 0.01	0.85	10.50 (9.87-11.18)	13.65 (12.83-14.53)	67.78	High
Pichanur	360	18.29± 0.01	0.78	11.64 (11.06-12.24)	14.35 (13.64-15.10)	75.10	High
Muthur	360	13.95± 0.01	0.80	9.45 (8.85-10.10)	12.45 (11.66-13.30)	61.01	High
Nallur	360	13.90± 0.01	0.62	10.40 (9.75-11.09)	13.70 (12.84-14.62)	67.10	High
Susceptible	360	3.23± 0.06	0.38	0.15 (0.11-0.20)	0.52 (0.38-0.70)	-	-
				Mite growth regulators			
				Spiromesifen			
Puthupalayam	360	10.64± 0.01	0.99	504.69 (465.35-547.37)	720.95 (664.75-781.91)	251.84	Extremely high
Pichanur	360	12.31± 0.01	0.95	601.72 (561.19-645.18)	819.23 (764.05-878.39)	300.26	Extremely high
Muthur	360	9.52± 0.02	0.99	445.45 (406.87-487.69)	663.47 (606.00-726.39)	222.28	Extremely high
Nallur	360	27.50± 0.00	0.86	452.02 (437.74-466.76)	519.58 (503.16-536.52)	225.56	Extremely high
Susceptible	360	2.85± 0.06	0.62	2.00 (1.46-2.73)	7.75 (5.67-10.58)	-	-
				Buprofezin			
Puthupalayam	360	22.37± 0.00	0.99	1985.81 (1910.14-2064.47)	2352.51 (2262.87-2445.71)	383.65	Extremely high
Pichanur	360	32.58± 0.00	0.99	2162.91 (2102.39-2225.16)	2429.55 (2361.57-2499.48)	417.87	Extremely high
Muthur	360	66.52± 0.00	0.97	1980.35 (1952.10-2009.02)	2097.11 (2067.19-2127.46)	382.60	Extremely high
Nallur	360	27.47± 0.00	0.99	2189.06 (2119.61-2260.78)	2512.78 (2433.06-2595.11)	422.92	Extremely high
Susceptible	360	3.73± 0.05	0.16	5.17 (4.04-6.61)	15.63 (12.22-19.99)	-	-
				Sodium channel modulator			
				Fenpropathrin			
Puthupalayam	360	6.75± 0.03	0.76	0.85 (0.74-0.97)	1.50 (1.30-1.72)	6.64	Low
Pichanur	360	5.76± 0.03	0.91	0.87 (0.75-1.02)	1.71 (1.46-1.99)	6.86	Low
Muthur	360	2.59± 0.07	0.80	0.26 (0.19-0.36)	1.15 (0.83-1.61)	2.07	Low
Nallur	360	2.44± 0.07	0.62	0.49 (0.35-0.70)	2.41 (1.70-3.41)	3.89	Low
Susceptible	360	3.33± 0.05	0.76	0.12 (0.09-0.16)	0.41 (0.31-0.54)	-	-

N - Number of mites tested, SE - Standard Error,
LC_{50} - Median lethal concentration, FL - Fiducial limit, RR - Resistance Ratio

Table 2. Estimation of detoxification enzymes in populations of *Tetranychus urticae*

Locations	Protein content (mg/ g)	*SA of Glutathione S Transferase (GST)	Ratio	*SA of Mixed Function Oxidase (MFO)	Ratio	*SA of Carboxylesterase (CarE)	Ratio
Puthupalayam	123.97	20.63	4.54	0.75	10.06	673.65	15.06
Pichanur	127.96	9.71	2.14	0.63	8.49	267.02	5.97
Muthur	112.87	6.63	1.46	0.24	3.21	375.87	8.40
Nallur	124.48	6.45	1.42	0.36	4.85	481.99	10.77
Susceptible	80.54	4.53	-	0.07	-	44.71	-

SA - Specific activity, *Enzyme activity in nmoles ml^{-1} min^{-1} mg of $protein^{-1}$

propargite (43.80 to 60.63-folds) and chlorfenapyr (61.01 to 75.10-folds) when compared with laboratory susceptible population. The Pichanur, Muthur and Nallur populations exhibited low resistance to diafenthiuron (5.35 to 10.21-folds), while Puthupalayam population was moderately resistant (12.25-folds). The mite growth regulators, spiromesifen (222.28 to 300.26-folds) and buprofezin (382.60 to 417.87-folds) had shown extremely high resistance to all the field populations. Among the field populations, Puthupalayam one had developed high resistance to propargite (60.63-folds) and diafenthiuron (12.25-folds), Pichanur population to chlorfenapyr (75.10-folds), spiromesifen (300.26-folds) and fenpropathrin (6.86-folds), Muthur population to fenazaquin (7.13-folds) and Nallur population to buprofezin (422.92-folds). The toxicity of acaricides in descending order is as follows, fenpropathrin > fenazaquin > diafenthiuron > chlorfenapyr > propargite > spiromesifen > buprofezin (Table 1).

Sharma (2017) and Titiksha (2019) reported low fenazaquin resistance in *T. urticae* (6.67-folds, 3.62-folds) from brinjal and capsicum, respectively which is in confirmation with our present findings. In *T. urticae*, resistance to propargite was moderate (9.03 to 18.36-folds) in brinjal at Bangalore (Sharma, 2017) and extremely high (3,725-folds) in Okra at Punjab (Hany et al., 2020). The magnitude of resistance reported by Mohin (2020) in tomato viz., propargite (149.0 to 164.0-folds), diafenthiuron (41.73 to 55.93-folds), chlorfenapyr (58.21 to 68.59-folds) and spiromesifen (592.31 to 625.86-folds) were more or less correlated. Similarly, low diafenthiuron resistance (10-folds) was reported in *T. truncatus* collected from okra at Kerala (Anushree et al., 2019). In *T. urticae*, Xu et al. (2018) and Lu et al. (2016) reported low to extremely high (2.38 to 952.22-folds) and high (44.64 ppm) chlorfenapyr resistance in vegetables and rose at China, respectively. Similarly, extremely high spiromesifen resistance (431.26 to 969.10-folds) was observed by Syed et al. (2018) in tomato. The extremely high buprofezin resistance was found by Wu et al. (2018) to *Nilparvata lugens* in China. The *O. coffeae* infesting tea was examined low fenpropathrin resistance (1.23 to 2.04-folds) (Roy et al., 2018, Amsalingam et al., 2016). Pan et al. (2020) observed low to moderate level of fenpropathrin resistance to *Panonychus citri* from Southwestern China.

The variation in results of resistance level in field populations depend on the extent of acaricides usage pattern by the farmers in a particular area. The enhanced resistance in the Puthupalayam and Pichanur populations possibly may result from a long history of continuous exposure to acaricides since these areas has been highlighted as major vegetable growing areas following mono-cropping patterns in Coimbatore. The acaricides which exhibited low level of resistance viz., fenpropathrin (pyrethroid) and fenazaquin (MET-inhibitor) can be recommended to control *T. urticae* in Coimbatore region of Tamil Nadu. The Puthupalayam population recorded higher specific activity of GST (20.63 nmoles ml^{-1} min^{-1} mg of $protein^{-1}$) which was 4.54-folds higher than that of susceptible population. Similarly, the MFO (0.75 nmoles ml^{-1} min^{-1} mg of $protein^{-1}$) and CarE activity (673.65 nmoles ml^{-1} min^{-1} mg of $protein^{-1}$) were 10.06 and 15.06-folds higher than the susceptible population (Table 2). A pairwise correlation coefficient analysis between resistance ratio of diafenthiuron and CarE activity (r = 0.981*), fenpropathrin and MFO activity (r = 0.964*) were positively significant at p = 0.05. Similarly, Riaz et al. (2014) found elevated level of CarE activity in diafenthiuron treated *Brevicoryne brassicae* (313.33 µmol/ min/ mg) at LC_{50} after 24 hours when compared to control (250 µmol/ min/ mg). Xin-Ju and Hui-Min (2011) reported 17.386- folds increased MFO activity in fenpropathrin resistant *T. urticae* (247.35-folds).

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DIAGNOSTICS OF THE TETTIGONIID GENUS *CONOCEPHALUS* OCCURRING IN THE RICE FIELDS

S V Dharini and N Chitra*

Department of Entomology, Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India
*Email: chitra.bookworm@gmail.com (corresponding author)

ABSTRACT

In this study, the genus *Conocephalus* (Orthoptera: Tettigoniidae) collected from the rice fields of Coimbatore and Bhavanisagar, Tamil Nadu are taxonomically analysed. Three species viz., *C. longipennis*, *C. maculatus* and *C. rentzi* inhabiting rice fields have been redescribed and illustrated. Occurrence of *C. rentzi* in rice with description of male genitalia is reported for the first time.

Key words: Diagnostics, Tettigoniidae, Tamil Nadu, Bhavanisagar, redescribed, *Conocephalus longipennis*, *C. maculatus*, *C. rentzi*, rice, male genitalia, occurrence

Genus *Conocephalus* (Orthoptera: Tettigoniidae: Conocephalinae) was erected by Thunberg in 1815 with *Gryllus (Tettigonia) conocephalus* L., as type species along with description of 24 species. Genus *Conocephalus* is the largest of the tribe Conocephaliini and is cosmopolitan in distribution. *Conocephalus* comprises 151 species worldwide (Cigliano et al., 2021) while in India 10 species have been documented so far (Shishodia et al., 2010; Nagar and Swaminathan, 2016; Farooki and Usmani, 2018) with two species recorded in rice ecosystems (Chitra et al., 2000). The insect diversity and abundance is relatively more in rice compared to other cultivated crops. Genus *Conocephalus* plays an important functional role in rice ecosystem by minimizing the damage incurred by insect pests (Pantua and Litsinger, 1984; Manley, 1985; Rubia et al., 1990a). This study analyses the taxonomy of the species of this genus as inhabiting rice in Tamil Nadu.

MATERIALS AND METHODS

Conocephalus specimens were collected during 2020 and 2021 from the rice fields of Coimbatore (11˚00'09 ″N 76˚55'33 ″E; 10˚59'44 ″N 76˚54'59 ″E) and Bhavanisagar, Erode (11˚28'40 ″N 77˚08'32 ″E; 11˚28'59 ″N 77˚08'22 ″E; 11˚28'51 ″N 77˚07'43 ″E) in Tamil Nadu. Collected specimens were killed with chloroform (99.8%) and subsequently pinned and labelled. The dry preserved specimens were deposited in the TNAU Insect Museum. Morphological and genitalia characters were examined under stereo zoom microscope (Leica M205A, Software LAS v4.12). Photographs and measurements were taken with LAS X Application suite montage software. Morphological description and terminologies used to illustrate wings and male genitalia follow Nagar and Swaminathan (2016), Farooki and Usmani (2018), Rentz, (1970) and Cedillo-Salinas et al., (2019). Description of female genitalia follows Torre-Bueno (1989). Genitalia extraction follows the methodology of Rengifo and Andrade (2014). Abdomen was detached with forceps and placed in water for 5 -10 min to facilitate softening of membranes and enable easy handling. Relaxed specimens are then transferred to cavity blocks with (5%) KOH for 10 min and further washings with distilled water carried out. Supra anal plate removed with the aid of entomological pin and genitalia extracted by bending the lamina subgenitalis. The abbreviations used: FW: Fore wing; HW: Hind wing; Male genitalia: Ti: Titillators (Ti. R - Right titillator; Ti. L - Left titillator); Female genitalia: Dv: Dorsal valves; Vv: Ventral valves.

RESULTS AND DISCUSSION

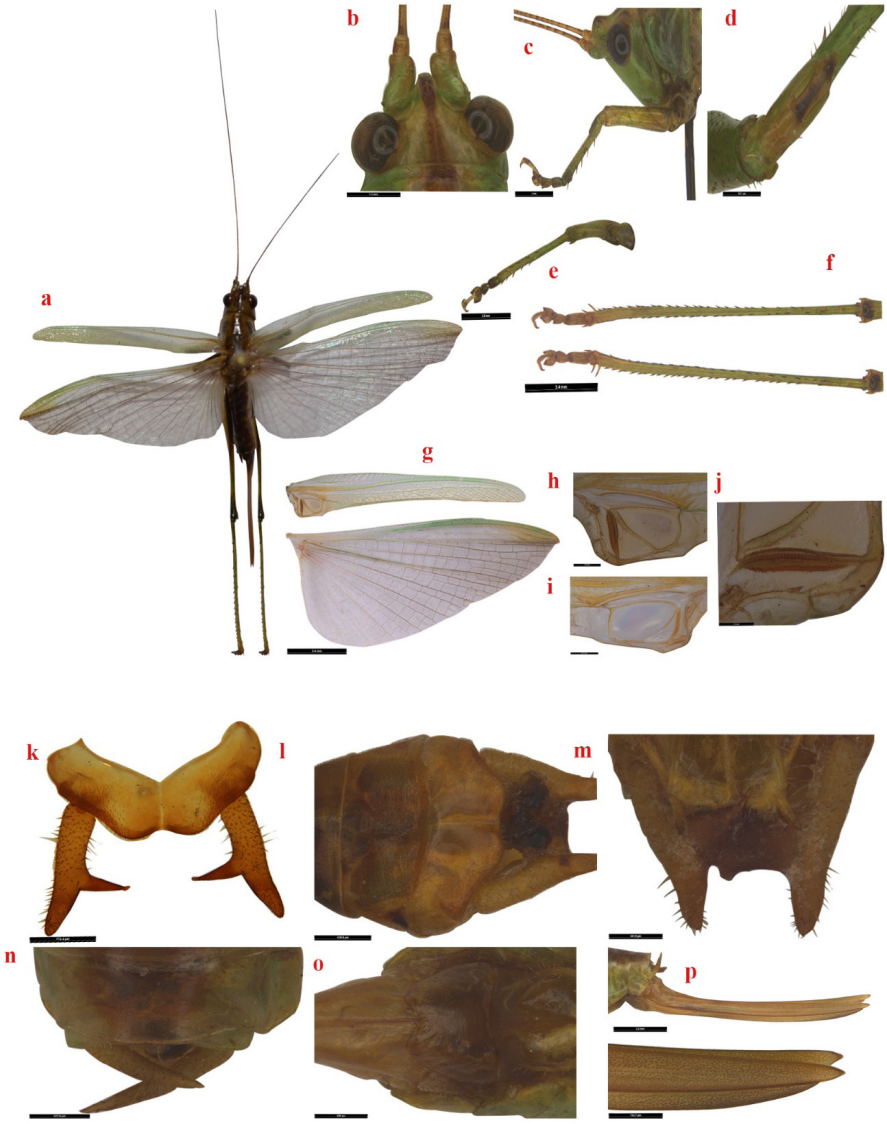
Genus *Conocephalus* Thunberg (1815)

Diagnosis: Body small to medium, greenish in colour with wider brown or black patch medially running from vertex to lower margin of pronotum. Compound eyes bulging out and antenna filiform. Brown patches present or absent in tegmen. In FW, costal cell with numerous cross veins; radial vein branch into two veinlets and medial vein branch into 8 veins; cubitus vein dissolve in the mid-basal area. Median and cubitus vein arise from a thick unbranched vein from humeral angle. Left stridulatory file and right mirror well developed. Internally toothed cerci in male whereas in female, cerci lack an internal tooth.

1. *Conocephalus longipennis* (de Haan) (Figs. 1a-p)

Locusta (Xiphidium) longipennis. Haan, 1843: 188–189; *Conocephalus carolinensis* Willemse, 1942: 98; *Xiphidium (Xiphidium) longicornis* Redtenbacher, 1891: 513; *Conocephalus carolinensis* Willemse, 1942: 99; *Xiphidium spinipes* Stal, 1877: 47.

Redescription: ♂ Head yellowish green; a dark brown patch running from mid inter-ocular space to occipital sulcus with margins on both extremes not straight present. Eyes globular, projected outwards and black in colour with bright yellow rim basally. Antenna dull brown throughout with base of each flagellomere darker. Scapus finely pubescent along inner dorsal margin. Length of scapus two times longer than inter-ocular distance. Fastigium narrower and brownish apically on dorsal side. Frontal ridge on frons distinct. Clypeo-labral suture brownish and distinct. Labrum dark yellowish with apex flattened. Gena not pitted and greenish. Both palps pubescent with tips faint brown in colour. Apex of fifth segment of both palpi enlarged than the base. Thorax with pronotum with upper and lower margins straight and lateral margin rounded. Apical edge of pronotum terminates into a wide rounded lobed extension over mesonotum. Median carina of pronotum and humeral sinus not clearly visible. Lateral



Figs. 1a-p: *Conocephalus longipennis* (de Haan) Female: a. full view; Male: b. head dorsal; c. fore leg; d. tympanum; e. mid leg; f. hind tibia; g. fore and hind wings; h. right mirror and file; i. left mirror and file; j. left stridulatory file; k. cerci; l. supra anal plate; m. sub genital plate; Female: n. cerci and supra anal plate; o. sub genital plate; p. ovipositor

lobes of pronotum trigonal with secondary tympanum along posterior edge. Secondary tympanum oviform with thin cuticular structure and partially cover the thoracic auditory spiracle. Prothoracic spiracle ovate and pubescent along inner edges. Prosternum with a pair of spines. Mesosternal lobes semi-circular and meet in the middle forming no mesosternal interspace. Metasternal lobes feebly rounded with apical excision.

Legs with tibia and femur not spotted basally. Ventral fore coxae with a single spine. Tympanum darker, closed bilaterally and situated basally on fore tibia. Fore- and mid-femur with no armature on ventral side. Hind femur with one sub-basal spine on inner edge and four sub-basal spines on outer edge. Genicular lobes of fore femur with two spines on inner side, mid femur with one spine on inner and two spines on outer side. Hind femur with two spines each on both sides. Fore- and mid-tibia with no dorsal armature but ventrally with six spines each on inner and outer side. Hind tibia with darkened spines along inner margin (30 numbers) and outer margin (33 numbers) dorsally. Ventrally spines present along inner (6 numbers) and outer margin (9 numbers). Hind leg 1.85 times longer than body length. Wings with: FW: Nearly one third region of remigium greenish. Brown patches absent. Subcostal cell from mid to apex appear dark green. Cubitus vein dissolve medially above anal margin into two veinlets. Left stridulatory file with evenly arranged teeth (65 nos). Size of teeth decreases gradually towards both extremities. Stridulatory file on right tegmen comparatively shorter than left file. Right mirror feebly square shaped and left mirror rectangular in shape. HW: Costal cell dull green from mid to apex. Distal region of subcostal and marginal cell dull yellowish.

Abdomen with tergites brownish medially with faded greenish yellow irregular margins on both sides. Sternites pubescent and yellowish. Male: Supra-anal plate wider with slightly incised in the middle and lateral apical edges feebly depressed. Sub-genital plate pubescent with apical margin nearly straight bearing a pair of stylus on lateral extremes. Stylus tipped dull brown and pubescent. A pair of cercus widely at base. Apex of cerci blunt. Cercus toothed internally and tips of the internal tooth globular in shape. Internal tooth present just below middle region of cercus. Female: Supra-anal plate with median excision clearly visible and wider than long. Sub-genital plate triangular, broader than long with medially depressed. Cerci shorter than male with no internal tooth and densely hairy. Ovipositor long, dull yellowish. Dv longer than Vv. Apex of Dv project as a blunt tip beyond ventral valves and slightly thickened. Outer and inner side of both valves appear pitted throughout. Sexual dimorphism present. Abdomen of male bright yellowish while females greenish.

Measurements: Male: 17.09-17.39 mm long; head: 3.16-3.46 mm wide; pronotum: 2.96-3.26 mm long and 2.17-2.47 mm wide; hind leg: 31.7-32.0 mm long; fore wing: 13.83-14.13 mm long; stridulatory file: left: 1.40-1.41 mm long; right: 0.96-1.01 mm long; hind wing: 20.26-20.56 mm long; cerci: 1.51-1.64 mm long. Female: 18.47-18.77 mm long; head: 2.62-2.92 mm long and 3.38-3.68 mm wide; pronotum: 3.34-3.64 mm long and 2.07-2.37 mm wide; hind leg: 33.75-34.05 mm long; fore wing: 20.66-20.96 mm long; hind wing: 22.52-22.82 mm long; cerci: 1.07-1.37 mm long; ovipositor: Dv: 11.29-11.35 mm long; Vv: 11.07-11.21 mm long.

Materials examined: 4 specimens: Tamil Nadu, Coimbatore (11˚00'09 ″N 76˚55'33 ″E; 10˚59'44 ″N 76˚54'59 ″E and 417 masl): 1♂ (03.02.2021), 3♀ (03.02.2021; 16.03.2021), 2 specimens: Tamil Nadu, Erode, Bhavanisagar (11˚28'40 ″N 77˚08'32 ″E; 11˚28'59 ″N 77˚08'22 ″E; 11˚28'51 ″N 77˚07'43 ″E and 256 masl): 2♀ (09.04.2021), leg. DharinI S V

Distribution: India (Shisoidia et al., 2010), Pacific regions of the Cariline islands and Somao (Pitkin, 1980).

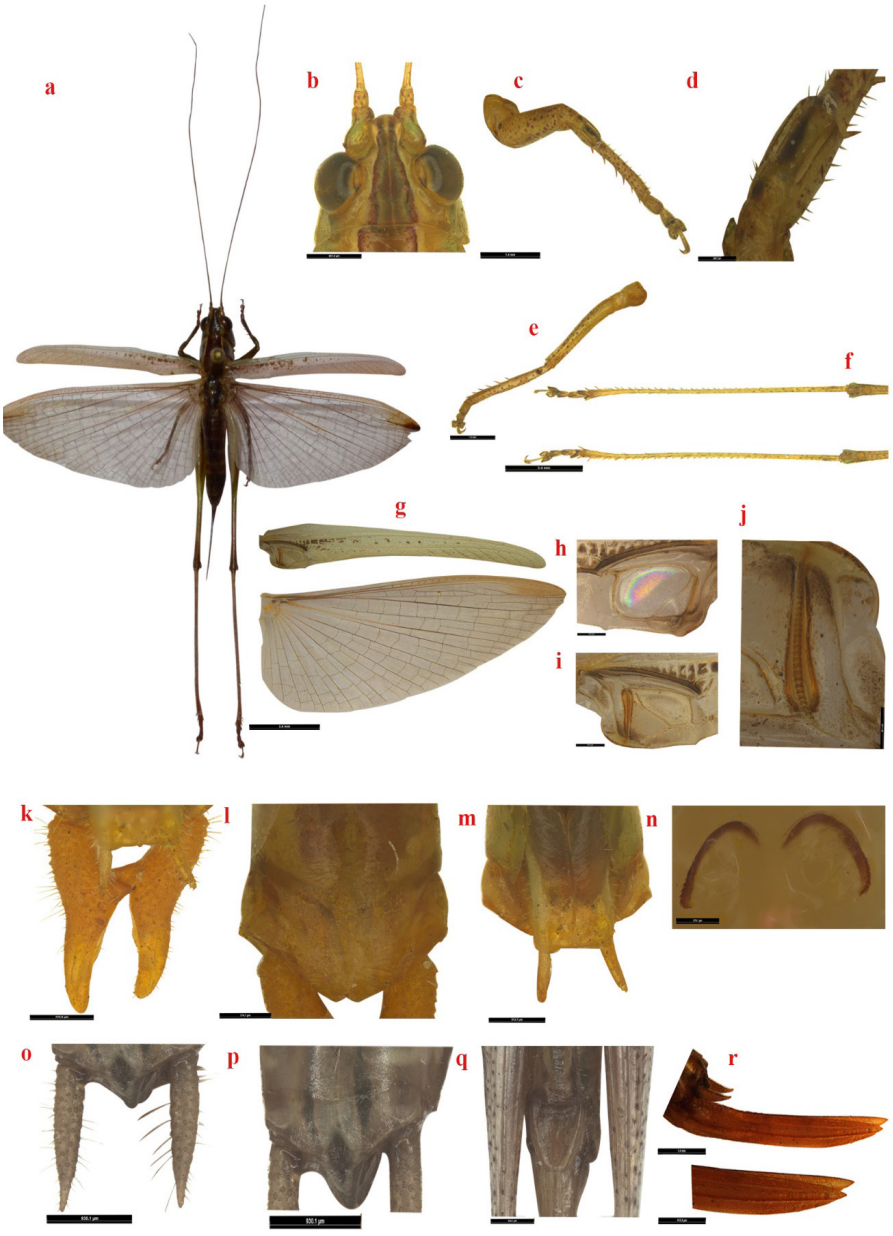
Comments: Rothschild (1970) documented *C. longipennis* as a predator on nymphs and eggs of rice ear bug, *Leptocorisa oratorius* (F.) in Sarawak. *C. longipennis* was recorded as a generalist predator of on egg masses of yellow stem borers, leaf folders and rice earhead bugs, nymphs and adults of leafhoppers and plant hoppers and adults of leaf folders, stem borers, whorl maggot and earhead bugs (Pantua and Litsinger, 1984; Rubia et al., 1990b; Ito et al., 1995; Kraker et al., 1996; Chitra et al., 2000). This species was reported as an opportunistic predator on egg masses of stem borers by exposing them to other parasitoids (Manley, 1985). Grist and Lever (1969) recorded this species as a minor pest of rice in Sarawak and New Guinea. Chitra et al. (2000) noticed typical longitudinal slits made by this species on rice leaf blades and its preference for mature rice grains.

2. *Conocephalus maculatus* (Le Guillou) (Figs. 2a-r)

Xiphidion maculatus. Le Guillou, 1841: 294; *Conocephalus (Xiphidion) arabicus* Uvarov, 1933: 262; Popov, 1981: 114-148; *Conocephalus bidens* Uvarov,

1957: 363; Popov, 1981: 127; *Xiphidium continuum* Walker, 1869: 271; *Locusta (Xiphidium) lepida* Haan, 1843: 188–189; *Xiphidion neglectum* Bruner, 1920: 123; *Xiphidium sinensis* Walker, 1871: 35; Panhwar et al., 2013: 173; *Xiphidium dimidiatum* Matsumura and Shiraki, 1908: 56, Ito and Ichikawa, 2004: 59.

Redescription: ♂ Head brownish yellow and not wider than long. Eyes spherical, protuberant outwards and yellowish rimmed basally. Antenna dull brownish with minute pubescent hairs throughout the length. Scapus equally long as inter ocular distance and two times wider than inter-ocular distance. Median reddish brownish patch with straight margins and fainted yellowish line in the centre extending from apex of fastigium to hind margin of pronotum. Lateral extremes of the patch covered by dark yellowish streaks. Apical fastigium rounded and projected outwardly over frons. Frons with globe shaped yellowish spot present just beneath apex of fastigium. Epistomal suture distinct



Figs. 2a-r: *Conocephalus maculatus* (Le Guillou): Female: a. full view; Male: b. head; c. fore leg; d. tympanum; e. mid leg; f. hind tibia; g. fore and hind wings; h. right mirror and file; i. left mirror and file; j. left stridulatory file; k. cerci; l. supra anal plate; m. sub genital plate; n. male genitalia; Female: o. cerci; p. supra anal plate; q. sub genital plate; r. ovipositor

and sub-ocular suture not clearly visible. Apical margin of clypeus flat and depressed medially. Labrum wide rounded apically with lateral margins feebly concave. Palpi of maxilla and labium pubescent. Apical segment of both palpi tipped dull brownish. Apex of both palpi slightly bigger than base. Thorax with pronotum with feebly concave upper margin and lower margin extended over mesonotum and sub-obtuse. Lateral margin concave. Median carina distinct but humeral sinus weak. Lateral lobes appear faintly elevated and partially cover secondary tympanum. Secondary tympanum ovoid, a thin cuticular structure and cover half of spiracle of propleuron. Prothoracic spiracle in the lateral lobe of pronotum obovate and partly covered by secondary tympanum. Mesonotum depressed medially with triangular mesonotal lobes. Mesonotal lobes elongated and longer than wide. Mesosternum with median raised ridge yellowish in colour and lobes rounded.

Legs irregularly round darker spots present on tibia and femur. Spots darker in mid tibia. Ventral side of outer coxae unispinose. Femur lack spines both on dorsal and ventral side. Fore femur with a single inner spine and no outer spine on knee lobes. Mid- and hind femur with one apical spine each on both sides. Tympanum appear slit-like, situated basally on fore tibia. Opening present on either side laterally and the tympanum appear to be present within a shallow depression. Fore- and mid-tibia lack dorsal spines. Dorsally, hind tibia armed with minute to small black tipped spines on inner (38 numbers) and outer margins (32 numbers). Fore-, mid- and hind tibia ventrally armed with varying number of spines on both margins. Hind tibia with spines on inner side (7 numbers) and spines on outer side (11 numbers) ventrally. Hind tibia with one pair of apical spur dorsally and two pairs of apical spurs ventrally. The inner pair of spurs shorter than outer pair of spurs. Wings with FW: Yellowish with darker veins. Irregularly spread brown patches present below radial vein; dense in the basal cell but only few in the sub-marginal cell. Mirror square shaped with slightly elevated top margin on right tegmen while left mirror appear broad and rectangular, not well developed. Right stridulatory file plumpier basally and terminate into thin profile towards apex enclosing closely arranged teeth. However, the left file plumpier throughout except thin extremities with evenly placed teeth (50 numbers). Basal anal margin straightened but towards apex feebly curved. HW: Subcostal and marginal cell dull yellowish subapically. A series of 18 to 20 thick transverse veins present in the subcostal cell.

Abdomen with tergites with black patch running medially along the entire abdominal length. Male with tenth abdominal tergite wider than long with visible median carina and weakly bilobed along apical margin. Supra-anal plate widely rounded and concave. Sub genital plate yellowish medially depressed. Apical margin of sub genital plate inwardly bent in the median region weakly. A pair of bilateral stylus curved and yellowish. Cerci single toothed just above mid-internal side and pubescent. Tooth of cercus tipped black and sharp edged. Ti present as pairs, well sclerotized and yellowish brown in colour. Ti. R and distinctly curved inwards but Ti. R is 1.12 times longer than Ti. L. Ti spinulate asymmetrically with no further division apically. Ti. R bears 12 spines and Ti. L bears 13 – 14 spines along the outer margin. Female: Prominent raised ridge present medially on tenth abdominal tergite. Apical margin of supra anal plate with a median incision. Sub genital plate roughly triangular with acute apical margin. Cerci with no internal tooth but pitted and pubescent. Ovipositor brownish yellow with visible depression throughout the length of bottom half of Dv. Dv longer than Vv and terminate into a sharply projecting tip with lower margin slightly elevated and upper margin straight beyond apex of Vv. Inner and outer sides of both valves except the depressed region appear pitted.

Measurements: Male: 14.38-14.68 mm long; head: 2.54-2.84 mm long and 2.47-2.77 mm wide; pronotum: 2.93-3.23 mm long and 1.6-1.9 mm wide; hind leg: 25.97-26.27 mm long; fore wing: 16.72-17.02 mm long; stridulatory file: left: 1.29-1.33 mm long; right: 0.91-0.99 mm long; hind wing: 18.86-19.16 mm long; cerci: 1.51-1.81 mm long. Female: 14.9-15.2 mm long; head: 1.97-2.27 mm long and 2.64-2.94 mm wide; pronotum: 2.97-3.27 mm long and 1.76-2.06 mm wide; hind leg: 30.17-30.47 mm long; fore wing: 18.6-18.9 mm long; hind wing: 19.6-19.9 mm long; cerci: 1.23-1.53 mm long; ovipositor: Dv: 7.33-7.41 mm long; Vv: 7.09-7.16 mm long.

Materials examined: 5 specimens: Tamil Nadu, Coimbatore (11˚00'0 ″N,76˚55'33″E; 10˚59'44″N,76˚54'59″E, 417 masl): 3♂ and 2♀ (10.02.2021; 09.03.2021), 3 specimens: Tamil Nadu, Erode, Bhavanisagar (11˚28'40″N, 77˚08'32″E; 11˚28'59″N,77˚08'22″E; 11˚28'51″N,77˚07'43″E, 256 masl): 1♂ and 2♀ (09.04.2021), leg. Dharini S. V.

Distribution: India, Pakistan, Singapore, Africa, Australia, China, Indonesia, Java, Malaysia, Nepal, New Guinea and Philippines (Shishodia et al., 2010;

Tan, 2010; Zhou et al., 2010; Panhwar et al., 2013; Kashakuro, 2017; Abrori and Leksono, 2021.)

Comments: Based on the feeding habit, *C. maculatus* is carnivorous on lepidopteran eggs and larvae, apple snails, sometimes even dead insects and also phytophagous feeding on seeds, flowers and grains of grass species (Kraker, 1996; Oda and Ishii, 1998; Chitra et al., 2000; Litsinger et al., 2006; Takahashi and Kiritani, 2008; Wason and Pennings, 2008; Chakraborty, et al., 2014). Further, it was suggested to bioindicator of climate change (Senthilkumar and Sanjayan, 2008).

3. *Conocephalus rentzi* Farooki and Usmani (Figs. 3a-r)

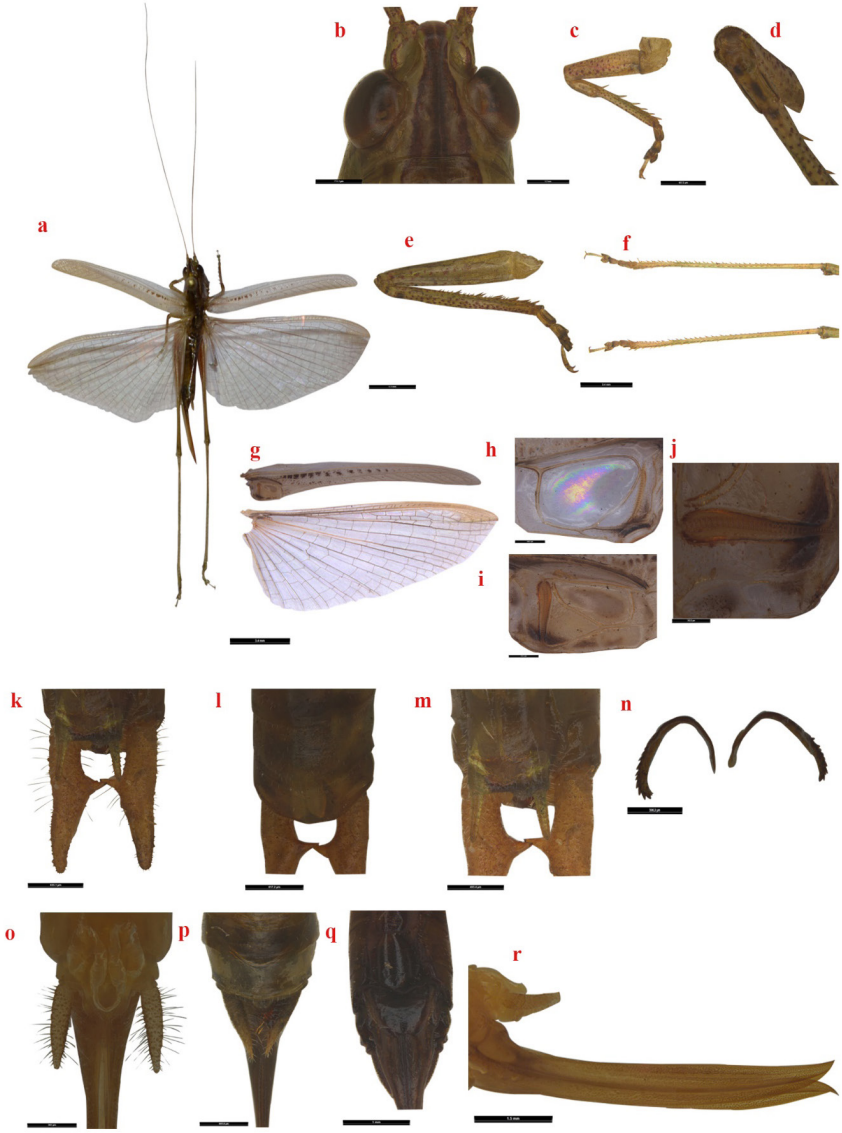
Conocephalus rentzi Farooki and Usmani, 2018: 381-398.

Redescription: ♂ Head with compound eyes dark, circular, brownish and rimmed basally. Antenna finely pubescent and greenish throughout. Vertex wide apex blunt and terminate into a laterally compressed fastigium. Vertex with reddish patch bilaterally margined by yellowish streak on both sides. Fastigium narrow and 1.7 times less wide than inter-ocular distance. Frons greenish yellow with dark brown tear drop shaped spot present just beneath fastigium. Fronto-clypeal suture distinct. Pre-ocular ridge not clearly visible. Apex of clypeus feebly flat with a median lobe - like extension. Labrum feebly rounded and give flap-like appearance. Maxillary palpi 5 segmented with apex of fifth segment not slanted and tipped brownish. Labial palpi 3 segmented with apex of last segment slanted and tipped dull brown. All segments of palpi with minute pubescent hairy structures. Thorax with upper margin of pronotum straight. Lateral margin concave. Dorsal region with median brownish patch bilaterally covered by irregular thick yellowish streaks. Median carina indistinct with humeral sinus. Spiracle on pronotum covered partially by secondary tympanum. Secondary tympanum elliptical present as a thin cuticular structure but raised slightly near posterior edge of pronotal lobes. Widely spaced hyaline small pair of spurs present on prostrenum. Mesosternal interspace hardly present, covered by triangular and widened mesosternal lobes. Metasternal lobes apically slightly excised in the middle and mesosternal interspace indistinct.

Legs dark pinkish spots of irregular size cover all sides of tibia and femur of all pairs. A yellowish spine present on venter of fore coxae on outer side. Knee lobes of femur roughly round and spinose. Genicular lobes of fore femur with one inner spine only and no outer spine, mid femur with one spine on each side and hind femur with two spines on each side ventrally. Tympanum present on basal first half fore tibia. Tympanum with small pits present on either of the anterior region of fore tibia. Fore- and mid-tibia unarmed dorsally but with six spines each on inner and outer sides of ventrally. Hind tibia with spines along inner (30 numbers) and outer margin (26 numbers) dorsally. Hind tibia with a pair of apical spurs on dorsal side and two pair of apical spurs on ventral side with outer pair longer than inner pair. Tarsus coloured black apically. Basitarsus apical margin nearly straight but not straight in other three tarsomeres. Wings with FW: Yellowish brown with dark veins. Brownish patches (13 to 15 numbers) of irregular size run along radial vein beneath from base to middle remigium. Stridulatory file of left FW with short and evenly spaced teeth (44 numbers). Base of mirror and file in the left FW wider than apex. Right mirror equally wide and long but file not well developed. HW: Wholly hyaline with distal costal and subcostal cell dull brown.

Abdomen having tergites with a middle dull brownish patch across the length throughout. Lateral sides of abdomen appear greenish yellow. Male: Triangular and feebly broadened tenth abdominal tergite with distinct median carina; basal margin of which appear indented. Supra-anal plate broader than long with prominent mid raised ridge and apex not sharp rather weakly flat. Sub-genital plate long with visible median carina. Apical lamina subgenitalis with a pair of pubescent stylus bilaterally and a distinct central excision. Cerci pitted with inwardly directed tooth situated just above median region. Tip of the internal tooth coloured black. Paired Ti dark brownish and curved inwardly. Ti. R and Ti. L equally long and spinulate symmetrically. Ti. R feebly bifurcate apically. Both Ti bear 10-11 spines along the outer distal margin. Female: Apex of penultimate tergite rounded with a median excision. Supra-anal plate triangular with a median groove and apical angle obtuse. Sub-genital plate wider than long with feebly triangular excised apex. Ovipositor yellowish basally but slightly become yellowish brown towards apex. Dv longer than ventral valves. Apical Dv more projected into a sharply curved tip beyond apical Vv. Mid to apical region of outer and inner sides of both valves appear pitted and feebly pubescent.

Measurements: Male: 13.09-13.39 mm long; head: 18.9-2.19 mm long and 2.53-2.83 mm wide; pronotum: 2.29-2.59 mm long and 2.1-2.4 mm wide; hind leg: 28.97-29.27 mm long; fore wing: 16.66-16.96 mm long; stridulatory file: left: 1.27-1.35 mm long; right: 1.03-1.11 mm long; hind wing: 18.0-18.30 mm long;



Figs. 3a-r: *Conocephalus rentzi* (Farooki and Usmani): Female: a. full view; Male: b. head; c. fore leg; d. tympanum; e. mid leg; f. hind tibia; g. fore and hind wings; h. right mirror and file; i. left mirror and file; j. left stridulatory file; k. cerci; l. supra anal plate; m. sub genital plate; n. male genitalia; Female: o. cerci; p. supra anal plate; q. sub genital plate; r. ovipositor

cerci: 1.48-1.67 mm long. Female: 14.77-15.07 mm long; head: 2.08-2.38 mm long and 2.63-2.93 mm wide; pronotum: 2.11-2.41 mm long and 1.63-1.93 mm wide; hind leg: 28.09-28.39 mm long; fore wing: 16.42-16.72 mm long; hind wing: 18.86-19.16 mm long; cerci: 1.10-1.14 mm long; ovipositor: Dv: 6.86-6.95 mm long; Vv: 6.79-6.84 mm long.

Materials examined: 9 specimens: Tamil Nadu, Coimbatore (11˚00'09″N,76˚55'33″E; 10˚59'44″N,76˚54'59″E,417 masl): 6♂ (17.02.2021; 04.03.2021; 16.03.2021), 3♀ (29.12.2020; 17.02.2021), 5 specimens: Tamil Nadu, Erode, Bhavanisagar (11˚28'40″N 77˚08'32″E; 11˚28'59″N,77˚08'22″E;11˚28'51″N,77˚07'43″E,256 masl): 2♂ and 3♀ (09.04.2021), leg. Dharini S V.

Distribution: Uttar Pradesh, India (Farooki and Usmani, 2018).

Comments: *C. rentzi* closely resembles *C. maculatus*. This is the first record of this species on rice. However, functional role of this species remains to be studied.

Conocephalus spp. have been documented both as predators and pests in rice crop (Pitkin, 1980). Deep insight focusing on functional significance of

Conocephalus spp., might pave way for evolving as a potential biocontrol agent on serious rice pests.

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KAIROMONAL EFFECT OF SCALES FROM *EARIAS VITELLA* F. AND *CORCYRA CHEPHALONICA* STAINTON ON BIOLOGY OF *TRICHOGRAMMA CHILONIS* (ISHII)

Devendra Kumar Meena*[1], Niraj S Satpute[2], Adimulam Vijay Kumar[3] and Kanchan Digambar Marwade[4]

Department of Entomology
Dr. Panjabrao Deshmukh Krishi Vidypeeth, Akola 444104, Maharashtra, India
*Email: devdmeena631@gmail.com (corresponding author)

ABSTRACT

The hexane extracts of scales of male and females of *Earias vitella* F. and *Corcyra chephalonica* Stainton were evaluated along with standard octacosane on the performance of *Trichogramma chilonis* under laboratory conditions and potted plants. Results revealed that eggs of *C. cephalonica* treated with hexane extract of female *E. vitella* and *C. cephalonica* scales at 10000 ppm resulted in maximum parasitism of 81.99% and 75.99% by *T. chilonis,* respectively, as against 40.66% in untreated (only hexane). Maximum emergence of 71.03% was observed in eggs treated with female extracts of *C. cephalonica* female followed by *E. vitella* (70.08%). Similar was the trend with fecundity and longevity with extract of female *C. cephalonica*. The effect of kairomones on parasitism evaluated with potted plants revealed significantly more parasitism when stapled egg cards of *C. cephalonica* on cotton and pigeonpea were treated with extract of female *E. vitella* scales (66.66 and 70.05%, respectively).

Key words: Kairomone, *Trichogramma chilonis*, *Earias vitella*, *Corcyra cephalonica*, scales, hexane extracts, octacosane, parasitism, emergence, potted plants, egg cards

Kairomone is an interspecific semiochemical or a mixture of semiochemicals, produced by one species which induces responses advantageous to an individual of a different species perceiving the signal (Dicke and Sabelis, 1988). Herbivores in natural ecosystems are limited, not so much by food supply, but rather by natural enemies (Hairston et al., 1960). Chemical cues play a major role in the process of host selection by parasitoids (Milonas et al., 2009). Chemicals released from hosts, their secretions and by-products and associated organisms influence the behaviour of natural enemies. Foraging female insect parasitoids use these chemical cues extensively to locate, identify and exploit their hosts (Alhmedi et al., 2010; Penaflor et al., 2011). Among the insect parasitoids, the egg parasitoid *Trichogramma chilonis* Ishii is widely distributed in the Indian subcontinent, and used against lepidopterans. It is extensively used to manage bollworm complex viz., *Helicoverpa armigera* (Hubner), *E. vitella*, *E. insulana* F., *S. litura* F. and *Pectinophora gossypiella* Saunders (Kumar et al., 2009; Fant et al., 2013). The rice meal moth *Corcyra cephalonica* Stainton is an important factitious host utilised in many biocontrol laboratories in India for the mass production of *T. chilonis*. Spotted bollworms *Earias vitella* F. is one of the major destructive pests of okra, cotton and hollyhock, and a serious pest of okra causing 52.33- 70.75% damage (Choudhury et al., 2021). The present study examined the effect of kairomones from host insects on biological parameters *viz*., parasitism, adult emergence, fecundity, adult longevity and sex ratio of *T. chilonis* on hosts, *C. cephalonica* and *E. vitella* under laboratory and potted plant conditions.

MATERIALS AND METHODS

Trichogramma chilonis and *C. cephalonica* culture were maintained in the Biocontrol Laboratory, Department of Entomology, Dr PDKV Akola Experiments were conducted during 2018-19 using freshly laid, cleaned, UV irradiated *Corcyra* eggs glued on a strip of card sheet (6 x 2 cm) in a single layer using gum. These cards were exposed to *T. chilonis* for maintenance of the culture. Fine streaks of honey and water (1:1) were provided as adult food. After 24 hr, the parasitized egg cards were transferred to fresh glass tubes (15x 2.5 cm). The parasitoids that emerged from the cards were used. The larvae *E. vitella* were collected from okra at the research farm of Department of Entomology Dr PDKV, Akola. These were reared on the fruits of okra under laboratory condition, with 10% honey provided as adult diet. The rearing was carried out at 25± 2°C and 65± 5% RH. Healthy pupae of *E. vitella* were selected and sexed at pupal stage (Mahapatro and Gupta, 1999). Pupae were collected separately in petriplate (10 cm dia) and transferred to rearing cages

(30 cm^3) separately for adult emergence. The male and female moths were used for kairomone extraction. The culture of *C. cepholonica* required for multiplication of *T. chilonis* was maintained under laboratory condition using standard procedure on grains of sorghum. Healthy adults of *C. cephalonica* were selected and sexed using labial palpi (Rajasekhar et al., 2016).

The scale extracts from *E. vitella* and *C. cephalonica* adults were prepared following Ananthakrishnan et al. (1991). Freshly emerged, healthy, 0-24 hr old male and female moths were collected and kept in a deep freezer at -20^{0}C for 15 min for immobilization. Ten grams of moths were weighed and soaked in 100 ml distilled hexane for 24 hrs and shaked in water bath (Haake, SWB 20) at 28^{o}C for two hours and later held at 50^{o}C for 20 min. It was filtered through Whatman No.1 filter paper (Yasuda 1997). Anhydrous sodium sulphate was added @ 1g/10g and kept for 1 hour for dehydration. The extract was again filtered through Whatman No. 1 filter paper. The extract was distilled at 60-70^{o}C in water bath and the residues left at the bottom of the round bottom flask were collected by rinsing with small quantity of HPLC grade distilled hexane in small tube. The tube was kept in water bath for evaporation and the resultant extract was diluted to the required concentration by using HPLC grade hexane and the volume was made up in a 5ml volumetric flask. The extracts were stored at -20^{0}C in deep freezer for further studies.

One % (10000 ppm) of each extract was prepared with hexane (diluent) and was used for the experimentation (100 mg/10 ml of hexane). Clean, healthy and 0-24 hr old eggs of *C. cephalonica* sterilized with 4 w UV light (45 min) were washed twice in hexane to remove the traces of scales or natural kairomones present on the surface of eggs and shade dried. These eggs were pasted with white gum on trichocards, at the rate of 30 eggs (*C. cephalonica*) piece (egg card) per replication. Kairomonal extracts (10000 ppm) of host insects were used to treat the egg cards by micropipette (50 µl/card) separately and shade dried (Baskarn et al., 2018). Laboratory studies of moth scale extract of host insects on parasitization by *T. chilonis* was carried out at ambient conditions. The procedure adopted was similar to the one described by Ananthakrishnan et al. (1991). The treated egg cards were arranged in a circular fashion at equidistance in a Petri-dish (150x 15 mm dia.) and the parasitoids were released at the centre at 6:1 ratio. After 24 hr exposure, egg cards were kept in glass tube and incubated at 25± 2 ºC and 65± 5% RH. The parasitization was observed on 6th day after exposure. Choice tests were conducted separately for each extract. Laboratory experiment was conducted at 25± 2°C, 65± 5% RH. Each treatment was replicated five times, with one egg card considered as one replication.

Cotton and pigeon pea plants were grown in pots in a nethouse. These potted plants were arranged at equidistant from the point of release and covered with a net. These potted plants were stapled with trichocards containing *Corcyra* eggs. Kairomonal extracts of various host insects were used to treat the egg cards (50 µl/ card) and shade dried. The *T. chionis* adults were released from a distance of 3 feet to study the preference of *T. chilonis* for parasitization considering the attraction by different kairomones. Release of adults were done during morning hours only i.e. before 11 a.m. Egg cards were collected after 24 h and kept in vials for development at an ambient temperature. After 4 days, parasitisation was recorded on the basis of black colouration of eggs (Ananthakrishnan et al., 1991). Number of parasitized eggs in each replication was counted after five days as the eggs turn black and thus the per cent parasitization was calculated. When the emergence of adult parasitoids from the parasitized eggs was completed, the black eggs with exit holes were counted in all the treatments. Per cent adult emergence in each replication was thus recorded. In order to determine the fecundity, newly emerged, mated female parasitoid was released in a separate glass vial (4.3 cm diameter and 5.5 cm length) containing 20, one-day old *C. cephalonica* eggs, on egg card (rectangular 5 cm x 1.5 cm). Undiluted honey was placed inside the lid of each vial as a drop and the vial was closed. After every 24 hours, egg card was replaced with new egg card, which has 20 *Corcyra* eggs. This procedure was done till all the females in the glass vial died. For observing longevity of the adult parasitoids, the emerged adults from all the 5 replications in each treatment were placed in separate test tubes where a streak of honey provided as food on paper strips. The per cent females in the progeny in each treatment were noted by counting the number of male and female adults after their death in each treatment. Appropriate transformations were followed and all the transformed data were analysed using CRD (Completely Randomized Design) for ANOVA (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Effect of hexane extracts of host insects on performance of *T. chilonis* evaluated under laboratory

conditions depicted in Table 1 reveal differences indicating that the hexane extracts significantly influence the parasitization by *T. chilonis*. Significantly maximum parasitism (81.99%) was observed in hexane extract of female *E. vitella* which was significantly superior. The hexane extract of male *C. cephalonica* (67.99%) and octacosane kairomone dust (64.74%) were the next best, both being at par. The data regarding the effect of host insect kairomones on % adult emergence of *T. chilonis* from treated eggs of *C. cephalonica* was in the range of 52.77 to 71.03%. Application of hexane extract of female *C. cephalonica* showed significantly maximum emergence (71.03%) which was followed by hexane extract of female *E. vitella* (70.08%), male *C. cephalonica* (69.55%) and male *E. vitella* (67.57 %). These results are in line with those of Singh et al. (2002) on the female body wash of *C. cephalonica* and *H. armigera* on adult emergence in *T. chilonis* and *Trichogramma exiguum* Pinto and Platner. Maruthadurai et al. (2011) observed maximum adult emergence in egg cards treated with whole body wash of male *S. litura* followed by female *E. vitella* by *T. brasiliensis* and *T. chilonis*. In the present study, whole body wash of female *C. cephalonica* followed by female of *E. vittella* recorded higher emergence by the egg parasitoid *T. chilonis*. Parthiban et al. (2015) reported similar observations with *T. chilonis*. Significantly maximum fecundity of *T. chilonis* was observed with hexane extract of female *C. cephalonica* i.e. 73.2 eggs/ female, followed by hexane extract of female *E. vitella* and hexane extract of male *C. cephalonica*; maximum longevity of female was 9.8 days when egg cards were treated with hexane extract of female *C. cephalonica*, which was at par with hexane extracts of female and male *C. cephalonica*.

Present study indicated that kairomonal compounds from *C. cephalonica and E. vitella* female whole body wash increased the fecundity. Nordlund et al. (1976) observed kairomonal response of *Heliothis zea* treated host scale on *Trichogramma pretiosum* Riley. Zaborski et al. (1987) observed more fecundity when eggs of spruce budworm were treated with such a hexane extract and Angoumois grain moth scales by *Trichogramma minutum* Riley. Nordlund et al. (1976) observed that *T. pretiosum* showed a longevity of 12.2 days when there was constant exposure to the kairomones found in the scales of *H. zea*. TuncbIlek and Ayvaz (2003) reported significant effect of 50% honey+50% host egg extracts of *Ephestia kuehniella* and *Sitotroga cerealella* on longevity of *Trichogramma evanescens* Westwood. No significant differences were observed in the number of males and females in the progenies after rearing the *T. chilonis* with treatments; maximum male: female ratio of 1:1.03 was observed in hexane extract of scales of female *E. vitella;* thus, different moth scales extracts do not influence the sex ratio. Nordlund et al. (1976) observed sex ratio (male: female) on scale extract of *H. zea* to be 0.93.

Parasitism by *T. chilonis* was significantly higher

Table 1. *T. chilonis* on eggs of *C. cephalonica*, as influenced by hexane extracts of host insects, and parasitism by *T. chilonis* on hexane extracts of host insect scales treated *C. cephalonica* eggs stapled on cotton and pigeonpea

Treatments	% parasitism	% Emergence	Fecundity (Eggs/ female)	Female longevity (Days)	Sex ratio (M: F)	Cotton	Pigeonpea
C. cephalonica (male)	67.99 (55.58)	69.55 (56.56)	69.6 (56.63)	8.4 (16.85)	1:1.00	53.33 (46.91)	62.11 (52.03)
C. cephalonica (Female)	75.99 (60.79)	71.03 (57.68)	73.2 (58.86)	9.2 (17.66)	1:0.90	57.26 (49.18)	54.05 (47.35)
E. vitella (male)	71.99 (58.09)	67.57 (55.32)	66.4 (54.62)	8.0 (16.43)	1:0.84	54.66 (47.68)	57.99 (49.63)
E. vitella (Female)	81.99 (68.58)	70.08 (56.86)	71.8 (57.94)	9.8 (18.24)	1:1.03	66.66 (54.90)	70.05 (56.89)
Octacosane Dust	64.72 (53.59)	60.81 (51.21)	63.0 (52.55)	7.8 (16.22)	1:0.91	51.33 (45.76)	55.39 (48.16)
Control (Hexane)	40.66 (39.61)	52.77 (46.60)	42.2 (40.51)	7.0 (15.34)	1:0.81	40.664 (39.61)	38.66 (38.43)
SE(m)±	1.17	1.05	1.8	0.02		1.33	1.87
CD (p = 0.05)	3.42	3.09	5.25	0.06		3.89	5.84

*Mean of seven replications; Figures in parentheses arc sin transformed values

when stapled egg cards of *C. cephalonica* on cotton plants were treated with hexane extract of *E. vitella* female scales (66.66 %). On pigeonpea *T. chilonis* release is not recommended, hence, performance was evaluated under greenhouse on potted plants. *Corcyra* egg cards with kairomones from host insect scales were used and the results revealed significant differences (Table 1; hexane extract of female *E.vitella* scales was found to be the most effective (70.05 %). These results corroborate with the earlier ones- Lewis et al., 1975; Elzen et al., 1984; Nordlund et al., 1984; Nordlund 1987 and Shu et al., 1990. Paul et al. (1997) also observed that the cards treated with whole body washings of female *C. cephalonica* registered maximum parasitization by *T. brasiliensis* and *T. japonicum* Ashmead. Ananthakrishnan et al. (1991) reported 83.4% parasitism on whole body wash of *H.armigera* treated eggs and 68.5% parasitism on whole body wash of *C. cephalonica* treated eggs. Rani et al. (2007) also observed that mean parasitism of *T. japonicum* increased with hexane extract of yellow stem borer adult body, frass extract, larval extract and control under field and potted plant conditions. Parthiban et al. (2015) observed significantly more parasitism on eggs of *Spodoptera litura* (F.) when egg cards were treated by whole body wash of female and male, and larval extract of *C. cephalonica*, with *T. chilonis*.

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INSECTS DIVERSITY IN AN AGROECOSYSTEM OF BHABAR REGION OF UTTRAKHAND

Rekha*, Deepika Goswami, Deeksha Arya and B R Kaushal

Department of Zoology, Kumaun University, Nainital 263002, Uttarakhand, India
*Email: rekhayadav303@gmail.com (corresponding author)

ABSTRACT

Species diversity and abundance of insects associated in an agricultural ecosystem was studied in Bhabar region of district Nainital in Uttarakhand from March 2018 to February 2020. Data revealed a total of 148 insect species belonging to 47 families and nine orders (Lepidoptera, Coleoptera, Hemiptera, Orthoptera, Hymenoptera, Odonata, Diptera, Dictyoptera, and Phasmida), identified from 2007 specimens. These were classified into five functional trophic groups: phytophagous, predators, omnivores, saprophages and decomposers. The diversity indexes showed significance- Diversity (H′=1.778), Evenness (E=0.9689), and Margalef's Index (d=1.924). Diversity indices of insect orders showed Lepidoptera to be the most diverse (H′=1.994) with maximum species richness having high Margalef's index (d=2.607), and dipterans with highest evenness (E=0.9572). A total of 1331 individuals of insect pollinators/ visitors were observed, belonging to 99 species of 5 orders (Lepidoptera, Hymenoptera, Coleoptera, Hemiptera, and Diptera).

Key words: Insects, diversity, relative abundance, trophic guilds, diversity indexes, species richness, pollinators/ visitors, agroecosystem, Bhabar region, insect pollinators

Insects are the most dominating, diverse and comprise >75% of the known species of the animals (Westfall and Tennessen, 1996). The diversity of insect species is a function of the environmental condition (Yi et al., 2012). They inhabit all habitat types and play major roles in the function and stability of terrestrial and aquatic ecosystems (Godfray, 2002). Insects are important because of diversity, ecological role, and their influence on agriculture (Adetundan et al., 2005; Premalatha et al., 2011). Though the diversity of insect fauna associated in agroecosystems is well documented (Mokam et al., 2014; Banu et al., 2016; Atencio et al., 2018; Sayuthi et al., 2018; Emmanuel and Anuluwa, 2019), it is still difficult to study the interactions within the ecosystem. In addition, the effects of farming practices for better yield causes phytotoxicity and decline of favourable organisms such as predators, parasitoids, microorganisms and pollinators, particularly indiscriminate use of fertilizers and chemical insecticides (Luckman and Metcalf, 1978; Tilman et al., 2006). The insect fauna associated with agroecosystems include pests, predators, parasitoids, pollinators and non-economic importance species (Mitra et al., 2014; Mokam et al., 2014; Atencio et al., 2018; Ghani et al., 2019; Subedi and Subedi, 2019). Pollination is an essential process in maintaining a healthy and diverse ecosystem, and include a wide variety of organisms like birds, bats, other mammals and insects (Willmer et al., 1994). Various insect groups which are of prime significance in pollination of crops mainly of the orders Hymenoptera, Diptera, Coleoptera, Lepidoptera, Thysanoptera, Hemiptera and Neuroptera (Free, 1993; Kearns et al., 1998; Mitra et al., 2008; 2014). This study documents diversity and abundance of insects, trophic guilds, diversity indexes, and diversity of insect pollinators/ visitors in an agroecosystem of Bhabar region at village Chhoi near Ramnagar in district Nainital, Uttarakhand from March 2018 to February, 2020.

MATERIALS AND METHODS

Geographically, the village Chhoi is located in the subtropical zone (29°22′15.50″N, 79°08′ 47.20″ E, 348 masl) in the Bhabar region of Uttarakhand, situated in the foothills of central Himalaya. Three crops are grown in a year: July to October (paddy/ soybean), November to April (wheat/mustard) and seasonal vegetables (May-June), with shallow soil (5 cm). Sampling of insects was done at an interval of 30 days from March, 2018 to February, 2020, using "sweep sampling method", following Gadagkar et al. (1990) and hand picking (Jonathan, 1990). The net sweeps were made with nets made of thick cotton cloth (30 cm dia, with bag length of 60 cm). A randomly selected areas of each study sites was divided into a quadrate of 10x 10 m. Hand picking method was used for larger, ground living insects and insects living under the stones. Collected insects were identified with keys and available literature, after separated into orders and families, with voucher

specimens preserved in the laboratory. The species which could not be identified were got identified from the Forest Research Institute, Dehradun. The trophic level in a food chain was assigned to these as phytophagous, predators, omnivores, saprophages and decomposers. Shannon's diversity index or Shannon-Wiener diversity (1963), evenness (Hill, 1973), and Margalef's species richness index (Margalef's, 1970) were calculated. Diversity and abundance of insect pollinators and their foraging activities were observed in the field from 08.00-17.00 hrs. The foraging behaviour of insect pollinators visiting flowering plants was also recorded.

RESULTS AND DISCUSSION

Table 1 shows the diversity and abundance of insects collected amounting to 2007 individuals belonging to 148 species, 47 families and 9 orders. Maximum number of species belonged to the order Lepidoptera (68) followed by Coleoptera (20), Hemiptera (18), Orthoptera (16), Hymenoptera (13), Odonata (13), Diptera (10), Dictyoptera (3), and Phasmida (1). Lepidoptera, Coleoptera, Hemiptera, Orthoptera, Hymenoptera, Odonata and Diptera, because of their high abundance and species richness, were the major constituents, while Dictyoptera and Phasmida were the minor ones. Species richness was higher in summer (81 species) and rainy season (82 species) than in winter (13 species). Species richness was significantly correlated with maximum temperature ($r=0.886$; $P<0.01$, $df=12$), minimum temperature ($r=0.853$; $P\leq0.01$, $df=12$), and with rainfall ($r=0.444$; $P<<0.05$, $df=12$). Maximum number of individuals belonged to the order Lepidoptera (838) followed by Hymenoptera (232), Coleoptera (215), Odonata (198), Orthoptera (187), Hemiptera (181), Diptera (139), Dictyoptera (16), and Phasmida (1). Higher number of insects were recorded during summer and rainy seasons and lower in winter season. Abundance of insects was significantly correlated with maximum temperature ($r=0.908$; $P\leq0.01$, $df=12$), minimum temperature ($r=0.851$; $P\leq0.01$, $df=12$), and rainfall ($r=0.338$; $P<<0.05$, $df=12$). In the present study, low and higher temperature and rainfall influenced the species richness and abundance of insects and are in accordance with the findings of Regniere et al. (2012), Abbas et al. (2014) and Garia et al. (2016, 2017).

Five trophic groups were identified: Phytophagous, predators, omnivores, saprophages and decomposers; of these phytophagous insects were numerically predominant (68% of all species and 72% of all individuals) followed by predators (22% of all species and 22% of all individuals), omnivores (6% of all species and 2% of all individuals), saprophages (3% of all species and 3% of all individuals), and decomposers (1% of all species and 1% of all individuals) recorded (Fig. 1). A total of 34 species of bioregulators (predators) were collected in the present study. Many ecologists have grouped insects into various functional trophic guilds to study the ecological interactions between insects, their hosts, their enemies and climate (Speight et al., 2008). Based on their feeding activities observed, Mokam et al. (2014) recognized three guilds, phytophagous (carpophagous and sap suckers), saprophagous, and carnivores (predators and parasitoids in insects collected from two agroecological zones, Cameroon). Globally, phytophagous insects have been reported to be predominant, representing upto 96.1% of individuals collected in different ecosystems (Gadakar et al., 1990; Dev et al., 2009; Chouangthavy et al., 2017; Atencio et al., 2018; Ghani and Maalik, 2019). Our results obtained in the present study show that phytophagous insects were dominant both in terms of species richnesss and abundance, and are very similar to those reported in different ecosystems.

The Shannon-Wiener Diversity Index (H′), Evenness (E), and Margalef's species richness Index (d) of insect fauna collected were computed and are presented in Table 2 and 3. Maximum Species Diversity Index (H') was 1.778, Evenness (E') was 0.9689, and Margalef's Species Richness Index (d) was 1.924. Table 3 shows the pooled relative abundance based on orders and their diversity indices. It is evident that Lepidopteran insects have the highest diversity index (H′=1.994), and species richness index (d=2.607), and Dipterans have highest Evenness (E=0.9449; highest value is 1). Insect diversity in conventional agroecosystems is usually low because farmers use a monoculture system, the use of artificial fertilizers and pesticides, and also the vegetation structure. As a result of these treatments, non-target insects including natural enemies die (Altieri and Letournean, 1982). However, maximum index recorded for terrestrial ecosystems is in the range of 5 and such high values have been reported from rainforests .

A total of 1331 individuals of insect pollinators belonging to 99 species, 5 orders, and 22 families were recorded (Table 1). Five insect orders found were Lepidoptera (Pieridae, Nymphalidae, Lycanidae, Papilionidae, Hesperiidae, Erabidae, Noctuidae, Zygaenidae, Sphingidae, Crambidae and

Table 1. Diversity of insect species and trophic components- Chhoi, Uttarakhand (March, 2018-February, 2020

S. No.	Taxonomic composition	Trophic level	2018-2019 Relative abundance (%)	2019-2020 Relative abundance (%)
	LEPIDOPTERA			
	Family: Pieridae			
1.	*Pieris brassicae* (L.)	P	2.32	2.18
2.	*Pieris canidia indica* (Spr.)	P	1.16	1.31
3.	*Pontia daplidice* (L.)	P	1.39	0.70
4.	*Eurema brigitta (*Cr.)	P	2.09	2.01
5.	*Leptosia nina* (F.)	P	0.58	0.87
6.	*Gonepteryx* sp.	P	0.58	0.17
7.	*Aporia agathon* (Gray)	P	0.93	0.87
8.	*Pareronia valeria* Cr.	P	1.16	1.31
9.	*Colias fieldi* Men.	P	0.93	0.87
10.	*Catopsilia pyranthe* (L.)	P	2.44	1.31
11.	*Catopsilia pomona* F.	P	1.74	0.70
12.	*Belenois aurota* F.	P	0.81	1.22
13.	*Cepora nerissa phryne* F.	P	0.93	1.05
	Unidentified sp.	P	0.93	0.96
	Family: Nymphalidae			
14.	*Kallima inachus* (Bois.)	P	0	0.17
15.	*Vanessa indica* Herb.	P	0.58	0.70
16.	*Symbrenthia* sp.	P	0.93	0.87
17.	*Aglais caschmiriensis* (Kollar)	P	1.16	1.31
18.	*Cynthia cardui* L.	P	0.58	0.52
19.	*Precis iphita* (Cr.)	P	0.70	0.70
20.	*Sephisa dichroa* (Kollar)	P	0.70	0.70
21.	*Precis lemonias lemonias* L.	P	2.67	2.62
22.	*Precis almana* (L.)	P	0.93	1.05
23.	*Precis orithya* (L.)	P	0.23	0.44
24.	*Neptis sankara* Kollar	P	0.58	0.70
25.	*Euthalia patala* Kollar	P	0.58	0.00
26.	*Symphaedra nais* (Forster)	P	0.23	0.35
27.	*Hypolimnas bolina* L.	P	0.12	0.17
28.	*Phalanta phalantha* (Drury)	P	0.70	0.44
29.	*Ariadne merione* (Cr.)	P	0.23	0.17
30.	*Ypthima* sp.	P	0.93	0.44
31.	*Danaus chryssippus* (L.)	P	0.93	1.40
32.	*Euploea core* (Cr.)	P	0.23	0.09
	Family: Lycaenidae			
33.	*Heliophorus* sp.	P	0.23	0
34.	*Heliophorus sena* Kollar	P	0.58	0
35.	*Talicada nyseus* (Guerin-Meneville)	P	0.58	0.87
36.	*Leptotes plinius* (F.)	P	0.23	0.44
37.	*Neopithecops zalmora* Butler	P	0.23	0.35
38.	*Zemeros flegyas* Cr.	P	0.23	0.35
39.	*Zizeeria* sp.	P	2.32	2.18
40.	*Catochrysops strabo* F.	P	0.23	0.44
41.	*Arhopala amantes* Hewitson	P	0.23	0.26
42.	*Acytolepis* sp.	P	0	0.17
	Unidentified sp.	P	0.23	0.35
	Family: Papilionidae			
43.	*Atrophaneura aristolochioae* F.	P	0.93	0.35

(contd.)

Table 1 (contd.)

44.	*Papilio polytes* L.	P	1.04	0.87
45.	*Graphium* sp.	P	0	0.09
46.	*Papilio demoleus* L.	P	0.46	0.44
47.	*Papilio clytia clytia* L..	P	0	0.09
	Unidentified sp.	P	2.2	1.48
	Family: Hesperiidae			
48.	*Telicota* sp.	P	0.12	0.09
49.	*Parnara guttata* Bremer & Grey	P	0.58	0.35
50.	*Polytremis eltola* Hewitson	P	0.12	0.09
	Family: Erabidae			
51.	*Amata* sp.	P	0.46	0.17
52.	*Eressa confinis* (Walker)	P	0	0.09
53.	*Erebus* sp.	P	0	0.09
54.	*Lithosiini* sp.	P	0	0.17
55.	*Cyana coccinea* Moore	P	0	0.70
56.	*Ceryx imaon* Cr.	P	0.58	0.52
	Family: Noctuidae			
57.	*Calyptra ophideroides* Guen.	P	0.58	0.00
58.	*Episteme adulatrix* Kollar	P	0	0.17
	Family: Eupterotidae			
59.	*Eupterote* sp.	P	0.12	0
	Family: Zygaenidae			
60.	*Campylotes histrionicus* Westwood	P	0.46	0.17
	Family: Sphingidae			
61.	*Daphnis nerii* (L.)	P	0.12	0.17
	Family: Crambidae			
	Unidentified sp.	P	0	0.17
	Family: Geometridae			
62.	*Anonychia grisea* Warren	P	0	0.09
	COLEOPTERA			
	Family: Scarabaeidae			
63.	*Metopodontus biplagiatus* Westwood	P	0	0.09
64.	*Gymnopleurus ruficornis* Mot.	D	0.58	0.70
65.	*Phyllophaga* sp.	P	0.23	0.44
66.	*Popillia japonica* Newman	P	0.12	0.17
67.	*Pseudolucanus cantor* Hope	P	0.70	0.61
68.	*Onthophagus* sp.	D	0.23	0.44
69.	*Rhomborrhina* sp.	Pre	0.12	0.00
	Family: Chrysomelidae			0.00
70.	*Sagra femorata* (Drury)	Pre	0.23	0.09
71.	*Aulacophora* sp.	P	0.70	0.70
72.	*Mimastra* sp.	P	0.23	0.09
73.	*Raphidopalpa foveicollis* (Lucas)	P	0.58	0.26
	Family: Coccinelidae			
74.	*Coccinella septempunctata* (L.)	Pre	2.90	4.37
75.	*Coccinella* sp.	Pre	1.39	1.75
76.	*Cheilomenes sexmaculata* (F.)	Pre	0	0.70
77.	*Oenopia kirbyi* (Mulsant)	Pre	0	0.44
78.	*Harmonia dimidiata* (F.)	Pre	0.23	1.05
	Family: Cerambycidae			
79.	*Synaphaeta* sp.	P	0	0.09
	Unidentified sp.	P	0	0.09
	Family: Meloidae			
80.	*Mylabris variabilis* (Pallas)	Pre	0.23	0.17
	Family: Tenebrionidae			
81.	*Mesomorphus* sp.	O	0	0.17

(contd.)

Table 1 (contd.)

	ORDER: HYMENOPTERA			
	Family: Apidae			
82.	*Apis cerana* F.	P	5.80	5.24
83.	*Apis dorsata* F	P	2.32	3.06
84.	*Bombus* spp.	P	0.70	0.61
	Family: Formicidae			
85.	*Lasius niger* (L.)	P	1.28	1.75
	Family: Sphecidae			
86.	*Sceliphron caucasicum* Dalla Torre	Pre	0.23	0
87.	*Sceliphron coromandelicum* Lepeletier	Pre	0.23	0
	Unidentified sp.	P	0.12	0
	Family: Vespidae			
88.	*Vespa* sp.	Pre	0.58	0.17
89.	*Vespa cincta* F.	Pre	0.23	0.17
90.	*Polistes* spp.	Pre	0.12	0.09
91.	*Delta dimidiatipenne* Saussure	P	0.12	0
92.	*Vespa basalis* Smith	O	0	0.09
	Family: Xylocopidae			
93.	*Xylocopa auripennis* Lepeletier	P	0.12	0.17
	ORTHOPTERA			
	Family: Acrididae			
94.	*Acridium melanocorne* L.	P	1.16	0.44
95.	*Paraconophyma scabra* (Walker)	P	2.55	1.40
96.	*Patanga japonica* Bolivar	P	0.93	0.87
97.	*Spathosternum p. prasiniferum* Walker	P	1.16	0.79
98.	*Ceracris fasciata* Brunner von Wattenwyl	P	2.09	1.75
99.	*Cyrtacanthacris tatarica* (L.)	P	0.58	0.61
100.	*Xenocatantops* sp.	P	0	0.09
101.	*Oedipoda* sp.	O	0.23	0.44
	Family: Gryllidae			
102.	*Gryllus* sp.	O	0.12	0.17
103.	*Teleogryllus testaceus* Walker	O	0.12	0.09
104.	*Gryllotalpa* sp.	O	0	0.17
	Family: Tettigonidae			
105.	*Letana linearis* Walker	O	0	0.09
106.	*Caedicia simplex* (Walker)	P	0.46	0.44
107.	*Elimaea* sp.	P	0.23	0.44
108.	*Neoconocephalus* sp.	P	0.23	0.17
	Unidentified sp.	O	0.58	0.52
	ODONATA			
	Family: Libellulidae			
109.	*Neurothemis* sp.	Pre	1.28	0.70
110.	*Orthetrum chrysis* (Burmeister)	Pre	1.80	1.05
111.	*Orthemis ferruginea* (F.)	Pre	1.39	0.79
112.	*Aethriamanta brevipennis* (Rambur)	Pre	0.58	0.87
113.	*Crocothemis servilia* (Drury)	Pre	0.93	0.87
114.	*Orthetrum pruinosum* (Burmeister)	Pre	1.16	0.70
115.	*Orthetrum taeniolatum* Schneider	Pre	1.28	0.70
116	*Libellula* sp.	Pre	0	0.09
	Family: Calopterygidae			
	Unidentified sp.	Pre	2.44	1.05
	Family: Chlorocyphidae			
117.	*Aristocypha fenestrella* Rambur	Pre	0.70	0.44
	Gomphidea			
118.	*Paragomphus lieantus* (Selys)	Pre	0.58	0.70

(contd.)

Table 1 (contd.)

	Family: Lestidae			
119.	*Lestes* sp.	Pre	0	0.17
	DIPTERA			
	Family: Muscidae			
120.	*Musca* sp.	S	1.28	2.18
	Family: Calliphoridae			
121.	*Lucilia* sp.	S	0	0.44
122.	*Calliphora* sp.	S	0.58	0.70
	Family: Sarcophagidae			
123.	*Sarcophaga* sp.	S	0	0.09
	Family: Asilidae			
124.	*Philodious javanus* Wied.	Pre	0.58	0.52
125.	*Stenopogan oldroydi* Josephs & Pauri	Pre	0.81	0.70
	Family: Tipulidae			
126.	*Tipula himalayensis* Brunetti	O	0.58	0.52
127.	*Tipula* sp.	O	0.70	0.70
	Family: Syrphidae			
128.	*Eristalis* sp.	Pre	0.70	1.05
129.	*Eristalis tenax* (L.)	Pre	0.58	0.87
	HEMIPTERA			
	Family: Reduviidae			
	Unidentified sp.	Pre	0.12	0.175
	Family: Fulgoridae			
130.	*Lycorma delicatula* (White)	P	0.23	0
	Family: Coreidae			0
131.	*Cletus punctiger* (Dallas)	P	0.58	0.52
	Unidentified sp.	P	0.23	0.44
	Family: Pentatomidae			
132.	*Nezara viridula* L.	P	0.58	0.87
133.	*Chinavia* sp.	P	0	0.17
134.	*Murgantia histrionic* Hahn	P	0.58	0.61
135.	*Dalpada* sp.	P	0.12	0.44
136.	*Lonicera* sp.	P	0	0.09
137.	*Halyomorpha halys* (Stal)	P	0	0.44
138.	*Bagrada hilaris* (Burmeister)	P	0	0.17
139.	*Eurydema pulchrum* (Westwood)	P	0	0.87
	Family: Alydidae			
140.	*Leptocorisa varicornis* F.	P	1.28	1.75
141.	*Leptocorisa* sp.	P	1.16	1.31
	Family: Largidae			
142.	*Physopelta gutta* (Brumeister)	P	0.93	1.05
143.	*Physopelta schlanbuschi* (F.)	P	0.58	0.87
	Family: Pyrrhocoridae			
144.	*Dysdercus cingulatus* (F.)	P	0.58	0.70
	Family: Cicadaidae			
145.	*Neotibicen pruinosus* (Say)	P	0	0.09
	DICTYOPTERA			
	Family: Mantidae			
146.	*Mantis* sp.	Pre	0.23	0.44
147.	*Acontista* sp.	Pre	0	0.17
	Family: Hymenopodidae			
148.	*Ephestiaslu intermedia* Werner	Pre	0.23	0.44
	ORDER: PHASMIDA			
	Unidentified sp.	Pre	0	0.09

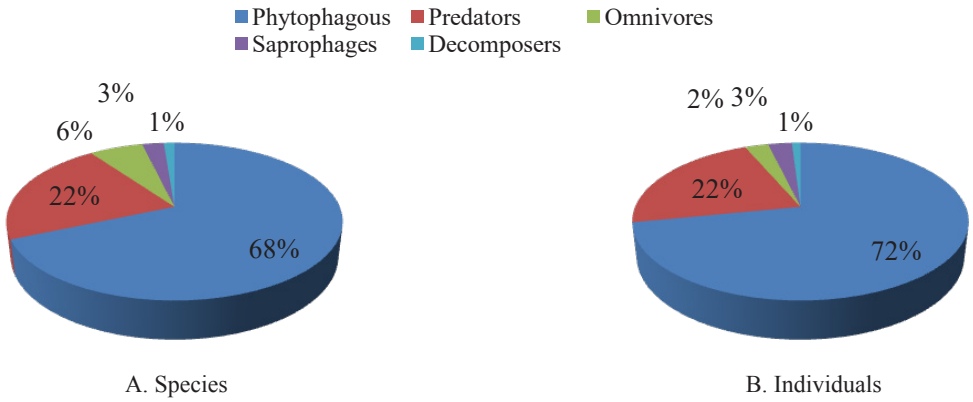
P- Phytophagous, Pre- Predators, O- Omnivores, S- Saprophages, D- Decomposers

Table 2. Species diversity and species richness of insect fauna- Chhoi, Uttarakhand (March, 2018-February, 2020)

Months	2018-2019			2019-2020			2018-2020		
	Shannon index (H')	Evenness (E')	Margalef (d)	Shannon index (H')	Evenness (E')	Margalef (d)	Shannon index (H')	Evenness (E')	Margalef (d)
March	1.478	0.5482	1.924	1.594	0.6152	1.789	1.549	0.5881	1.683
April	1.61	0.6252	1.818	1.778	0.7398	1.683	1.654	0.6537	1.597
May	1.581	0.6941	1.55	1.537	0.6643	1.465	1.523	0.655	1.398
June	1.642	0.6457	1.739	1.693	0.6037	1.847	1.65	0.5784	1.82
July	1.45	0.609	1.471	1.456	0.6126	1.385	1.318	0.5337	1.362
August	1.48	0.6276	1.504	1.548	0.6719	1.412	1.439	0.6026	1.385
September	1.39	0.5733	1.674	1.368	0.5612	1.586	1.302	0.5255	1.46
October	1.417	0.5894	1.731	1.542	0.6679	1.484	1.518	0.6519	1.403
November	0.4506	0.7846	0.5581	0.5004	0.8247	0.4343	0.5402	0.8582	0.3899
December	0	0	0	0	1	0	0	1	0
January	0	0	0	0.6616	0.9689	0.4809	0.6555	0.963	0.417
February	0	1	0	0	1	0	0	1	0

Table 3. Relative abundance, species diversity and species richness of insect orders- Chhoi, Uttarakhand (March, 2018-February, 2020)

Order	Relative abundance (%)	Shannon Index (H')	Evenness (E')	Margalef (d)
Lepidoptera	41.98	1.994	0.6121	2.607
Coleoptera	12.35	1.566	0.7977	1.669
Hemiptera	11.11	1.826	0.7758	2.422
Orthoptera	9.88	1.024	0.928	0.7213
Hymenoptera	8.02	1.439	0.8432	1.559
Odonata	8.02	1.179	0.65	1.559
Diptera	6.17	1.748	0.9572	2.171
Dictyoptera	1.85	0.6365	0.9449	0.9102
Phasmatodea	0.62	0	1	0
Total	100.0			



A. Species B. Individuals

Fig. 1. The guild structure of insect fauna

Geometridae). Hymenoptera (Apidae, Formicidae, Vespidae, Xylocopidae), Coleoptera (Chrysomelidae, Coccinellidae, Meloidae), Hemiptera (Fulgoridae, Coreidae and Meloidae), Diptera (Syrphidae). Lepidoptera with 832 individuals (62.5%) was the most abundant followed by Hymenoptera with 227 individuals (17.1%). Family Pieridae (25.0%) was the most abundant of all families. Insect pollinators of all five orders were found active throughout the day, but peak foraging activity was different. Lepidopterans were only nectar foragers and active during afternoon but less active in the morning. All hymenopterans were both pollen and nectar forager, and active during day time. Foraging activities of coleopterans and hemipterans remained relatively constant throughout the day. Insect pollinators are of prime significance in pollination of different agricultural, medicinal herbal and horticultural crops mainly belong to insect orders: Hymenoptera, Lepidoptera, Coleoptera, Diptera, Thysanoptera, Hemiptera and Neuroptera (Sihag, 1988; Free, 1993; Mitra et al., 2008; Bhowmik et al., 2014; Subedi and Subedi, 2019; Singh and Mall, 2020). Thus, the present study concludes from 2007 individuals that these belong to 148 species, 47 families and 9 orders. Phytophagous were the most dominant trophic group. Significant diversity (H′=1.778) and evenness (E=0.9689) were observed; and Margalef's Index was 1.924). Pollinators belonged to the orders Lepidoptera, Coleoptera, Hymenoptera, Diptera and Hemiptera.

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NATURAL ENEMIES OF *PENTALONIA NIGRONERVOSA* COQUEREL, A VECTOR OF BUNCHY TOP OF BANANA AND BIOLOGY OF ITS MOST EFFECTIVE PREDATOR *SCYMNUS NUBILUS* MULSANT

J Poorani*, A Mohanasundaram and R Thanigairaj

ICAR-National Research Centre for Banana, Thogamalai Road,
Thayanur Post, Tiruchirappalli 620102, Tamil Nadu, India.
*Email: pooranij@gmail.com (corresponding author)

ABSTRACT

Natural enemies of *Pentalonia nigronervosa* Coquerel (Hemiptera: Aphididae), a vector of bunchy top of banana, are reported from Tamil Nadu, South India. Totally four predators including three coccinellids (*Pseudaspidimerus trinotatus* (Thunberg), *Scymnus* (*Scymnus*) *nubilus* Mulsant, *Cheilomenes sexmaculata* (F.)) and one hemerobiid (*Micromus timidus* Hagen) were recorded. Only one parasitoid, *Aphelinus* sp. nr. *gossypii* Timberlake (Hymenoptera: Aphelinidae) was recorded. Biology of *S. nubilus*, the most effective predator of *P. nigronervosa,* was also studied in the laboratory and the results are presented.

Key words: Banana, aphid, bunchy top, population dynamics, predators, parasitoid, India, predatory potential, biology, *Scymnus nubilus*

Banana production in the tropical countries including India is greatly hampered by the bunchy top disease caused by the *Banana bunchy top virus* (BBTV) and it is considered as the most devastating virus disease affecting bananas and plantains (Vézina et al., 2020). The disease is transmitted primarily by infected planting material and secondarily by the banana black aphid (*Pentalonia nigronervosa* Coquerel), its only known vector, in a persistent circulative manner. The aphid also transmits the banana bract mosaic virus in a non-persistent manner (Selvarajan, 2015). The aphid is usually controlled by the application of recommended systemic insecticides, but the aphids tend to remain hidden under leaf sheaths on banana plants and this may limit the efficacy of insecticide applications on aphid populations (Robson et al., 2006). Despite the presence of many bioagents in the banana ecosystem, systematic attempts have not been made to document and utilize them in aphid management. In this study, the natural enemies of banana aphid in Tamil Nadu, South India, were documented. The biology of *Scymnus nubilus* Mulsant (Coleoptera: Coccinellidae), known to be an efficient predator of banana aphid (Johnson 1972; 1983) was also studied in the laboratory and the details are presented.

MATERIALS AND METHODS

Seasonal incidence of banana aphid and its natural enemies was monitored in the field banana germplasm bank maintained in the research farm of the National Research Centre for Banana (NRCB), Trichy, Tamil Nadu, during 2018-21. Natural enemies collected in the field were identified and the voucher specimens are maintained in the banana insect collection at the NRCB. Immature stages and adults of the bioagents were observed and photographed under a Leica M205A stereo microscope fitted with a DMC 4500 digital camera. The biology of *S. nubilus,* the most common predator, was studied on banana aphid maintained on excised banana leaf bits with intact midribs. Five mating pairs of beetles were allowed to oviposit on banana leaves colonised by the aphid. Freshly hatched, first instar larvae were transferred to banana leaf bits in petri dishes covered with a muslin cloth and secured with a rubber band and reared individually. Leaf bits with aphids were provided every day to each larva and the feeding rate/ day was recorded. Total number of aphids fed by each larva and per day feeding were worked out from the mean consumption of larvae that reached the pupal stage. Observations on the number of eggs laid/ day, total fecundity and adult longevity were also recorded.

RESULTS AND DISCUSSION

In this study, aphid activity on banana was almost absent during summer (May- October). The aphid was active during the cooler months and the incidence was maximum during November–February on all the germplasm accessions maintained at NRCB, Trichy. Aphid incidence started building up from November and the peak was observed during winter (January-February) and thereafter steadily declined. Incidence was observed on 369 germplasm accessions belonging

to various genome types of banana (30 AA, 33 AAA, 113 AAB, 26 AB, 119 ABB, 10 ABBB, 36 BB and 2 *Musa ornata* / *Rhodochlamys*). Only one accession (Bathesa Ash – ABB genome type) was found to be free from aphids. It is interesting to note that certain banana genome types appear to be resistant to bunchy top disease transmitted by *P. nigronervosa* though the aphid seems to be present across banana genotypes.

In field conditions, five predators (one hemerobiid and four coccinellids) and one aphelinid parasitoid were recorded as natural enemies of *P. nigronervosa* in Tamil Nadu. Totally four predators were found to feed on banana aphid in the field conditions (Fig. 1). Immature stages and adults of three coccinellids, *Cheilomenes sexmaculata* (F.) (Fig. 1a, e), *Pseudaspidimerus trinotatus* (Thunberg) (Fig. 1c, g), and *Scymnus* (*Scymnus*) *nubilus* Mulsant (Fig. 1d, h) (Coleoptera: Coccinellidae) and one brown lacewing, *Micromus timidus* Hagen (Fig. 1b, f) (Neuroptera: Hemerobiidae) were found to be active predators. Of these, *P. trinotatus, S. nubilus,* and *C. sexmaculatus* have been recorded as predators of banana aphid from Kerala by other workers (Johnson, 1972, 1983; Padmalatha and Singh, 1998). Padmalatha and Singh (1998) recorded seven species of coccinellids in banana aphid colonies from Kerala, which included *C. sexmaculata, P. trinotatus, Scymnus quadrillum, S. pyrocheilus, Adalia bipunctata, Coccinella septempunctata* and *Nephus luteus*.

Of these, *A. bipunctata* and *N. luteus* are certainly based on wrong identifications. There is no record of hemerobiids feeding on banana aphid in India until now and the association of *M. timidus* with *P. nigronervosa* appears to be new for this region. In Hawaii, *M. timidus* has been used for controlling aphids, including banana aphid (under the name *Nesomicromus navigatorum* (Brauer)) (Tinzaara and Gold, 2008). Only one parasitoid, *Aphelinus* nr. *gossypii* Timberlake (Hymenoptera: Aphelinidae) (Fig. 2c) was recorded on *P. nigronervosa* in Tamil Nadu. The parasitoid was found to parasitize older nymphs (3-4 instar stage) (Fig. 2a, b). Few parasitoids of banana aphid are known from India and elsewhere. Stary and Stechmann (1990) successfully propagated *Ephedrus cerasicola* Starý (Hymenoptera: Braconidae: Aphidiinae) on *P. nigronervosa* in a glasshouse and found it to be a promising agent in the biocontrol of *P. nigronervosa* in Pacific islands (Tonga). Muratori et al. (2009) described a new species of cecidomyiid parasitoid, *Endaphis fugitiva* Gagné and Muratori, on banana aphid and described its life history.

The biology of *S. nubilus* was studied on banana aphid in the laboratory at 25–30°C and 75–85% RH. The eggs (Fig. 3a) are oval, pale pink to yellowish-orange and the chorion has a conspicuous reticulate pattern. The larva (Fig. 3b, c) is pale yellow and covered with characteristic white waxy strands. The pupa (Fig. 3d)

Fig. 1. Predators of *P. nigronervosa*: a, e. *Cheilomenes sexmaculata*: b, f. *Micromus timidus*, c, g. *Pseudaspidimerus trinotatus*; d, h. *Scymnus nubilus*

Fig. 2. a, b. Parasitized banana aphids; c. Adult female of *Aphelinus* sp. nr. *gossypii*

Fig. 3. Life stages of *Scymnus nubilus*: a. Eggs; b, c. Larva; d. Pupa; e, f. Adult

is yellow and covered with white waxy filaments. The adult (Fig. 3e, f) is reddish or yellowish brown with a median black marking on pronotum and a black sutural stripe of variable width starting from basal margin and gradually narrowed towards apex and occasionally the lateral borders are narrowly dark brown to black at middle. Egg laying started a week after adult emergence. Eggs were laid either singly or in small groups on the leaf substrate on which the aphid colony was found or glued to the moulted skins of the aphids. The number of eggs laid / day / female was 3–36 (mean 9.86 eggs/ day). Egg laying started from the sixth day after adult emergence and continued for up to 46 days. *Scymnus nubilus* passed through four larval instars and the total development from egg to adult emergence took 15–19 days. The egg, larval, prepupal and pupal period lasted 4.5± 0.53, 7.88± 0.88, 1.50± 0.46 and 3.0± 0.76 days, respectively (Table 1). The number of aphids consumed/ day by the larvae of *S. nubilus* gradually increased with age and the daily consumption rate was 2–4 aphids in the first instar, 3–5 in the second instar, 4–9 in the third instar and 2–20 in the fourth instar. Total prey consumption during the entire larval period was 36.0–65.0 nymphs. Adult longevity was greater in females (62.13± 5.22 days) than males (18.86± 6.74 days) and the longest-lived adult female consumed 534 aphids in its lifetime of 71 days and the per day prey consumption by an adult beetle ranged from 7.15 to 11.53 (mean 8.42± 1.35).

Johnson (1972) studied the biology of *S. nubilus* on *P. nigronervosa* in Kerala conditions. He stated that

Table 1. Biology and prey consumption of *S. nubilus* reared on *P. nigronervosa* in the laboratory

Parameter	Duration (days)	Mean± SD	Prey consumption/ day	Mean ± SD
Egg period	4–5	4.5± 0.53	--	--
Larval period				
I instar	1.0–1.5	1.13± 0.23	2.0–4.0	2.88± 0.83
II instar	1.0–1.5	1.19± 0.26	3.0–5.0	4.63± 1.41
III instar	1.0–1.5	1.31± 0.26	4.0–9.0	7.88± 2.10
IV instar	4.0–5.0	4.25± 0.46	2.0–20.0	32.63± 7.37
Total larval period	7.0–8.0	7.88± 0.88	36.0–65.0	48.0± 10.31
Prepupal period	1.0–2.0	1.50± 0.46	--	--
Pupal period	3.0–4.0	3.0± 0.76	--	--
Adult longevity				
Female	58.0–71.0	62.13± 5.22	7.15–11.53	8.42± 1.35
Male	12.0–30.0	18.86± 6.74		
Total fecundity	298–454	393.38± 48.76	--	--

eggs were laid singly during an oviposition period of more than a month. Our observations indicate eggs are laid either singly or in groups, but the durations of life stages are within the range recorded by Johnson (1972). However, development of *S. nubilus* took longer when reared on pink mealybug (*Maconellicoccus hirsutus* (Green)), with the egg, larval, prepupal and pupal stages lasting 5.5, 10.45, 1.7 and 7.71 days, respectively, and the fecundity / day was 13.7 and the adult longevity was 49.9 days (male) and 57.23 days (female) (Santhakumar and Chakraborty, 1997). Aphids appear to be the more favourable host insects because the adult females lived longer (62.13±5.22) with high fecundity on *P. nigronervosa*. Rosagro et al. (2020) found *S. nubilus* was a promising bioagent for managing *Aphis spiraecola* Patch and *Cinara juniperi* (De Geer) (Hemiptera: Aphididae) infesting Azorean endemic plants reared in forestry nurseries. Calilung (2008) recorded four species of coccinellids feeding on *P. nigronervosa* on banana and abaca, none of which are found in India and studied their life history. *Scymnus nubilus* is one of the most common species of coccinellids in India and has a wide distribution in the Oriental and Palaearctic regions. Its high fecundity, adult longevity and feeding potential are ideal for its utilization for augmentative biological control, for which protocols for mass production need to be standardized.

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EFFECT OF SILICON AMENDMENT ON HERBIVORE INDUCED PLANT VOLATILES OF RICE PLANT INFESTED BY BROWN PLANTHOPPER *NILAPARVATA LUGENS* (STÅL)

Prabhulinga Tenguri[+], Subhash Chander[1*], Suresh Nebapure, Arya P S, Madhu T N[2+] and Yogesh Yele

Division of Entomology, ICAR-Indian Agricultural Research Institute (IARI);
[1]ICAR-National Research Centre for Integrated Pest Management (NCIPM), New Delhi 110012, India
[2]Department of Entomology, University of Agricultural Sciences (UAS), GKVK,
Bengaluru 560065, Karnataka, India
[+]Current Address: ICAR-Central Institute of Cotton Research, Nagpur 440010, Maharashtra, India
*Email: schanderthakur@gmail.com (corresponding author)

ABSTRACT

Silicon (Si) is known to play a very important role in a plant's direct and indirect defense. In rice plants, its impact on induced volatiles released upon brown planthopper (BPH) *Nilaparvata lugens* feeding is less understood. The BPH-induced volatile compounds from Si amended rice plants were analyzed using Gas Chromatography-Mass Spectrometry (GC-MS). The alteration in Herbivore Induced Plant Volatiles (HIPV's) blend was observed, wherein, total 38 HIPVs were found to be differentially released. The HIPV mainly belongs to alkane, alkene, alcohol and terpene groups. Overall, Si amendment caused a significant effect on the composition of HIPVs in rice, some of which are involved in tritrophic interaction.

Key words: GCMS, herbivore, induced plant defense, Pusa Basmati 1121, rice, semiochemical, silicon, TN1, tritrophic interaction, volatile organic compounds

Rice *Oryza sativa* L. is one of the important cereal crops, and its production is affected by biotic and abiotic stresses. Among these, insect pests are the major ones, and around 52% of the production is lost annually because of the biotic factors, of which insects pests contribute nearly 21% (Khush, 1979; Sogawa et al., 2003). Brown planthopper (BPH) *Nilaparvata lugens* (Stål) (Homoptera: Delphacidae) is the important insect pests of rice, which damages the crop directly by its typical phloem sap-feeding and indirectly by transmitting virus diseases such as rice grassy stunt and ragged stunt (Cabauatan et al., 2009). In recent years in Asia, the rice production has been threatened by the BPH infestation (Brar et al., 2009; Prasannakumar et al., 2013; Prahalada et al., 2017). The management of this pest has relied upon insecticides; however, their indiscriminate use disrupts the natural balance of rice ecosystem (Sarao and Mangat, 2014; Prahalada et al., 2017). In order to minimize the negative effects of insecticides, use of safe alternatives is required. Silicon (Si) application is one such safe alternative, and Si is a quasi-essential nutrient. The evidence from recent investigation reveals its roles in plant defense against biotic and abiotic stress (Epstein,1994; Luyckx et al., 2017; Cooke and Leishman, 2016) including against insect herbivores and pathogens in agriculture (Ye et al., 2013; Wang et al., 2017). Si application enhances the plant defense by increasing the rigidity of the plant by increasing the deposition of Si on the plant surface and by inducing the production of defense chemicals (Yang et al., 2017). Also, the Si application indirectly enhances the plant defense by altering the composition of herbivore induced plant volatile (HIPV) which acts as synomones (Becker et al., 2015) to which natural enemies such as predators and parasitoids get attracted that act on the herbivores (Mumm and Dicke, 2010; Schuman et al., 2012). The present study evaluates the effect of Si application on the compositional changes of HIPVs in rice induced by BPH feeding.

MATERIALS AND METHODS

BPH population was collected from rice fields of ICAR- Indian Agricultural Research Institute (IARI), New Delhi (28°38'N, 77°09'E). The population was reared on rice varieties viz., TN1, and Pusa Basmati 1121 in the glasshouse with optimum rearing conditions of 27+2°C, 75%± 5% relative humidity and 14 hr light/10 hr dark photoperiod. The established population was further used for the experiments. The rice variety, Pusa Basmati 1121, which is susceptible to *N. lugens,* was used in the investigation and its nursery was raised by following all the package of practices. The 21 days old seedlings were transplanted in pots (25x 22 cm) filled with silicon treated soil following seedling root

Table 1. Relative abundance (% of total peak area) of volatile organic compounds (VOC) in Si treated Pusa Basmati 1121 rice after BPH infestation

S. No.	VOCs	Functional group	% of total peak area of VOCs in Si-treated plant	% of total peak area VOCs in without Si-treated plants
1	D-Limonene	Monoterpene	0.66± 0.04	0.49± 0.01
2	(*E*)-2-Hexanol	Alcohol	2.51± 0.11	1.92± 0.14
3	Dodecene	Alkene	0.31± 0.02	0.35± 0.01
4	b-linalool	Monoterpenoid	3.2± 0.14	2.87± 0.12
5	Nonane	Alkane	0.47± 0.01	0.41± 0.02
6	Docosane	Alkane	0.53± 0.01	4.56± 0.45
7	Cyclopentane	Cycloalkanes	1.85± 0.23	3.93± 0.36
8	Tetradecane	Alkane	2.42± 0.12	0.28± 0.01
9	Hexadecane	Alkane	0.74± 0.03	0.33± 0.11
10	Toluene	Aromatic hydrocarbon	7.65± 1.2	3.78± 0.23
11	Eucalyptol	monoterpenoid	0.49± 0.05	-
12	Mesitylene	Aromatic Hydrocarbon	7.7± 0.97	4.4± 0.50
13	Z-8-Octadecen-1-ol acetate	Alcohol	0.21± 0.01	0.46± 0.02
14	Benzene, 1-ethyl-2-methyl-	Toluene	2.5± 1.1	2.12± 0.74
15	1,2-Benzenedicarboxylic acid	Phthalic acid	1.12± 0.47	1.08± 0.33
16	Undecane	Alkane	0.66± 0.11	0.75± 0.17
17	o-Xylene	Arene	6.0± 0.98	3.75± 0.36
18	n-Eicosane	Alkane	0.20± 0.01	0.37± 0.02
19	Benzene, propyl-	Arene	0.36± 0.04	0.21± 0.01
20	a-cedrene	Sesquiterpene	0.04± 0.01	-
21	Benzene, 1,2-dichloro-	Arene	1.73± 1.0	1.74± 0.54
22	2-Piperidinone	piperidine	0.34± 0.01	0.31± 0.01
23	1-Decanol	Alcohol	0.68± 0.03	0.75± 0.11
24	Naphthalene	Alkene	15.54± 2.12	3.36± 0.98
25	3-Carene	Monoterpene	0.4± 0.01	-
26	(+)-2-Bornanone	-	0.57± 0.21	-
27	Spiro [3.5]nona-5,7-dien-1-one, 5,9,9-trimethyl-		0.1± 0.04	0.15± 0.03
28	Heptane	Alkane	0.48± 0.01	0.36± 0.07
29	7-Oxabicyclo [2.2.1] heptane	-	0.21± 0.02	0.32± 0.01
30	2-Propyl-1-pentanol	Aliphatic alcohol	2.07± 0.45	1.89± 0.66
31	Benzene, 1,3-diethyl-	Aromatic hydrocarbon	6.93± 1.21	7.23± 1.74
32	Benzene, 1,3-diethyl-	Aromatic hydrocarbon	9.0± 2.30	6.79± 2.11
33	3-Heptyne-2,6-dione, 5-methyl-5-(1-methylethyl)-	-	1.84± 0.11	1.55± 0.25
34	1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester	-	1.08± 0.02	1.47± 0.31
35	17-Pentatriacontene	Paraffin Hydrocarbon	0.23± 0.02	0.21± 0.01
36	alfa.-Copaene	Sesquiterpene	0.12± 0.02	0.08± 0.01
37	Dichloroacetic acid, 6-ethyl-3-octyl ester	-	0.48± 0.04	1.02± 0.01
38	2-Pentanone, 4-hydroxy-4-methyl-	Ketone	0.45± 0.11	0.73± 0.09

treatment carbendazim @ 0.2%. As a source of silicon, calcium silicate (CaSiO3) (≥ 87% SiO2 and 12-22% CaO) was used in two concentrations i.e., 0 g and 0.32 g Si/ kg soil. After transplanting the pots were caged with (mylar sheet) and kept in a glasshouse until further use. The BPH nymphs (2^{nd}-3^{rd} instar) were transferred to caged rice plants at 10:1 insects/ plant. The volatile organic compounds (VOC) released from Pusa Basmati 1121 rice were collected by the dynamic headspace collection (Liu et al., 2017) for the experimental treatments: +Si +Herbivore; +Si -Herbivore; -Si +Herbivore; and -Si -Herbivore. Porapak Q (80-100 mesh; Sigma-Aldrich) was used as a volatile adsorbent. VOCs collection was started after 24 hr post infestation (hpi) from 60 days old seedlings and done for 5 hr and then eluted using 300 µl dichloromethane (DCM). The internal standard nonyl acetate (100 ng/ µl) was added DCM. Elute was analysed through GC-MS (Shimadzu QP 2000). The oven temperature was held at 40°C for 3 min then increased at 5°C to 220°C min^{-1}. Compounds were identified by using the mass spectra with the inbuilt library (NIST 14).

RESULTS AND DISCUSSION

Thirty-eight identified compounds from the volatile blend belongs to alkane (nonane, docosane, tetradecane, hexadecane, undecane, n-eicosane, heptane, cyclopentane,), alkene (dodecene, naphthalene), ketone (2-pentanone, 4-hydroxy-4-methyl-), alcohol ((*E*)-2-hexanol, Z-8-octadecen-1-ol acetate, 1-decanol, 2-propyl-1-pentanol), terpenes (D-limonene, b-linalool, eucalyptol, a-cedrene, 3-carene, alfa - copaene), aromatic hydrocarbons (toluene, mesitylene, 1,3-diethyl-benzene, 1-ethyl-3-methyl- benzene) and arene, paraffin hydrocarbon, phthalic acid and toluene groups were found to be released (Table 1). However, the composition of volatile blends was affected by *N. lugens* infestation as also reported earlier (Lou et al., 2005). Some of these volatiles emitted by plants after herbivore damage play the roles of semiochemicals (Pare and Tumlinson, 1999; Degenhardt et al., 2003), which are involved in tritrophic interaction (Vet and Dicke, 1992; Lou et al., 2005). Many of the HIPVs recorded from Si treated and untreated plants are the same except for the differences in their relative abundance.

It has been observed earlier those parasitoids of leaf folder *Cnaphalocrocis medinalis* had greater attraction towards the blend of HIPVs produced by plants without Si treatment (Liu et al., 2017). The role of these HIPVs in tri-trophic interactions needs to be studied further. Silicon is the second most abundant element in the earth's crust, but the majority of it is in unavailable form (Ma and Yamaji, 2006). However, many investigations have proved that it is required in large quantity in available form viz., silicic acid [Si(OH)4] or $Si(OH)3O^-$. The significance of Si to the plants defense against biotic and abiotic stresses has been shown in many crops. Especially, in rice, the Si has shown direct defense by increasing the rigidity of the plant tissue and indirectly by inducing the production of defensive chemicals (Yang et al., 2017). However, the change in volatile compounds composition in Si treated plants upon *N. lugens* infestation is unexplored. In this study we could identify and compare the HIPVs of +Si and –Si plants, some of which are having semiochemical properties. Further, for more understanding, the role of important HIPVs against natural enemies of BPH needs to be studied by using olfactometer tests.

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AUTHOR CONTRIBUTION STATEMENT

PT, SC, SN conceived and designed research. PT, APS, and YY conducted experiments. PT, SN, and MTN analyzed data. PT and SN wrote the manuscript. All authors read and approved the manuscript.

CONFLICTS OF INTEREST

Authors declares that there is no conflict of interest

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DISTRIBUTION OF *SPODOPTERA LITURA* (F) IN UTTARAKHAND

Rashmi Joshi*, Neeta Gaur and Sudha Mathpal

Department of Entomology, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U S Nagar 263145, Uttarakhand, India
*Email: rashmipandey.hdw@gmail.com (corresponding author): ORCID ID: 0000-0003-2343-1463

ABSTRACT

***Spodoptera litura* (F.) is one of most important defoliators occurring in Uttarakhand causing significant losses to crops. Its occurrence in the different regions of Uttarakhand was explored through survey conducted from 2018-2020. Environmental variables for current and future climatic scenario were used in Maxent software for Species Distribution Modelling, and QGIS 3.22 software was used for map processing. These analyses and results revealed that highly suitable area for occurrence of *S. litura* increased with change in climatic variables.**

Key words: *S. litura*, Maxent, Species distribution modelling, AUC, ROC, Uttarakhand, QGIS, Climate scenario, CCAFS, North-Western Himalaya

India holds one of the richest biodiversity in world (Ghosh,1996) containing four out of the 34 identified biodiversity hotspots viz., the Himalaya, the Western Ghats, the Indo-Burma region and Sundaland (IUCN, 2019). A number of insect-pests are found in different regions of Uttarakhand which is situated in NW Himalaya of India, since a range of climatic conditions prevail in the region viz., tropical, subtropical, temperate, cold and frigid cold at elevations ranging from below 300 m to above 3400 m.The five physiographic division in which Uttarakhand is divided are: i) Tarai, Bhabhar and Doon Valley; ii) Shivalik ranges and river valley region; iii) Middle/ Lesser Himalaya; iv) Great Himalaya and v) Trans- Himalaya **(**Sati, 2020**)**. Major insect pests groups present in the region include defoliators, sucking pests, borers etc. About 887 species of moths were recorded from only Kumaun region (Smetacek, 2008). *Spodoptera litura* is one such defoliator prevalent in different regions of Uttarakhand causing significant losses to crops. Singh and Sachan (1992) reported that defoliators are plenty at podding and later stages of crop. Climate change in last few decades has influenced distribution of many species (Bale et al., 2002) and hence the prediction of potential distribution of species by use of species distribution model (SDM) has become an important tool for risk assessment and early monitoring of pests (Li and Qin, 2018). Maxent is one of such popular open access software which helps in studying SDM by predicting potential occurrence using simple machine algorithms (Phillips et al., 2006). The present study was conducted with objective of risk analysis and effective management practices by studying the potential quantitative risk of invasion of *S. litura* in North-Western Himalaya of Uttarakhand, identification of climatic factors responsible for potential distribution and correlation of *S. litura* infestation in relation to climate.

MATERIALS AND METHODS

The occurrence data of *S. litura* from different regions of Uttarakhand was collected in a survey conducted from 2018-2020. In total 9 districts viz. Nainital, Almora, Pithoragarh, Bageshwar, Champawat, Udham Singh Nagar, Chamoli, Dehradun and Haridwar were covered and 29 places of these districts were studied during survey. Sampling was done by hand-picking. The geographical coordinates of places were collected from https://power.larc.nasa.gov/data-access-viewer/ and was proofread from Google Earth (Wang et al., 2020). The variables for current climatic scenario were downloaded from Worldclim (https://www.worldclim.org/) at ~30s spatial resolution which represented average for the year 1979-2000. Representative Concentration Pathways, RCP2.6 (minimum greenhouse gas emission scenario), RCP4.5 (medium greenhouse gas emission scenario) and RCP8.5 (maximum greenhouse gas emission scenario) were chosen for future species distribution of *S. litura* (Wang et al, 2018; IPCC, 2014). Climate variables for the future scenario of 2030s (2021-2040) were downloaded from Climate Change, Agriculture and Food Security (CCAFS) website (http://www.ccafs-climate.org/) at ~30s spatial resolution.

Maxent software was used to analyse the potential distribution of *S. litura* in present study (Phillips et al., 2006). Before starting species distribution modelling, all the bioclimatic variables were filtered on the basis of correlation and permutation importance. Highly correlated variables with Pearson's correlation coefficient |r|> 0.8 were eliminated. A total of eight variables i.e. Bio2 (Mean Diurnal Range Temperature), Bio3 (Isothermality), Bio4 (Temperature Seasonality), Bio6 (Min Temperature of Coldest Month), Bio7 (Temperature Annual Range), Bio12 (Annual Precipitation), Bio14 (Precipitation of Driest Month) and Bio15 (Precipitation Seasonality) were reserved for modelling to study current and future distributions. Linear and quadratic features were used in Maxent software because of the small sample size (Kumar et al., 2014) and the filtered reserved environmental layers were imported. In settings of Maxent software "Random seed" was selected and 10 replicate models were run (Wang et al., 2020). In this study the ROC (Receiver Operating Characteristics) curve or AUC (Area Under ROC Curve) was used evaluate model's performance (Cokola et al., 2020). The theoretical values of AUC ranges from 0.5-1 and is an effective threshold-independent measure of model's ability to predict habitat suitability (Wang et al., 2018). The closer the value of AUC is to 1 the better is the performance of model with AUC values 0.5-0.7 as low accuracy, 0.7-0.9 as good accuracy and >0.9 as high accuracy models (Manel et al., 2002). QGIS 3.22 (https://qgis.org/en/site/index.html#) software was used for map processing.

RESULTS AND DISCUSSION

In this study 29 places were surveyed from both hills and plains of Uttarakhand. The weather data and scale of infestation (Vennila et al., 2010) for *S. litura* was observed for different districts and the AUC values from ROC curve were used to evaluate performance of maxent model. Under climate scenario AUC values were 0.999 and 0.853 for the test data and training data, respectively. It was observed in the model that highest percentage contribution was made by Bio6 (i.e. 42.3%) followed by Bio14 (33.9%), Bio12 (18.1%) and Bio3 (5.7%). The potentially suitable area under *S. litura* infestation was found to be 18.4 %. Under three future scenarios of climate change, the suitable area for *S. litura* increased gradually. The test data AUC were 0.987, 0.982 and 0.970 for RCP2.6, RC4.5, RCP 8.5 respectively. In all the three scenarios the highest percent contribution was made by Bio6 i.e. 55.7% in RCP2.6, 66.6% in RCP4.5 and 59.7% in RCP8.5 climate change scenario. The potential area under distribution was found to be 48.27%, 49.72% and 52.53% under RCP2.6, RCP4.5 and RCP8.5 climate change scenario, respectively. *S. litura* is an important economic polyphagous lepidopterous pest belonging to the family Noctuidae (CABI Datasheet, 2018). Life cycle of *S. litura* is about five weeks (EPPO, 2015), the eggs are generally laid in batches of 200-300 on underside of host leaves and the incubation period is about two days at 35°C and 14 days at 15°C (Hill, 1983 and Fand et al., 2015). Temperature is one of the key factors in growth and development of *S. litura* and both the higher as well as lower temperature influence the survival and development of this insect (Prasad et al, 2021; Srinivasrao and Prasad, 2020; Rao et al., 2014). Climate change over the last three decades has influenced the distribution and abundance of insect species present on earth (Sykes, 2009).

In the present study local distribution data of species was collected for high accuracy of species distribution modelling. The AUC values from ROC curve was used to evaluate the accuracy of model, the closer the value of AUC curve is to 1 the better the performance of maxent model (Breiner et al., 2015). The AUC values observed in present study was found to be in acceptable range i.e. >0.9 making them highly accurate models. Among the environmental variables used in Maxent species distribution modelling of *S. litura*, Bio6 (Minimum temperature of coldest month) played a major role. The plots of prediction model reflected the dependency of distribution of species on Bio6 variable, with Jackknife test depicting similar results. According to Chattopadhyay et al. (2019) outbreak of *S. litura* was observed at temperature between 21-27°C and RH above 90%. This could be related to the insect collected from Pantnagar, since the insects collected in the month of May were not able to survive due to possibly high temperature and absence of optimum RH required for the insect and so, is the reason for survival of *S. litura* in September since the insect was getting optimum temperature and RH at that time of the year in Pantnagar (Fig. 1).

The correlation studies of infestation scales were done with both temperature and RH and a correlation coefficient of 0.467 was observed between RH and infestation scale, similarly a correlation coefficient of 0.323 was found between infestation scale and temperature. Ratner (2009) classified the strength of correlation coefficient into 6 broad categories and the correlation values of *S. litura* with both temperature and

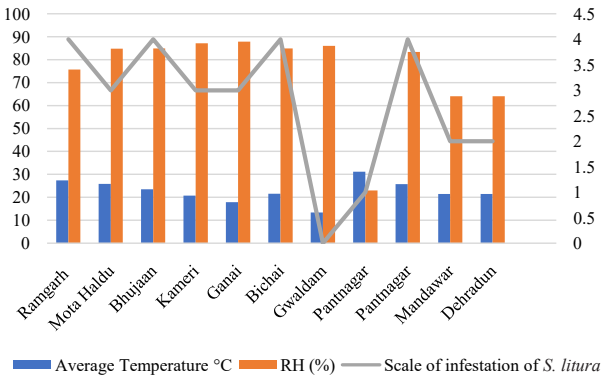

Fig. 1. Relation of infestation with temperature and humidity

RH indicates a moderate positive linear relationship, indicating the requirement of optimum RH and temperature for survival of *S. litura*. The results showed that the growth and distribution of *S. litura* is dependent on temperature and change in temperature will affect the shift in species suitable areas (Stange and Ayres, 2010; Khan et al., 2019). Due to warming of climate, mortality due to extreme cold in winters in insects is reduced (Lombardero, 2000) and climate warming affects dispersal of insect species population directly (Bale et al., 2002). Warm climate generally helps in spreading of insects mid- to high latitudes which caused a major shift in insect dispersal over past half century (Stange and Ayres, 2010). Previous studies have shown that extreme cold in winters phenomenon has majorly affected dispersal of some insect species (Wang et al., 2020; Atwal et al., 1970; Huang et al., 2015). The shift in area from current climatic scenario (18.4%) to 48.27% in 2030s RCP 2.6, 49.72% in RCP 4.5 and 52.53% in RCP 8.5 to northward direction was observed in study. Some of the previous studies are consistent with our simulation predicting more northerly distribution of insect species with climate change in future climatic conditions (Wang et al., 2015), and wider potential distribution of *S. litura* under various climatic conditions (Yoon and Lee, 2021). The results of present study provide the basis for assessment of potential distribution of polyphagous pest *S. litura* in North-Western Himalayan region and could be used formulating management policies to vulnerable potential areas of region. The study indicated that the potential distribution of *S. litura* is dependent on temperature and due to warming of climate in future the insect could increase its activity area, and it is important to design management techniques for effective measure and prevention of further spread. Risk analysis by effective and efficient monitoring system is recommended for potential distribution assessment and precise management practices of pest.

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AUTHOR CONTRIBUTION STATEMENT

Dr Rashmi Joshi is the main author and did complete research with Sudha Mathpal in field study, under guidance and mentorship of Dr Neeta Gaur.

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OCCURRENCE OF TEA MOSQUITO BUG *HELOPELTIS ANTONII* SIGNORET ON NEEM IN NORTHERN KARNATAKA

Shankara Murthy M*, Prabhuraj A[1] and Bheemanna M[1]

Department of Agricultural Entomology, College of Agriculture,
Bheemarayanagudi 585287, Karnataka, India
[1]Department of Agricultural Entomology, University of Agricultural Sciences,
Raichur 584104, Karnataka, India
*Email: smurthyent@gmail.com (corresponding author)

ABSTRACT

Severe incidence of tea mosquito bug *Helopeltis antonii* Signoret (Hemiptera: Miridae) on neem *Azadirachta indica* A. Juss was noticed during 2021-22 in Northern parts of Karnataka. The incidence level (expressed in damage score) varied from 1 to 4 across the surveyed locations, and mean damage score of 3 (25-50% incidence) was observed. Adults and nymphs were found desapping the tender parts of the twigs resulting in black patches and gummosis on the feeding zone initially. Later, affected twigs were found drying along with leaves giving burnt appearance. In this paper, details of survey conducted, different life stages of the pest recorded along with symptoms of damage are discussed.

Key words: *Azadirachta indica*, *Helopeltis antonii*, Tea mosquito bug, neem, margosa, Indian lilac, damage score, survey, incidence, gummosis, life stages, nymph, northern Karnataka.

Azadirachta indica A. Juss commonly known as neem or margosa or Indian lilac is native to Indian subcontinent. It is known to be attacked by 110 insect pest species (Boa, 1995) of which tea mosquito bug (TMB) *Helopeltis antonii* Signoret (Hemiptera: Miridae) was viewed as one of the major sucking pests, affecting tender shoots (Onkarappa, 1993; Boa, 1995). It is a polyphagous pest, known to attack a wide variety of other plant species also such as cashew, guava, mango, apple, rose apple, custard apple, grapevine, ber, cocoa, drumstick, black pepper, cotton, cowpea, cinchona, Singapore cherry, mahogany, heaven tree and Compositae weeds (Saroj et al., 2016). The neem is considered as primary host of *H. antonii* especially in Tamil Nadu, Andhra Pradesh and southern parts of Karnataka (Raviprasad and Vanitha, 2020). Tea mosquito bug as a pest of neem trees in southern parts of India particularly from Coimbatore region was reported by Rao (1915). Likewise, Onkarappa (1993) reported *H. antonii* as a major sucking on pest on neem in southern parts of Karnataka. Thirumalaraj and Puttaswamy (2003) and Kalloor et al., (2020) studied the seasonal incidence of *H. antonii* on neem in southern Karnataka and Tamil Nadu, respectively. However, no reports are available on the occurrence of *H. antonii* on neem from northern Karnataka region.

MATERIALS AND METHODS

To record the activity and incidence of *H. antonii* on neem, a roving survey was carried out in two districts of Northern Karnataka viz., Raichur and Yadgir during 2021-22. The locations surveyed in Raichur district include UAS, Raichur campus (16.20443°N, 77.3324°E), Hunsihalhuda (16.20079°N, 77.25123°E), Gonhal (16.19874°N, 77.22497°E), Kalmala (16.19925°N, 77.20643°E), Murhapur (16.23909°N, 77.19056°E), Sultanpur (16.25452°N, 77.1869°E), Kallura (16.13879°N, 77.21557°E), Hokrani (16.10589°N, 77.1714°E), Betadoor (16.04968°N, 77.12582°E), Neermanvi (16.04558°N, 77.1044°E), Hirekotnekal (15.96163°N, 76.95371°E), Pothnal (15.92269°N, 76.89155°E), Mannikeri camp (15.88673°N, 76.84488°E), Jawalagera (15.86557°N, 76.81592°E), Venkatareddy camp (15.84067°N, 76.79903°E), Heliport (15.76862°N, 76.73247°E), Mullur E.J. camp (15.82633°N, 76.74094°E), Panduranga camp (15.87716°N, 76.68391°E), Basapura EJ camp (15.85179°N, 76.70454°E), Rangapura (15.89758°N, 76.6789°E), Maski (15.95543°N, 76.65422°E), Ankusadoddi (16.03715°N, 76.60974°E), Santhe Kallur (16.05555°N, 76.56681°E), Lingasugur (16.12678°N, 76.52691°E), Devadurga (16.42414°N, 76.93386°E), Sasvigera (16.41742°N, 76.9579°E), Chikkahonnakunni (16.39651°N, 76.98804°E), Miyapur (16.38608°N, 76.99966°E), Masarakal (16.36777°N, 77.02054°E), Kakargal (16.33937°N, 77.05365°E), Sunkeshwarahal (16.32855°N, 77.09098°E), Khanapur (16.31421°N, 77.11717°E) and Gabbur (16.30219°N, 77.15643°E).

While in Yadgir district, Bheemarayanagudi (16.72959°N, 76.80034°E), Shahapur (16.6834°N, 76.84966°E), Vibutihalli (16.66426°N, 76.85672°E), Hattigudur (16.60258°N, 76.88012°E), Markal Kollur (16.50246°N, 76.9132°E), Kongandi (16.5771°N, 76.84698°E), Bijaspur (16.55529°N, 76.81905°E), Arkera Khalsa (16.54313°N, 76.80313°E), Rangampet (16.52829°N, 76.76924°E), Shorapur (16528201°N, 76.77267°E), Shorapur Bus Depot (16.53487°N, 76.78748°E), Kumbarpet (16.50505°N, 76.75337°E) and Kavadimatti (16.48254°N, 76.74781°E). In each location, neem trees/plants of all ages either planted along road side, in parks, in forest nurseries or in public places like temples/bus stops etc., were observed for presence and activity of tea mosquito bug. The adults and nymphs were collected and preserved as dry and wet preservatives, respectively. The identity of the species was confirmed with taxonomist, Dr. Yeshwanth, H.M., Department of Agricultural Entomology, University of Agricultural Sciences, Bengaluru. The incidence level in the sampled tree/ plant was assessed visually as % young twigs affected, and later converted into damage score as 0 - no incidence, 1- <10% incidence, 2 - 10-25% incidence, 3 - 25-50% incidence and 4 - >50% incidence (damage score reference).

RESULTS AND DISCUSSION

Presence of lifestages of *H. antonii* was recorded in all neem plants/ trees observed during the roving survey (Figs. 1-3). All the surveyed trees/ plants irrespective of age and place were affected (Fig. 5). Earlier report of *H. antonii* on neem in southern Karnataka was made by Onkarppa (1993). The incidence started in July 2021 and reached peak between October and December. The level of incidence varied from 1-4; in Maski, Ankusadoddi, Santhe Kallur, Lingasugur, Devadurga, Sasvigera, Chikkahonnakunni, Vibutihalli, Hattigudur and Markal Kollur, the damage score was 1 (<10% incidence); at UAS, Raichur campus, Hunsihalhuda, Gonhal, Kalmala, Murhapur and Sultanpur, the damage score was 2 (>10-25%); Rangapura, Miyapur, Masarakal, Kakargal, Sunkeshwarahal, Khanapur, Gabbur, Bheemarayanagudi, Shahapur, Kongandi, Bijaspur, Arkera Khalsa, Rangampet, Shorapur, Shorapur Bus Depot, Kumbarpet and Kavadimatti, it was 3 (>25-50%); while maximum of 4 (>50%) was recorded in Kallura, Hokrani, Betadoor, Neermanvi, Hirekotnekal, Pothnal, Mannikeri camp, Jawalagera, Venkatareddy camp, Heliport, Mullur E.J. camp, Panduranga camp and Basapura EJ camp.

A closure observation on the lifecycle revealed that, eggs were inserted into the epidermal tissues of tender shoots by female bug which can be spotted by the presence of two silvery filament like process arising laterally on both side of the eggs (Fig. 1). Eggs are white and ovo-elongate. Nymph is reddish or reddish-brown with long legs and antennae. Thorax usually with a pin-like nobbed scutellar process dorsally (Fig. 2). Adult is elongate, measuring 0.3-0.6 mm in length, body reddish brown with black head. Thorax is reddish- brown with a pin-like nobbed scutellar process. While abdomen has white band on its ventral side in both male and female, it is more prominent in female (Fig. 3). Nymphs and adults are commonly found on tender shoots. They feed by sucking the sap from tender shoots which leads to formation of a typical discolored necrotic area or a lesion around the point of feeding (Fig. 4). Later, the necrotic area or lesions on shoots coalesce and eventually result in drying of shoots. Under severe incidence, burnt appearance of the trees can be seen (Fig. 5). Further, exudation of a resinous gummy substance from the feeding punctures can also be seen (Fig. 6). Similar observations made by Onkarappa (1993) and Sundararaju and Babu (1996) confirm the present ones.

Fig. 1. Egg

Fig. 2. Nymph

Fig. 3. Adult

Fig. 4. Nymph sucking sap

Fig. 5. Damaged trees

Fig. 6. Gummosis

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LITTLE BEAR MOTH OF THE GENUS *PHYKODES* RINDSBERG (LEPIDOPTERA: BRACHODIDAE): A LESSER-KNOWN AND NEW PEST FROM THE WESTERN GHATS OF INDIA

Aparna Sureshchandra Kalawate* and Prachee Surwade

Zoological Survey of India, Western Regional Centre, Vidya Nagar, Sector-29, P.C.N.T. (PO), Rawet Road, Akurdi, Pune, Maharashtra 411044, India
*Email: k.aparna@zsi.gov.in (corresponding author): ORCID ID 0000-0001-6595-6749

ABSTRACT

This study reports a new pest, *Phykodes radiata* (Ochsenheimer (Lepidoptera, Cossoidea) from a poorly known family of moths, the Brachodidae on *Ficus* from Western Ghats of India.

Key words: *Phykodes radiata*, Phycodinae, Cossoidea, Sesioidea, Ficus, cucurbits, new record, Western Ghats, Gaganbawda, Maharashtra, day flying

An interesting day-flying moth, *Phykodes radiata* (Ochsenheimer, 1808) was collected from Gaganbawda of Kolhapur district, Maharashtra, India by the first author in 2016. Gaganbawda is situated on the Western Ghats, locally known as Sahyadri, an undisturbed beautiful hilly village of Kolhapur district, known for its rich biodiversity. *P. radiata* is known to feed on *Ficus glomerata*, *F. religiosa*, *F. carica*, *F. bengalensis*, *F. indica*, *F. tisela*, *F. benjamina var. nuda* (Moraceae) (Fletcher, 1917, 1919; Beeson, 1941; Wadhi and Batra, 1964; Nair et al., 1976; Kumar and Ramamurthy, 2010); *Paulownia* sp. (Scrophulariaceae) (Bajwa and Gul, 2000); *Mimusops elengi* (Sapotaceae) (Kumar and Ramamurthy, 2010); *Momordica charantia*, *Trichosantes anguina*, *Lagenaria siceraria* (Cucurbitaceae) (Kumar and Ramamurthy, 2010). In India, it is reported as a minor and sporadic pest of fig from Bihar, New Delhi, Kerala (Kavvai River basin) and Punjab parts of India (Kumar and Ramamurthy, 2010; Alex et al., 2021). The literature published on moths covering Western Ghats and Maharashtra did not record *P. radiata* or the family Brachodidae (Gurule and Nikam, 2013; Shubhalaxmi et al., 2011; Kalawate et al., 2018; Kalawate, 2021; Mitra et al., 2019). Till the present study, there is no published record of *P. radiata* from Western Ghats. Hence, this first report of *P. radiata* and the family Brachodidae from the Western Ghats and Maharashtra.

The family Brachodidae is small and comprising of only three subfamilies: Brachodinae, Pseudocossinae, and Phycodinae distributed worldwide with the exception of North America (Nieukerken et al., 2011;Kallies, 2013). It is a family of day-flying, rare moths, and was earlier assigned to the superfamily Sesioidea (Heppner and Duckworth, 1981; Minet, 1991). Recently, Nieukerken et al. (2011) included Brachonidae in the superfamily Cossoidea and the same is followed by Kallies (2013, 2016) and also in the present study. Brachodidae is well studied in the Sub-Saharan Africa, Oriental and Australia regions (Kallies, 1998; Kallies, 2004; Kallies, 2016), but poorly studied in India. The recorded host plant for the subfamily, Brachodinae are monocotyledonous; dicotyledons (also *Ficus*) for Phycodinae; palms for Pseudocossinae (Kallies, 2016). As per the various reports, number of extant species in Braconidae varies: 137 species (Heppner and Duckworth, 1981; Nieukerken et al., 2011; Kallies, 2013); approximately 135 (Heppner, 1981; Kallies, 2004); and < 150 (Kallies, 2016).

MATERIALS AND METHODS

Phykodes radiata was collected in the field by hand sweeping using insect net around the agricultural fields and was transferred to a killing bottle containing ethyl acetate vapours. After killing, the specimen was transferred to an insect packet made of butter paper and brought to the laboratory for further studies. It was stretched, pinned and stored in the entomological boxes filled with preservatives. For morphological studies the specimen was examined under Leica EZ4E stereomicroscope. The collected specimen was identified as per Kallies (2004) and Kumar and Ramamurthy (2010). The identified specimen is deposited in the National Zoological Collections of the Zoological Survey of India, Western Regional Centre, Pune, Maharashtra, India (ZSI/WRC).

RESULTS AND DISCUSSION

Taxonomy

Family Brachodidae
Subfamily Phycodinae Rebel 1907

Type genus. *Phycodes* Guenee 1852 (*Phykodes* Rindsberg 2019)

Phycodes Guenee 1852 preoccupied name by well known trace fossil (ichnofossil) *Phycodes* Richter 1850; hence, was replaced by *Phykodes* Rindsberg 2019.

Genus *Phykodes* Rindsberg 2019

1852. *Phykodes* Rindsberg, The Journal of the Lepidopterists' Society 73(1): 54-55.

Type Species. *Phykodes hirudinicornis* Guenée 1852 = *Phykodes radiata* (Ochsenheimer, 1808).

Phykodes radiata (Ochsenheimer, 1808)

1808. *Chimaera radiata* Ochsenheimer, *Schmett. Europa* 1 (2): 5.

Type locality. Austria.

Material examined: Stonarc resort, Gaganbawda, 16.5445N, 73.8266E, altitude 615 m, sweep netting sample, 03.x.2016, 1 ♀ (A.S. Kalawate).

Diagnosis: Adult (Fig. 1A). Female: Wing expanse. 26 mm. Head greyish smooth, eyes quite large, antennae filiform; thorax grey with purplish tinge under light. Forewings greyish with black irregular bands, scales greyish and in some places blackish with white spot on its tip; cilia greyish. Hind wing dark brown, the costal margin yellow, centre with two yellow prominent markings; cilia yellowish. Female Genitalia (Fig. 1B). Corpus bursae oval, membranous, with a single signum; signum consists of many small cornute (Fig. 1C), the surface surrounding the signa is scobinated; ductus bursae long, membranous; ostium bursae simple, sclerotized; anterior apophyses longer than posterior, reaching till corpus bursae; papilla analis long, sclerotized, covered with setae.

Distribution: India (Bihar; Kerala, Maharashtra (New record); New Delhi; Punjab); Afghanistan; Iran; Nepal; Pakistan, Peshawar; Sri Lanka (Kallies, 2004; Kumar and Ramamurthy, 2010; Ramezan et al. 2011; Alex et al., 2021).

Larval hosts: *Ficus glomerata*, *F. religiosa*, *F. carica*, *F. bengalensis*, *F. indica*, *F. tisela*, *F. benjamina var. nuda* (Moraceae); *Paulownia* sp. (Scrophulariaceae); *Mimusops elengi* (Sapotaceae); *Momordica charantia*, *Trichosantes anguina*, *Lagenaria siceraria* (Cucurbitaceae) (Fletcher, 1917, 1919; Beeson, 1941; Wadhi and Batra, 1964; Nair et al., 1976; Bajwa and Gul, 2000; Kumar and Ramamurthy, 2010).

The present study is a new record of pest of figs and cucurbit crops from the Gaganbawda village of Kolhapur district, Maharashtra, India. The detailed taxonomic characters of adults and larvae of *P. radiata*, its feeding habit has been provided by Kumar and Ramamurthy (2010). Hence, the present study provides only the key characters. *P. radiata* was reported from the Northern part of India (Kumar and Ramamurthy, 2010), and recently in 2021 it is reported from the Kavvai River Basin of Kerala, India (Alex et al., 2021). There are no reports of this pest from the Western Ghats and Maharashtra so far.

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AUTHOR CONTRIBUTION STATEMENT

ASK conceived, design the research, written the MS, PS contributed for dissection, photographs, spreading of the specimen.

CONFLICTS OF INTEREST

No potential conflict of interest was reported by the author(s).

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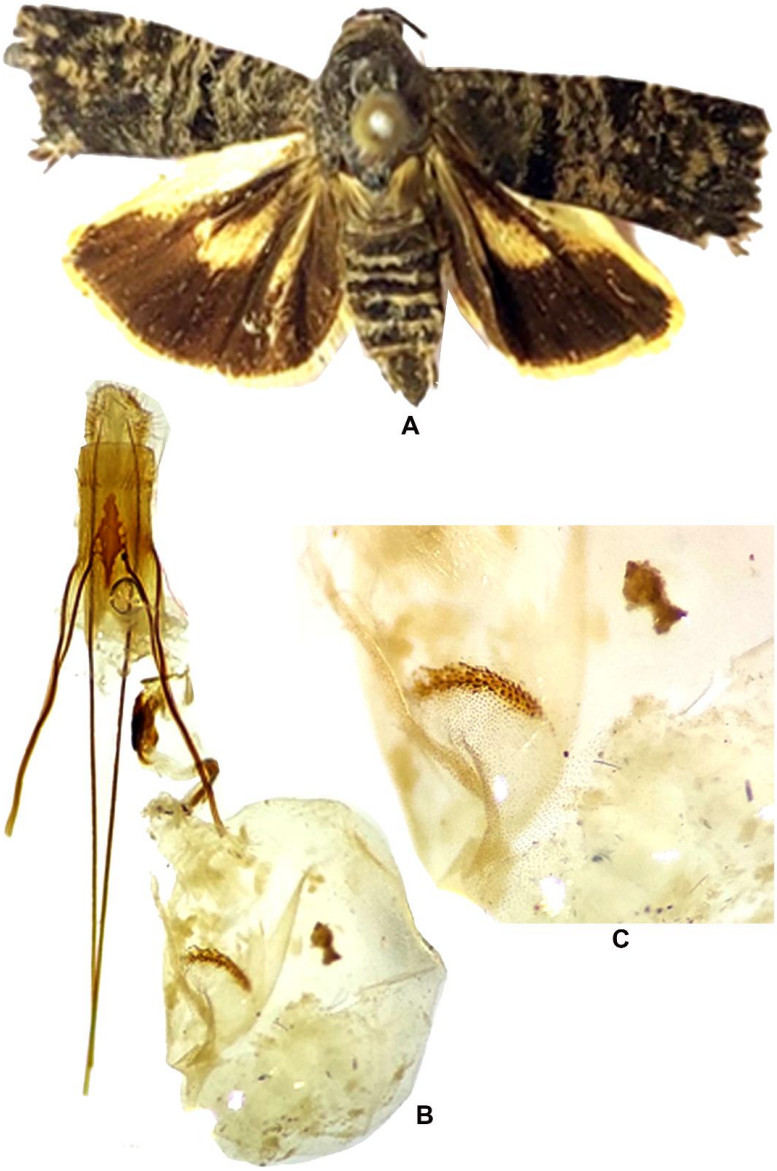

Fig. 1. *Phykodes radiata*: A. Female adult; B. Female genitlaia; C. enlarged view of spiny signum

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EFFICACY OF ACARICIDES AGAINST RED SPIDER MITE *TETRANYCHUS URTICAE* INFESTING YARD LONG BEAN

Rajashekharappa K*, Ambarish S, Ramesh M Maradi and Onkarappa S

Department of Agricultural Entomology, College of Agriculture, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga 577204, Karnataka, India
*Email: rajashekarappak@uahs.edu.in (corresponding author): ORCID ID: 0000-0001-7469-0946

ABSTRACT

Field experiments were carried out at Zonal Agricultural and Horticultural Research Station, Navile, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka India during kharif 2020 and 2021. A total of seven acaricides were evaluated, and the results revealed that spiromesifen 22.9SC @ 0.8 ml/ l was the most effective in reducing mites (87.21% reduction) followed by diafenthiuron 50WP @ 1.0 gm/ l (84.49%). Maximum marketable pod yield was obtained with spiromesifen 22.9SC (21.36 t/ ha) and it was closely followed by diafenthiuron 50WP (20.15 t/ ha). Maximum cost benefit ratio was observed with these, and thus spiromesifen 22.9SC @ 0.8 ml/ l and diafenthiuron 50WP @ 1.0 g/ l can be recommended against mites in yard long bean.

Key words: Cost economics, diafenthiuron 50WP, efficacy, spiromesifen 22.9SC, mite, *Vigna unguiculata sesquipedalis*, yield

Yard long bean (*Vigna unguiculata* subsp. *sesquipedalis* L.) is an important leguminous delicious vegetable crop. In India, Kerala state contributes a major share, accounting for nearly 90%, followed by Karnataka and Tamil Nadu. It is a highly nutritive vegetable containing a good amount of digestible protein (23.5- 26.3%) both in pods and in leaves (Ano and Ubochi, 2008). Its cultivation faces various problems including pests (Rashid, 1993), and about 150 species of insect pests are known, of which about 25 species are serious (Srivastava, 1987). In Karnataka, *Spodoptera litura* (F); *Maruca vitrata* (F); *Liriomyza trifolii* (Burgess); *Aphis fabae* (Scopoli) and a mite *Tetranychus urticae* (Koch) had been reported by Manjesh et al. (2017). Yard long bean is especially attractive to many sucking pests viz., *Aphis craccivora* (Koch); A*phis gossypii* (Glover); green stink bug *Nezara viridula* (L) and red spider mite (*Tetranychus* spp.) occur from sowing to harvest (Grubben, 1993). Among these red spider mites cause serious damage in open field, shade net and polyhouse conditions (Manjesh et al., 2017). The present study evaluates the efficacy of spme acaricides against these mites.

MATERIALS AND METHODS

Two field experiments were conducted during kharif 2020 and 2021 at the Zonal Agricultural and Horticultural Research Station (ZAHRS), Navile, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences (KSNUAHS), Shivamogga, Karnataka, India (75.35°E, 13.58°N, 588 masl). The station is located in the Southern Transition zone (Zone-7) of Karnataka. Yardlong bean variety, Arka Mangala was used and the crop was sown by dibbling method with a spacing of 120 x 30 cm. The crop was raised following a package of practices released by KSNUAHS, Shivamogga. Commercial formulations of chlorfenapyr 10EC (Interprid), fenazaquin 10EC (Magister), spiromesifen 22.9SC (Oberon), diafenthiuron 50WP (Pegasus), azadirachtin 10,000ppm (Econeem), propargite 57EC (Omite), and dicofol 18.5EC (Colonel-S) were procured from the local vendors. The experiment was laid out in a randomized block design with eight treatments and three replications. The treatments were imposed at 55 and 70 days after sowing when the crop was uniformly infested with mites. Knapsack sprayer fitted with a hollow cone nozzle was used for spraying. Incidence of mites was observed from top, middle and bottom canopy leaves collected from ten randomly selected plants. The leaf samples were collected separately in polythene bags (16x 18 cm) and brought to laboratory for examination under stereozoom microscope. Total number of mites (eggs, nymphs and adults) from each sample were counted and expressed in No./ cm^2. Observations were made a day before spraying and 3, 7, 10 and 14 days after the first and second sprays. The mean values were subjected to square root

Table 1. Efficacy of acaricides against *T. urticae* in yardlong bean (pooled data, 2020, 2021)

Treatments	Dosage (ml/ g/ l)	No. of mites/ cm^2									Mean	% reduction over control	Yield (t/ ha)	C:B ratio
		First spraying					Second spraying							
		DBS	3 DAS	5 DAS	7 DAS	14 DAS	3 DAS	5 DAS	7 DAS	14 DAS				
Chlorfenapyr 10EC	1.5	15.95 (4.06)	8.42 (2.99)^{de}	7.18 (2.77)^{de}	3.98 (2.12)^{e}	7.94 (2.91)^{d}	5.11 (2.37)^{e}	3.42 (1.98)^{de}	2.82 (1.82)^{d}	2.69 (1.79)^{d}	5.19	79.67	19.65	1: 3.80
Fenazaquin 10EC	2.0	16.26 (4.09)	9.25 (3.12)^{cde}	8.02 (2.92)^{d}	6.03 (2.55)^{d}	9.17 (3.11)^{cd}	6.34 (2.61)^{de}	3.94 (2.11)^{cd}	3.14 (1.91)^{cd}	3.27 (1.94)^{cd}	6.14	75.95	18.34	1: 3.55
Spiromesifen 22.9SC	0.8	16.48 (4.12)	6.91 (2.72)^{e}	5.68 (2.49)^{e}	1.86 (1.53)^{f}	3.67 (2.04)^{e}	3.00 (1.87)^{f}	2.38 (1.70)^{e}	1.38 (1.37)^{f}	1.27 (1.33)^{e}	3.27	87.21	21.36	1: 4.27
Diafenthiuron 50WP	1.0	15.76 (4.03)	7.51 (2.83)^{e}	6.15 (2.58)^{e}	2.66 (1.78)^{f}	4.32 (2.20)^{e}	3.58 (2.02)^{f}	3.03 (1.88)^{e}	2.44 (1.71)^{e}	2.01 (1.58)^{e}	3.96	84.49	20.15	1: 4.01
Azadirachtin 10,000ppm	2.0	15.70 (4.02)	12.58 (3.62)^{b}	11.34 (3.44)^{b}	7.94 (2.90)^{b}	12.24 (3.57)^{b}	10.01 (3.24)^{b}	6.80 (2.70)^{b}	6.00 (2.55)^{b}	6.24 (2.60)^{b}	9.14	64.21	16.95	1: 3.56
Propargite 57EC	2.0	15.81 (4.04)	10.73 (3.35)^{bcd}	8.79 (3.05)^{cd}	6.35 (2.62)^{cd}	10.23 (3.28)^{bc}	7.80 (2.88)^{cd}	5.10 (2.37)^{bc}	4.16 (2.16)^{c}	4.06 (2.14)^{bc}	7.15	72.01	18.72	1: 3.80
Dicofol 18.5EC	2.5	16.54 (4.13)	11.73 (3.50)^{bc}	10.13 (3.26)^{bc}	7.46 (2.82)^{bc}	11.45 (3.46)^{b}	9.28 (3.13)^{bc}	6.16 (2.58)^{b}	5.49 (2.45)^{b}	5.44 (2.44)^{b}	8.39	67.16	17.68	1: 3.73
Control	-	15.79 (4.04)	16.28 (4.10)^{a}	20.22 (4.55)^{a}	22.23 (4.77)^{a}	25.92 (5.14)^{a}	26.94 (5.24)^{a}	29.31 (5.46)^{a}	31.01 (5.61)^{a}	32.50 (5.74)^{a}	25.55	0.0	12.31	1: 2.96
	CD (p=0.05)	NS	0.41	0.33	0.25	0.32	0.33	0.30	0.21	0.32	-	-	-	-
	CV	6.36	7.31	6.06	5.54	5.70	6.49	6.33	5.07	5.70	-	-	-	-

Means followed by a common letter in a column not significantly different; DBS- Day before spraying; DAS- Days after spraying; Market price of yard long bean Rs. 10/ kg; Total cost of production/ ha 45,000; C: B ratio= GR/Cost of cultivation; Cost of protection (for two sprays/ ha) - Chlorfenapyr 10EC Rs.6675; Fenazaquin 10EC Rs. 6728; Spiromesifen 22.9SC Rs. 5072; Diafenthiuron 50WP Rs. 5274; Azadirachtin 10,000 ppm Rs. 2576; Propargite 57EC Rs. 4328; Dicofol 18.5EC Rs. 2420

transformation, before statistical analysis in ICAR WASP (Web Agri Stats Package) 2.0 software (p=0.05).

RESULTS AND DISCUSSION

The pooled mean data of mites did not significantly vary at one day before spraying (DBS) (15.70 to 16.54/ cm^2). There was significant reduction in incidence up to 14 days of first and second sprays; least No. of mites/ cm^2 was observed with spiromesifen 22.9SC @ 0.8 ml/ l, found to be on par with diafenthiuron 50WP @ 1.0 g/ l; and the least reduction was in azadirachtin 10000ppm @ 2.0 ml/ l followed by dicofol 18.5EC @ 2.5 ml/ l. The mites cm^2 during first and second sprays indicated that spiromesifen 22.9SC @ 0.8 ml/ l (3.27), followed by diafenthiuron 50WP @ 1.0 g/ l (3.96) were comparatively superior, giving 87.21 and 84.49% reduction, respectively over untreated control, while azadirachtin 10000 ppm @ 2.0 ml/l (64.21 %) followed by dicofol 18.5EC @ 2.5 ml/ l (67.16 %) were inferior. Maximum marketable pod yield of yard long beans was obtained with all the acaricides treated plots (16.95 to 21.36 t/ ha); maximum C: B ratio (1: 4.27) was observed with spiromesifen 22.9SC @ 0.8 ml/ l which was found to be on par with the diafenthiuron 50WP @ 1.0 g/ l (1: 4.01) (Table 1). Thus, spiromesifen 22.9SC @ 0.8 ml/ l and diafenthiuron 50WP @ 1.0 g/ l were equally effective. These results are conformity with those Sekh et al. (2007) that spiromesifen 240 SC @ 0.7 ml/ l rprovides effective control of two spotted spider mite on brinjal giving maximum fruit yield. Kavya et al. (2015) also observed spiromesifen reduced the incidence of mites significantly increasing yield of brinjal. Results of earlier workers in vegetables Varghese and Mathew (2013). Baladhiya et al. (2018) and Singh et al. (2020) corroborate with the present results.

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EFFICACY OF DIAFENTHIURON AGAINST *EMPOASCA FABAE* (HARRIS) IN POTATO

Subhakanta Naik, Arundhati Sasmal[1*], Ashok Mishra[2] and Anjan Kumar Nayak

Department of Entomology, College of Agriculture; [1]Regional Research and Technology Transfer Station (Coastal Zone); [2]All India Coordinated Research Project on Potato,
Odisha University of Agriculture and Technology, Bhubaneswar 751003, Odisha, India
* Email: sasmalarundhati@gmail.com (corresponding author)

ABSTRACT

This study evaluated the efficacy of diafenthiuron against potato leafhopper *Empoasca fabae* Harris during rabi, 2018-19 and 2019-20. Seed treatment with imidacloprid 17.8SL @0.4ml/ l along with foliar spray @150ml/ ha, thiamethoxam 25WG @100g/ ha, diafenthiuron 50WP @700g/ ha, castor oil @250ml/ ha, diafenthiuron 50WP @700g/ ha mixed with castor oil @250ml/ ha and untreated control were the treatments compared. The results revealed that the treatments consisting of first foliar spray of diafenthiuron 50WP @700g/ ha mixed with castor oil @250ml/ ha, and second spray of diafenthiuron 50WP @700g/ ha at 30 and 40 days after planting was the most effective. This treatment also gave maximum tuber yield (10.16± 0.11 t/ ha) which is a 43% increase over untreated control with a benefit: cost ratio of 1.62.

Key words: *Solanum tuberosum*, *Empoasca fabae*, diafenthiuron 50WP, castor oil, imidacloprid, thiamethoxam, foliar sprays, tuber yield, cost benefit ratio

Potato (*Solanum tuberosum* L.) is a native of South America's Andean highlands and it is grown in about 2.173 million ha, and with an annual production of 50.19 mt (Dept. of Ag. and FW, Govt. of India, 2018-19). Insect pests are the important biotic factors affecting potato yield, and losses are to an extent of 16% (Oerke et al., 1994), even up to 30 to 70% (Mujica and Kroschel, 2013; Kroschel and Schaub, 2013). Major pests include the sucking pests viz. aphids (*Myzus persicae* Sulzer), leafhoppers *Amrasca biguttula biguttula* Ishida and *Empoasca fabae* Harris, thrips *Thrips tabaci* Lindeman, and whiteflies *Bemisia tabaci* (Genn.). Of these *E. fabae*, the potato leafhopper also is a vector of virus diseases (CIP 1996; Cook et al., 2004; Larrain et al., 2003), leading 75% losses in yield (Backus et al., 2005; Cook et al., 2004; Medeiros et al., 2004; Radcliffe and Johnson, 1994). In some parts of India, *E. fabae* is a devastating pest causing severe hopper burn, especially in early planted crops (Verma et al., 1994). The evaluation of efficacy of insecticide efficacy against such pests is a constant activity. Properties such as selective toxicity to target pests and low toxicity to beneficial insects and/or natural enemies is urgently needed. Insecticides must also be more user-friendly and environment friendly. This study evaluates the efficacy of a biorational insecticide, diafenthiuron against *E. fabae* infesting potato.

MATERIALS AND METHODS

A field experiment was conducted at the Research farm of AICRP on Potato, OUAT, Bhubaneswar, Odisha (20°27'43"N, 85°78'88"E, 25.9 masl) in collaboration with Regional Research and Technology Transfer Station, Coastal zone, OUAT, Bhubaneswar, Odisha during rabi, 2018-19. The crop was raised with recommended agronomic practices, and the experiment was laid out in a randomized block design with three replications. There were seven treatments including-seed treatment with imidacloprid 17.8SL @ 0.4ml/ l of water before planting along with its first foliar spray @150ml/ ha at 30 days after planting (DAP) and second foliar spray with thiamethoxam 25WG @100g/ ha at 40 DAP (T1); foliar spray of diafenthiuron 50WP once @700 g/ha at 30 DAP (T2); first foliar spray of diafenthiuron 50WP @700g/ha at 30 DAP and second foliar spray of diafenthiuron 50WP@700g/ ha at 40 DAP (T3); foliar spray of castor oil once @250ml/ ha at 30 DAP (T4); foliar spray of diafenthiuron 50WP @700g/ ha mixed with castor oil @250ml/ha at 30 DAP once (T5); first foliar spray of diafenthiuron 50WP @700g/ ha mixed with castor oil @250ml/ ha at 30 DAP and second foliar spray with diafenthiuron 50WP @700 g/ ha at 40 DAP (T6); and untreated control (T7). The sprays were done using 500 l of spray fluid/ ha. Potato tubers were treated with imidacloprid 17.8SL solution @ 0.4 ml/ l of water for 30 min before being

Table 1. Efficacy of insecticides against *E. fabae* in potato (rabi, 2018-19, rabi, 2019-20, pooled)

Treatment details	Reduction in incidence of *E. fabae*																	
	Rabi, 2018-19							Rabi, 2019-20										
	First spray			Second spray			Mean Mortality (%) of rabi 2018-19	First spray			Second spray			Mean Mortality (%) of rabi 2019-20	Pooled Mean of all season	Potato yield (t/ha)	% yield improve-ment over control	B:C Ratio
	1 DBS	3 DAS	7 DAS	1 DBS	3 DAS	7 DAS		1 DBS	3 DAS	7 DAS	1 DBS	3 DAS	7 DAS					
ST+imidacloprid 17.8SL (30DAP)+ thiamethoxam 25WG (40DAP)	2.18	39.91 (39.16)	54.13 (47.35)	1.15	35.36 (36.47)	60.13 (50.83)	47.38 (43.38)	1.64	41.46 (40.07)	54.95 (47.82)	0.87	52.74 (46.55)	60.92 (51.31)	52.04 (46.15)	49.71 (44.82)	9.19	29	1.52
Diafenthiuron 50WP (30DAP)	2.27	35.39 (36.49)	48.90 (44.35)	1.20	17.50 (24.70)	19.11 (25.89)	30.22 (33.34)	1.73	38.15 (38.11)	53.28 (46.81)	0.78	30.50 (33.51)	33.40 (35.28)	38.43 (38.29)	34.32 (35.85)	7.98	12	1.30
Diafenthiuron 50WP (30DAP) + diafenthiuron 50WP (40DAP)	2.04	30.39 (33.43)	45.59 (42.45)	1.16	37.07 (37.48)	62.36 (52.14)	43.85 (41.45)	1.67	37.72 (37.87)	54.49 (47.56)	0.80	51.33 (45.75)	62.50 (52.22)	50.57 (45.31)	47.21 (43.38)	8.92	25	1.43
Castor oil (30DAP)	2.04	11.76 (19.77)	4.78 (12.59)	2.22	8.36 (16.80)	6.57 (14.80)	7.87 (16.26)	1.62	17.90 (24.99)	15.43 (23.12)	2.02	11.28 (19.61)	9.53 (17.93)	13.80 (21.80)	10.83 (19.20)	7,37	4	1.23
Diafenthiuron 50WP mixed with castor oil (30DAP)	2.13	48.83 (44.31)	66.67 (54.72)	0.73	20.58 (26.91)	21.45 (27.55)	39.38 (38.85)	1.60	49.24 (44.55)	68.69 (55.97)	0.60	32.11 (34.50)	35.78 (36.71)	46.12 (42.76)	42.75 (40.82)	8.10	14	1.32
Diafenthiuron 50WP mixed with castor oil (30DAP) + diafenthiuron 50WP (40DAP)	2.24	51.34 (45.75)	65.18 (53.82)	0.80	43.33 (41.14)	72.08 (58.10)	57.98 (49.57)	1.71	48.93 (44.37)	68.50 (55.84)	0.56	63.05 (52.55)	80.36 (63.23)	63.41 (52.76)	60.70 (51.16)	10.16	43	1.62
Untreated Control	2.09	0	0	2.25	0	0	0	1.67	0	0	2.04	0	0	0	0	7.10		1.18
SE(m)±		0.961	0.449		0.928	0.979	0.378		0.872	0.639		0.600	1.073	0.401	0.264			
CD(P=0.05)		2.992	1.400		2.890	3.050	1.178		2.716	2.160		1.869	3.342	1.248	0.823			

DAS: Days After Spraying DAP: Days After Planting ST: seed treatment with imidacloprid 17.8 SL @ 0.4 ml /l of water; Figures in parentheses angular transformed values

planted in T1. The spray schedule was first administered at 30 DAP and the second 10 days later. Observations on the incidence of *E. fabae* adult and nymph were made one day before treatment, (3 days after spray – DAS) and 7 DAS, five plants selected/ treatment at random. For observation three fully expanded leaves were examined from each plant - one each from the top, middle and lower parts. At maturity, the potato tubers were harvested separately from each treatment and the marketable yield in q/ ha computed. The benefit cost ratio was calculated taking the cost of production and cost of critical inputs. The pooled data on the incidence of *E. fabae* were subjected to angular transformation before statistical analysis following Gomez and Gomez (1984) using CD (p=0.05) with OPSTAT software

RESULTS AND DISCUSSION

The results on the efficacy of the treatments against *E. fabae* depicted in Table 1 reveal that, during rabi 2018-18 the pretreatment counts ranged from 2.04 to 2.27 or 0.73 to 2.25/ leaf. After two rounds of sprays i.e., first foliar spray of diafenthiuron @700g/ ha mixed with castor oil @250ml/ ha + second foliar spray of diafenthiuron 50WP @700 g/ ha gave maximum reduction in incidence followed by seed treatment with imidacloprid 17.8SL @0.4 ml/ l of water + first foliar spray of imidacloprid 17.8SL @150 ml/ ha + second foliar spray of thiamethoxam 25WG @100 g/ ha. Similar results were observed during rabi 2019-20. The results confirmed that the best treatment is first foliar spray of diafenthiuron 50WP @700 g/ ha mixed with castor oil @250 ml/ ha + second foliar spray of diafenthiuron 50WP @700 g/ ha. Among the treatments, castor oil was the least effective. The pooled data of rabi 2018-19 and 2019-20 confirmed these data on insecticide efficacy (Table1). Seed treatment with imidacloprid 17.8SL @ 0.4 ml/ l of water + first foliar spray of imidacloprid 17.8SL @ 150 ml/ ha was the next best, while single foliar spray of castor oil @ 250ml/ha was the least effective one. Kalyan et al. (2017) observed that diafenthiuron 50WP @ 300g a.i./ ha led to a maximum reduction of *E. fabae.* In contrast woth the present results, Ibekwe et al. (2014) concluded that castor seed oil significantly reduced the green leaf hopper population in brinjal. The present observations on the efficacy of imidacloprid, diafenthiuron and thiamethoxam corroborates with those of Razaq et al. (2005). Preetha et al. (2009) concluded that foliar application of imidacloprid 17.8SL @25g a.i./ ha as well as thiamethoxam were effective against green leaf hopper in okra. Raghuraman et al. (2011) concluded that imidacloprid 17.8% SL @ 80 g a.i/ ha was the most effective against the same. Ghosh et al. (2016) observed that thiamethoxam 25% WG @25g a.i./ ha was better in suppressing the population of jassids in okra. The superiority of imidacloprid and thiamethoxam was shown by Shobharani et al. (2019) against green leafhopper in black gram. The treatment first foliar spray of diafenthiuron @ 700 g/ ha mixed with castor oil @ 250 ml/ ha + second spray of diafenthiuron 50WP @700 g/ ha resulted in maximum potato tuber yield (10.16 t/ ha) with 43% increase over untreated control and a benefit: cost ratio of 1.62. Patel et al. (2009) observed that diafenthiuron gave maximum yield in chilli; Kalyan et al. (2017) observed this with cotton yield. Kharel (2016) observed that diafenthiuron 50 WP@ 312 g a.i./ ha increased green gram yield. Patil et al. (2018) who found that diafenthiuron results in maximum benefit cost ratio (1:1.17) followed by thiamethoxam (1:1.33).

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AUTHOR CONTRIBUTION STATEMENT

SN, AS and AM Conceptualized research; SN, AS and AM Designed the experiments; SN, AS and AM Contributed for experimental materials Execution of field experiments; SN collected data; SN, AS, AKN analyzed and interpreted data; SN, AS and AKN wrote the manuscript. All authors read and approved the manuscript.

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NEW RECORD OF MOSQUITO *COQUILLETTIDIA XANTHOGASTER* (EDWARDS) FROM INDIA

Santhosh Goud*, Subasini Pattnaik, Priyanka Dash, Ipsita Biswal, Jaya Kishor Seth, Rupenangshu Kumar Hazra[1] and Barsa Baisalini Panda[1]

Post Graduate Department of Zoology, Berhampur University, Brahmapur 760007, Odisha, India
[1]ICMR-Regional Medical Research Centre, Bhubaneswar 751023, Odisha, India
*Email: santhosh1090696@gmail.com (corresponding author)

ABSTRACT

This study reports *Coquillettidia xanthogaster* (Edwards, 1924) for the first time from India. It was collected from Berhampur University Campus, District Ganjam, Odisha. This species is considered to have medical importance, as it can carry pathogens like viruses and protozoans and can act as a potential vector. This new record adds to the understanding of its distribution and zoogeography.

Key words: *Coquillettidia xanthogaster*, Culicidae, new record, diversity, zoogeography, vector, medical importance, viruses, protozoans

Mosquitoes of the Culicidae family have long been a focus of entomological study due to their role as vectors of various severe viral and parasitic diseases that harm humans and animals. Malaria, Japanese encephalitis, chikungunya, dengue fever, West Nile fever, and lymphatic filariasis are among the diseases transmitted by mosquitoes. According to WHO estimates, 247 million people fell ill from mosquito-borne diseases in 2006, with around one million people dying (WHO 2008). Mosquitoes are a concern not just in the subtropics and humid tropics; they can also be a nuisance or spread illnesses to people in temperate climates, such as the Chikungunya fever outbreak in Italy or the West Nile virus outbreak in the US in 2007 (Depoortere et al., 2008). Mosquitoes are incredibly efficient organisms because of their capacity to adjust to a wide range of environmental conditions. Except in permanently frozen places, they can be found throughout the world. Adult mosquitoes have a wide range of bionomics, including biting, host-seeking, dispersal behaviour, and reproduction strategy. The global mosquito fauna consisted of 3597 species belonging to 113 genera, two subfamilies, and 11 tribes (Harbach, 2022). There are more than 404 mosquito species and subspecies in India, accounting for more than 12% of the global mosquito biodiversity (Tyagi et al., 2015).

Coquillettidia xanthogaster (Edwards) is widely distributed in different regions of Australia. The larvae of this species are usually found in freshwater marshes, creeks, and lagoons that are deeply covered with dense aquatic plants (Belkin, 1962). They lay eggs in rafts on the surface of the water. The females of this species are vicious biters during morning and daytime close to the breeding sites. The adult ones rest predominantly on vegetation near their breeding sites (Perry, 1949). This mosquito is a significant pest in many places in the northern part of Australia (Russell 1996b). *Coquillettidia xanthogaster* is not known to be a significant vector of any parasites but is susceptible to the Ross River virus in laboratory conditions (Russell, 1996a). Even though it is not considered the main communal health concern, the study of this mosquito is crucial as it can carry pathogens, including viruses, protozoans, and can be a potential vector. The present finding of the mosquito from Berhampur University campus, Ganjam, Odisha, is the first material evidence of this mosquito from India, adding to details on its distribution and zoogeography.

MATERIALS AND METHODS

Mosquitoes were collected from the campus area of Berhampur University, Odisha, India (19.2977358°N84.8781602°E). The collection was carried out from January 2018 to December 2019 using battery operated mechanical aspirator (Pooter) and torchlight. The collected mosquitoes were then transferred to a test tube, covered with a loose cotton plug, and examined in the laboratory for identification. Identification of these mosquitoes was made with a 10x fabric lens, and simultaneously the photographs were taken in a mobile camera mounted with a 10x macro

lens and LED. Identification of the mosquitoes was based on adult characters using standard taxonomic keys and catalogues- Christophers (1933), Barraud (1934), and online keys from NSW Arbovirus Surveillance and Vector Monitoring Program website:https://medent.usyd.edu.au/arbovirus/mosquit/photos/mosquitophotos_coquillettidia_mansonia.htm#xanth. The identity was confirmed with ICMR-RMRC, Bhubaneswar, and voucher specimens were deposited and registered in the National repository of EBRC-ZSI, Gopalpur-on-Sea, Odisha, India (Registration number: EBRC/ZSI/In-12261 A-P).

RESULTS AND DISCUSSION

***Coquillettidia xanthogaster* (Edwards, 1924)** (Fig. 1)

Redescription

Female with a distinct yellowish to orange colour, body length 0.7 to 0.8 cm; palps 1/5th the length of the proboscis with dark scales. Setae are present on pedicels without scales. Head integument yellowish to orange colour, with horizontal golden scales that are numerous laterally. Scutum's integument is evenly yellowish, with occasional darkening along the midline. The scutellum is normally yellowish in colour, with no distinct scales (Fig. 1 A). Pleurites scales are uniformly yellowish and silvery. Postspiracular setae are absent, and one lower mesepimeral seta is present (Fig. 1 C). Legs are with dark scales, with light golden scales on the basal 1/3 of the anterior side of the hind femur (Fig. 1 B). Dark narrow scales cover the wing veins uniformly, while the haltere knob is covered in light brown scales. Light golden scales along with some dark scales are present on the abdominal terga (Fig. 1 D), golden scales cover the sterna.

Material examined: 16 females, Berhampur University, Odisha, Coll., Santhosh Goud. (Registration No. EBRC/ZSI/In-12261 A-P).

Distribution: Australia, New Caledonia, New Hebrides, India (new record).

Remarks: *Coquillettidia xanthogaster* was first described by Edwards in 1924, and bionomics, distribution, and larval forms were documented by Perry in 1949 and Belkin in 1962. Its collection from Odisha now is a new record from the Indian subcontinent.

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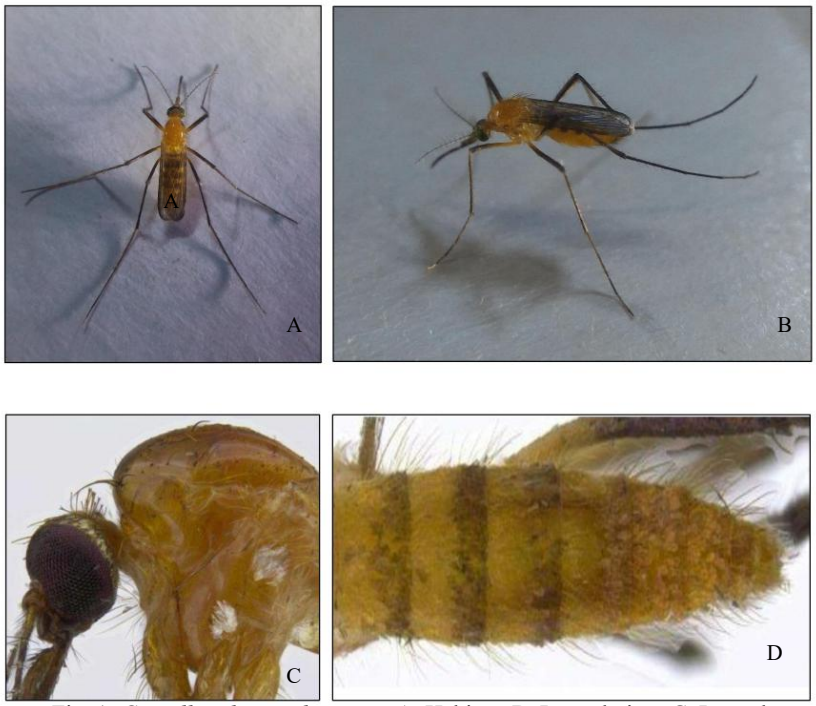

Fig. 1. *Coquillettidia xanthogaster*: A. Habitus, B. Lateral view, C. Lateral view of thorax, D. Dorsal view of the abdomen

AUTHOR'S CONTRIBUTIONS

S Goud conducted the survey, collected the specimen, and taken the photograph. Identified by S Goud and J K Seth, I Biswal, P Dash, B B Panda, S Pattnaik, and R K Hazra prepared the manuscript. All authors read and approved the manuscript.

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MORPHOMETRICS OF TOMATO PIN WORM *TUTA ABSOLUTA* MEYRICK ON DIFFERENT HOST PLANTS

Lakshmi Sireesha E T*, Ramesh Babu T[1] and Koteswara Rao S R[1]

Department of Entomology, S V Agricultural College (ANGRAU), Tirupati 517502, Andhra Pradesh, India
Dean of Student Affairs (ANGRAU), Lam, Guntur 522034, A.P, India
*Email: sireeshaetlakshmi@gmail.com (corresponding author): ORCID ID 0000-0003-1988-4945

ABSTRACT

The morphometrics of the *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) reared on tomato, potato and brinjal were analysed at the Insectary, Department of Entomology, S V Agricultural College, Tirupati. The results showed that the mean length and width of egg, I, II, III and IV instar larvae, pupa and adult was maximum when reared on tomato. The mean width head capsule of all instars was also more. These findings clearly indicated the preference of *T. absoluta* for tomato compared to potato and brinjal.

Key words: *Tuta absoluta*, morphometrics, tomato, potato, brinjal, egg, larval instars, pupa, adult, length, width, host effects, favourable host

The tomato leaf miner *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) is one of the most serious pests of tomato. It also attacks other cultivated solanaceous plants such as brinjal, potato, pepper, and tobacco (Campos et al., 2009; Pereyra and Sanchez, 2006), solanaceous weeds (Larrain, 1986) and garden bean (*Phaseolus vulgaris* L.). It is a native pest of South America but has spread to Africa, Asia and Central America. Since its introduction to Spain in 2006, it has invaded most of the countries in Europe, Mediterranean, Middle East, northern, western and eastern Africa and India in South Asia (Ghazwan et al*.,* 2017). In these countries, it causes 80-100% crop loss. In India, the pest was first reported in Pune, Maharashtra in 2014. It attacks the crop from seedling to harvesting stage. It feeds on leaves, stems, buds, young fruits and reduces the quality of fruits by invading secondary pathogens. In severe cases, it inflicts 50-100% yield loss in both greenhouse and field conditions (Shashank et al*.,* 2015). The pest can produce between 10 and 12 generations a year, and each female can lay 250-300 eggs in her lifetime. There are four larval instars; the first two instars mine the leaves by feeding on the mesophyll and leaving the epidermis intact, thus creating tunnels on the leaf commonly known as "mines". These mines reduce the photosynthetic surface of the leaves and result in early drying and eventual death of the plant. Later the third and fourth instar larvae leave the mines and bore into stalks, apical buds and fruits. Pupation takes place in the mines, in dried leaves or in soil. Adults are nocturnal and hide between leaves during the day time. Their activity is concentrated in the early hours of morning and late evening. Adults are silvery grey with black spots on the forewings and a wingspan reaching 10 mm. Adult longevity varies from 10-15 days in females and 6-7 days in males (Shiberu and Getu, 2017; Daniel and Srivastava, 2017). Since, it is a new introduced pest of tomato and other solanaceous crops, the information on morphometrics of this pest is lacking. Hence, in this study, the morphometrics of *T. absoluta* was studied under laboratory conditions rearing it on different hosts.

MATERIALS AND METHODS

Morphometrics of *T. absoluta* were studied on tomato, potato and brinjal using stereozoom microscope with Dewinter Calipers Pro Version 4.6 software under laboratory conditions (25± 2^0C, 75± 2%RH) at the Department of Entomology, S V Agricultural College, Tirupati. The initial culture of *T. absoluta* was collected from infested fields of tomato and transferred to plastic jars containing tomato leaves as a food source. The fresh and healthy tomato leaves were provided to the developing larvae as and when required till the larvae moults into pupa. The pupae were collected and transferred to oviposition cages (30x 30x 30 cm) and the newly emerged adults were provided with 10% honey solution containing vitamin E as a food source. Equal number of males and females were confined to the oviposition cages provided with tomato seedlings as an oviposition substrate.

The eggs laid by adults on tomato seedlings were collected daily and kept for egg hatching. After hatching,

fresh tomato leaves were provided for newly emerged neonate larvae until pupation. Pupae were collected and transferred to adult rearing cages provided with adult food. This process was repeated continuously and the culture was maintained under laboratory conditions throughout the experiment for further studies. Similarly, the culture was also maintained in nethouse, on tomato, potato and brinjal seedlings in plastic pots. Seed potatoes with eyes were brought from local market at Tirupati, washed and placed in dark condition in wet gunny bags for four to five days to induce sprouting. Later, these sprouted potatoes were maintained in plastic pots and transferred to rearing cage for further studies. Tomato, potato and brinjal plants were grown singly in plastic pots. The host plants with four to five leaves stage were placed in rearing cages. In each cage, one pair (male and female) of *T. absoluta* were released for oviposition. The width of head capsule of larval instars; length and width of egg, larva, pupa and adult stages were recorded. On daily basis, cotton dipped in 10% honey solution was provided for adult moths. The experiments were repeated for three generations and morphometric observations made on tomato, potato and brinjal plants. The data were analysed adopting completely randomised design (CRD) and in OPSTAT software.

RESULTS AND DISCUSSION

The morphometrics of the *T. absoluta* on tomato, potato and brinjal indicated that the mean egg length was 0.47, 0.46 and 0.42 mm with width of 0.26, 0.26 and 0.23 mm, respectively (Table 1). The result of present study are comparable with those of Desneux et al. (2010). Similarly, the mean length and width of I, II, III and IV instar larvae was 1.53, 1.34, 1.25 mm and 0.18, 0.17, 0.15 mm; 2.63, 2.51, 2.37 mm and 0.38, 0.35, 0.33 mm; 4.16, 3.83, 3.52 mm and 0.65, 0.56, 0.56 mm; 7.52, 6.82, 6.41 mm and 1.11, 1.01, 0.93 mm, respectively. The mean length and width of pupa was 4.51, 4.42, 4.22 mm and 1.27, 1.23, 1.21 mm, respectively (Table 1). These results agree with those of Nayana and Kalleshwaraswamy (2015) on pupal length and width on tomato. The mean length and width of adult was 10.15, 9.93, 9.05 mm and 1.79, 1.74, 1.71 mm on tomato, potato and brinjal. The mean width of head capsule of I, II, III and IV instar larvae on tomato, potato and brinjal was 0.17, 0.14 and 0.11 mm; 0.27 0.25 and 0.22 mm; 0.41, 0.36 and 0.35 mm and 0.72, 0.65 and 0.64 mm, respectively (Table 1). These results corroborate with those of Erdogan and Babaroglu (2014) on the width of the head capsule of larval instars.

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Table 1. Morphometrics of larval stages of *T. absoluta* on tomato, potato and brinjal

Host	Head capsule width (mm)			
	I instar	II instar	III instar	IV instar
Tomato	0.17	0.27	0.418	0.72
Potato	0.14	0.25	0.36	0.65
Brinjal	0.11	0.22	0.35	0.64
CD@0.01%	0.013	0.015	0.035	0.035
SE(m)	0.004	0.005	0.011	0.011

	Length (mm)						
	Egg	I instar	II instar	III instar	IV instar	Pupa	Adult
Tomato	0.47	1.53	2.63	4.16	7.52	4.518	10.15
Potato	0.46	1.34	2.51	3.83	6.82	4.428	9.93
Brinjal	0.42	1.25	2.37	3.52	6.41	4.22	9.05
CD@0.01%	0.014	0.024	0.017	0.02	0.101	0.019	0.026
SE(m)	0.005	0.008	0.005	0.006	0.032	0.006	0.008

	Width (mm)						
	Egg	I instar	II instar	III instar	IV instar	Pupa	Adult
Tomato	0.26	0.18	0.38	0.65	1.11	1.27	1.79
Potato	0.26	0.17	0.35	0.56	1.01	1.23	1.74
Brinjal	0.23	0.15	0.33	0.56	0.93	1.21	1.71
CD@0.01%	0.018	0.012	0.013	0.015	0.012	0.014	0.017
SE(m)	0.006	0.004	0.004	0.005	0.004	0.004	0.005

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EVALUATION OF FLONICAMID AGAINST RICE EAR HEAD BUG *LEPTOCORISA ACUTA* (THUNBERG)

K Srinivas*, M Raghuraman[1] and Anil Kumar S T[1]

Division of Entomology, ICAR- Indian Agricultural Research Institute, New Delhi 110012, India
[1]Department of Entomology and Agricultural Zoology,
Banaras Hindu University, Varanasi 221005, Uttar Pradesh, India.
*Email: srinugdml9@gmail.com (corresponding author): ORCID ID 0000-0002-3806-2325

ABSTRACT

This study evaluated the efficacy of flonicamid 50%WG (50, 75 and 100 g ai ha^{-1}) along with imidacloprid 17.8SL (25 g ai ha^{-1}), thiamethoxam 25%WG (25 g ai ha^{-1}), chlorpyriphos 19%ME (180 g ai ha^{-1}) and fipronil 5% SC (75 g ai ha^{-1}) against the rice ear head bug *Leptocorisa acuta* (Thunberg) in rice. The results revealed that flonicamid @ 100 g ai/ ha was the most effective (1.0 bugs hill^{-1}) followed by flonicamid @ 75 g (1.13 bugs hill^{-1}). Imidacloprid (1.22 bugs hill^{-1}) was statistically on par with that of flonicamid @ 50 g (1.23 bugs hill^{-1}) and thiamethoxam (1.24 bugs hill^{-1}). The yield and cost-effectiveness were maximum in the flonicamid (48.93 q ha^{-1} @ 100 g) and imidacloprid (B: C; 2.43:1).

Key words: Rice, earhead, *Leptocorisa acuta*, flonicamid, imidacloprid, thiamethoxam, chlorpyriphos, efficacy, yield, benefit: cost ratio

Rice is the most important staple food crop and it is being attacked by >300 arthropod pests but, only about 20 of them cause economic damage (BRRI, 2016 and Sudha et al., 2019). Among the sucking insect pests, brown plant hopper, green leafhopper, and rice ear head bug are the major ones causing economic damage. Rice earhead bug, *Leptocorisa acuta* (Thunberg) (Hemiptera: Alydidae) has been reported all over India (Soumya et al., 2019). Usually both stages of nymphs and adults cause damage during the pre-flowering phase and continue up to the milky stage of the crop (Rao et al., 1995). Under severe cases of damage, the yield may reduce to the extent of 30% (Tiwari et al., 2014). It has been developing resistance to insecticides, and hence need-based use, and newer insecticides having different modes of action should be included. (Sandeep and Raghuraman, 2014). This study evaluated some insecticides to promote their use against the rice ear head bug.

MATERIALS AND METHODS

The study focused on evaluating the efficacy of the pyridine group of insecticide (flonicamid) at different doses along with others. The field experiment was conducted at the Agricultural Research Farm, BHU, Varanasi (25° 16' 4.3608''N, 82°59', 25.7784''E). Transplanting was done with 21-day old seedlings of a variety "Moti" with spacing of 20x 15 cm and 3x 3 m plots. All recommended agronomic practices were followed. Randomized block design was followed with eight treatments and 3 replications viz., T_1 = flonicamid 50%WG @ 50g ai ha^{-1}; $T_{2=}$ flonicamid 50%WG @ 75 g ai ha^{-1}; $T_{3=}$ flonicamid 50%WG @ 100 g ai ha^{-1}; $T_{4=}$ chlorpyrifos 19%ME @ 180 g ai ha^{-1}; $T_{5=}$ imidacloprid 17.8%SL @ 25 g ai ha^{-1}; $T_{6=}$ thiamethoxam 25%WG @ 25 g ai ha^{-1}; $T_{7=}$ fipronil 5%SC @ 75 g ai ha^{-1} and $T_{8=}$ water sprayed control. A pneumatic hand sprayer with a spray fluid volume of 500 l ha^{-1} was deployed to impose the given treatments. For the better coverage of pesticide solution on the crop, the soap powder @ 0.2% (200 g/100 lit) is added to the spray fluid. Two sprays were given during 60 (vegetative stage) and 90 days after transplantation (reproductive stage), in evening hours upon the observation of a noticeable number of earhead bugs i.e., ETL @ 1.36 bugs/ earhead. The data in terms of the number/ hill at 1 day before spraying (DBS), and 1st, 3rd, 7th, 10^{th,} and 14th days after spraying (DAS). The species was identified using the characters described by Barrion et al. (1981). The mean values were subjected to ANOVA with SPSS software after square root transformation (Gomez et al., 1984). The grain yield was recorded plot-wise and extrapolated to q ha^{-1} and rhe benefit-cost ratio was also computed.

RESULTS AND DISCUSSION

The results revealed that pretreatment counts of *L. acuta* varied from 3.22 to 3.61 and the differences are statistically non-significant (Table 1). Among the

Table 1. Efficacy of newer insecticides against *Leptocorisa acuta* after 1st and 2nd insecticidal sprays and Benefit: Cost ratio

Treatments	Pre-count	Earhead bugs/ hill after 1st spray					Mean	Pre-count	Earhead bugs/ hill after 2nd spray						Overall mean	B: C
	1DBS	1DAS	3DAS	7DAS	10DAS	14DAS			1DAS	3DAS	7DAS	10DAS	14DAS	Mean		
Flonicamid 50% WG @ 50g ai ha^{-1}	3.38* (2.09) **	1.41 (1.55)	1.24 (1.50)	0.98 (1.41)	1.24 (1.49)	1.37 (1.54)	1.60 (1.45)	3.42* (2.10)**	1.33 (1.53)	1.19 (1.48)	0.95 (1.40)	1.30 (1.52)	1.31 (1.52)	1.58 (1.44)	1.59 (1.45)	2.34
Flonicamid 50% WG @ 75 g ai ha^{-1}	3.40 (2.10)	1.40 (1.55)	1.40 (1.55)	0.96 (1.40)	0.99 (1.41)	1.12 (1.46)	1.55 (1.43)	3.58 (2.14)	1.22 (1.49)	1.16 (1.47)	0.93 (1.39)	0.95 (1.40)	1.15 (1.47)	1.50 (1.41)	1.52 (1.42)	2.21
Flonicamid 50% WG @ 100 g ai ha^{-1}	3.22 (2.06)	1.38 (1.54)	1.13 (1.46)	0.82 (1.35)	0.95 (1.39)	0.97 (1.38)	1.41 (1.38)	3.53 (2.13)	1.16 (1.49)	1.01 (1.42)	0.81 (1.35)	0.85 (1.36)	0.93 (1.39)	1.38 (1.37)	1.39 (1.37)	2.15
Chlorpyrifos 19% ME @ 180 g ai ha^{-1}	3.41 (2.10)	1.76 (1.66)	1.52 (1.59)	1.32 (1.52)	1.12 (1.45)	1.03 (1.43)	1.69 (1.48)	3.53 (2.13)	1.82 (1.68)	1.42 (1.55)	1.19 (1.48)	1.05 (1.43)	0.96 (1.40)	1.66 (1.47)	1.67 (1.47)	2.27
Imidacloprid 17.8% SL @ 25 g ai ha^{-1}	3.45 (2.11)	1.43 (1.56)	1.34 (1.53)	0.97 (1.40)	1.28 (1.51)	1.34 (1.53)	1.64 (1.46)	3.43 (2.11)	1.43 (1.56)	1.15 (1.47)	0.94 (1.39)	1.14 (1.46)	1.17 (1.47)	1.54 (1.43)	1.59 (1.45)	2.43
Thiamethoxam 25% WG @ 25 g ai ha^{-1}	3.29 (2.07)	1.57 (1.60)	1.45 (1.57)	1.21 (1.49)	1.08 (1.44)	0.99 (1.41)	1.60 (1.45)	3.61 (2.15)	1.57 (1.60)	1.43 (1.56)	1.16 (1.47)	0.96 (1.40)	0.95 (1.40)	1.61 (1.45)	1.60 (1.45)	2.26
Fipronil 5% SC @ 75 g ai ha^{-1}	3.30 (2.07)	1.69 (1.64)	1.55 (1.60)	1.13 (1.46)	1.12 (1.45)	1.52 (1.59)	1.72 (1.49)	3.61 (2.15)	1.67 (1.63)	1.32 (1.52)	1.14 (1.46)	1.15 (1.47)	1.33 (1.52)	1.70 (1.48)	1.71 (1.49)	1.91
Control	3.55 (2.13)	3.53 (2.13)	3.47 (2.11)	3.21 (2.05)	3.15 (2.04)	3.53 (2.13)	3.41 (1.98)	3.53 (2.13)	3.33 (2.08)	3.15 (2.04)	3.19 (2.05)	3.13 (2.03)	3.32 (2.08)	3.28 (1.94)	3.34 (1.96)	1.82
CD (p=0.05)	NS	0.02	0.07	0.02	0.11	0.22	-	NS	0.02	0.07	0.05	0.05	0.08	-	-	2.34
SE(±m)	-	0.01	0.02	0.01	0.03	0.07	-	-	0.01	0.02	0.02	0.02	0.03	-	-	2.21

*Mean of three replications; **Figures in parenthesis square root transformed values; DBS- day before spraying; DAS- days after spray; NS- non-significant; B:C- Benefit: Cost ratio.

treatments, flonicamid 50%WG @ 100g ai/ ha (1.11 bugs hill^{-1}) gave maximum reduction in followed by its dose of 75g ai/ ha; and flonicamid @ 50 g ai/ ha was superior (1.25%) over others. These observations corroborate with those of Seni et al. (2019) and Pankaj et al. (2020) that flonicamid @ 50g ai/ ha was the most effective in controlling the sucking pests. Thiamethoxam 25% WG @ 25 g ai/ ha was the next best as observed by Girish and Balikai (2015), Sandeep and Raghuraman (2014) and Rath et al. (2015). Imidacloprid 17.8% SL @ 25g ai/ ha (1.28) also was significant in giving reduction, as observed by Rath et al. (2015); and by Sandeep and Raghuraman, (2014), Ashokappa et al. (2015) and Ghoghari et al. (2019). Chlorpyriphos and fipronil were effective (Mallikarjuna, 2017). Maximum benefit-cost ratio (2.43) was obtained with imidacloprid 17.8%SL @ 25 g ai ha-1 followed by flonicamid 50%WG @ 50 g ai ha^{-1} (2.34); and among different doses of flonicamid 50% WG, 50 g ai ha^{-1} showed very high B: C (2.34) followed by 75 g ai ha^{-1} (2.21) and 100 g ai ha^{-1} (2.15). Rath et al. (2015) observed that imidacloprid17.8% @ 300 g/ ha gave maximum grain yield and thiamethoxam was also effective. Thus, spraying of flonicamid can be recommended against L. acuta in rice.

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SUCKING PESTS AND THEIR NATURAL ENEMIES IN MULBERRY

Nilutpal Saikia* and Roshmi Borah Dutta[1]

Department of Sericulture; [1]College of Sericulture, Assam Agricultural University, Jorhat 785013, Assam, India
*Email: nilutpal489@gmail.com (corresponding author)

ABSTRACT

During 2018-2019, a study was conducted to study the sucking pests and their natural enemies in mulberry at the Regional Sericulture Research Station, Central Silk Board, Jamuguri, Jorhat, Govt. Sericulture Farm, Titabar and Assam Agricultural University, Jorhat. Five species of sucking pests were prevalent in various mulberry growing areas of the Jorhat district of Assam. *Paracoccus marginatus* was the most common of these; others include- *Maconellicoccus hirsutus, Pseudodendothrips mori, P. marginatus, Aleurodicus dispersus, Clovia puncta.* Three coccinellid predators *Coccinella septempunctata, Coccinella transversalis* and *Micraspis discolor*, as well as one species of lepidopteran predator *Spalgis epius* were found to associated with *P. marginatus.* and of these *S. epius* was the most abundant.

Key words: sucking pest, mulberry, predators, coccinellid, spalgis epius, jorhat, plant, insect, species, weather, parameters

Moriculture is the cultivation of mulberry, which serves as the basement of Sericulture. The silkworm, *Bombyx mori* L, feeds on mulberry leaves. Mulberry is an evergreen perennial plant with luxuriant foliage that provides an unlimited source of shelter and food for a diversity of insects. Mulberry cultivation in the entire Assam covered around 223926 ha (Anonymous, 2017). In India, several insect pests have been associated with the mulberry crop. Papaya mealybug (*Paracoccus marginatus*), pink mealybug (*Maconellicoccus hirsutus*), whitefly (*Aleurodicus disperses*), thrips (*Psedodendrothrips mori*) and spittlebug (*Clovia puncta*) are among them. Among the 300 insect pests documented to cause harm to the mulberry, the tukra mealybug, (*M. hirsutus*) is the most damaging (Rajadurai and Thiagarajan, 2003). The mealybug infestation of mulberry plants causes tukra symptoms such as leaf crinkling curling and crowding at the shoot terminals (Reddy and Kotikal, 1988). This study investigated the sucking pests and their natural enemies in mulberry in Jorhat district of Assam.

MATERIALS AND METHODS

This study was done in the Jorhat district of Assam covering 1) Department of Sericulture, Assam Agricultural University, Jorhat (26°43'N, 94°11'E); 2) Regional Sericulture Research Station, Central Silk Board, Jamuguri, Jorhat (26°43'N, 94°10'E); and 3) Govt. Sericulture Farm, Titabar (26°35'N, 94°10'E) from December 2018 to November 2019. The observations were done on the randomly selected plants at 15 days intervals. Regular inspections were carried out and various stages of sucking pests were collected in a plastic bag (7x 5cm) and brought to the laboratory for identification. The predacious insects (larvae and adults) were collected in a plastic container and brought to laboratory for identification and confirmation of their predacious behaviour. Adult predators were dry preserved and identified at the Department of Entomology, AAU, Jorhat. *Paracoccus marginatus* occurrence was assessed using the plant inspection method, with samples taken at 15 days intervals with 25 plants selected randomly by taking 5 plants from each of the four corners and centre. The population was estimated by counting the number of *P. marginatus*/ shoots (Mani et al., 2008). To determine the intensity of attack at a weekly interval the number of insects/ leaf (from the top, middle and bottom) was calculated (Chikkaswamy and Paramanik, 2014). For the thrips, similar methodology was followed, and the counts were averaged/ leaf (4^{th}, 5^{th} and 7^{th} leaves) at weekly interval. For spittlebug, similar plant inspection method was applied, and population in average number/ leaf at weekly intervals computed. While sampling sucking pests, their natural enemies were also counted in situ on 25 randomly selected plants. The number of predators/ plant was recorded for the predacious coccinellid adult, and the parasitized insects were also counted directly by inspecting the plants and brought to the laboratory for adult emergence. Lepidopteran larvae on the plants

were counted by examining the plants thoroughly (Singh and Rai, 2000).

RESULTS AND DISCUSSION

The results obtained reveal that during the 2018-19 field visit, five species of sucking pests were observed; these include papaya mealybug (*Paracoccus marginatus* Williams and Granara de Willink) (Hemiptera: Pseudococcidae), pink mealybug (*Maconellicoccus hirsutus* Green) (Hemiptera: Pseudococcidae), thrips (*Pseudodendrothrips mori* (Niwa) (Thysanoptera: Thripidae), whitefly (*Aleurodicus dispersus* Russel) (Hemiptera: Aleyrodidae) and spittlebug (*Clovia puncta* Walker) (Hemiptera: Cercopidae). The natural enemies of these viz., *Spalgis epius*, *Coccinella septempunctata, Coccinella transversalis, Micraspis discolor* and *Illeis indica* were also observed. Table 1 shows data on the relative abundance of these, maximum being of *P. marginatus* (83.52%) followed by *M. hirsutus* (7.33%), *P. mori* (6.98%), *A. dispersus* (1.35%) and *C. puncta* (0.80%). As regards natural enemies, maximum was of *S. epius* (50.88%) followed by *C. septempunctata* (22.32%), *C. transversalis* (13.78%), *M. discolor* (9.18%) and *I. indica* (2.82%). These observations were found to corroborate with those obtained from Jorhat district. The sucking pest includes mealy bug, thrips, spiralling whitefly, leafhoppers, jassids and scale insects which cause damage to the mulberry (Hosamani et al., 2020). The most dominant predator was *S. epius, C. septempunctata, C. transversalis, M. discolor* and *I. indica.* Several predators, mainly Coccinellidae (Coleoptera), have been reported to feed on *M. hirsutus* on mulberry (Janakiraman and Natarajan, 2018).

Table 1. Relative abundance of sucking pests of mulberry and their natural enemies (2018-2019)

Date of sampling	*P. marginatus* (no./ shoot)	*M. hirustus* (no./ shoot)	*A. dispersus* (no./ plant)	*P. mori* (no./ plant)	*C. puncta* (no./ plant)	*S. epius* (no./ plant)	*C. septempunctata* (no./ plant)	*C. transversalis* (no./ plant)	*M. discolor* (no./ plant)	*I. indica* (no./ plant)
15 Dec, 2018	42.02	1.31	0.00	3.31	0.00	1.05	0.02	0.12	0.17	0.01
31-Dec	38.13	1.03	0.00	3.03	0.00	0.00	0.02	0.10	0.00	0.01
15 Jan, 2019	35.44	4.44	0.00	4.44	0.00	0.00	0.00	0.15	0.00	0.00
31-Jan	48.21	3.43	0.00	4.43	0.00	0.00	0.00	0.00	0.01	0.00
15-Feb	62.29	10.48	0.61	7.48	0.41	0.46	0.05	0.04	0.02	0.00
28-Feb	74.36	10.47	0.06	7.47	0.04	1.01	1.00	0.07	0.45	0.00
15-Mar	92.09	12.56	3.00	11.55	2.00	1.41	1.00	0.56	0.22	0.00
31-Mar	75.33	12.55	3.02	11.54	2.02	1.49	0.02	0.42	0.16	0.01
15-Apr	92.05	16.34	2.59	8.34	1.59	0.92	1.02	0.30	0.33	0.00
30-Apr	104.76	16.33	2.58	8.33	1.58	1.35	1.02	0.95	0.40	0.01
15-May	75.54	17.06	3.44	11.06	2.44	1.22	0.65	0.18	0.34	0.02
31-May	65.06	17.05	3.43	11.59	2.42	0.75	0.62	0.22	0.22	0.00
15-Jun	54.37	5.06	2.04	7.06	1.04	1.66	0.15	0.00	0.23	0.00
30-Jun	42.31	5.05	2.05	7.05	1.05	0.72	0.30	0.35	0.12	0.03
15-Jul	63.55	4.11	2.37	5.11	1.32	1.42	0.20	0.39	0.22	0.02
31-Jul	33.12	4.12	2.38	5.12	0.31	0.62	0.00	0.20	0.12	0.01
15-Aug	65.09	3.67	0.00	4.67	0.00	1.17	0.50	0.04	0.02	0.03
31-Aug	35.41	3.66	0.00	4.66	0.00	1.55	0.32	0.20	0.01	0.02
15-Sep	90.11	1.02	0.00	3.06	0.00	1.35	0.03	0.47	0.02	0.02
30-Sep	85.19	1.01	0.00	3.05	0.00	1.43	0.07	0.27	0.56	0.01
15-Oct	125.07	0.21	0.00	2.54	0.00	4.35	1.34	0.80	0.53	0.00
31-Oct	100.09	0.24	0.00	2.53	0.00	2.85	1.25	0.76	0.43	0.00
15-Nov	120.41	0.00	0.00	3.00	0.00	4.00	1.05	0.89	0.44	0.00
30- Nov	105.04	0.00	0.00	3.01	0.00	3.40	3.20	0.76	0.60	0.00
Mean	71.87	6.31	1.17	6.01	0.69	1.44	0.66	0.39	0.26	0.08
Relative abundance (%)	83.52	7.33	1.35	6.98	0.80	50.88	23.32	13.78	9.18	2.82

Mean of 25 samples

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AUTHOR CONTRIBUTION STATEMENT

N Saikia and R B Dutta conceived and design the research. N Saikia wrote the manuscript and conducted the experiments.

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BIONOMICS OF ORIENTAL FRUIT FLY *BACTROCERA DORSALIS* (HENDEL) ON GUAVA

N U Visakh and Shantanu Jha

Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya (BCKV)
Mohanpur, Nadia 741252, West Bengal, India
Email: visakhnu17palazhi@gmail.com (corresponding author)

ABSTRACT

A study on bionomics and morphometrics of the Oriental fruit fly *Bactrocera dorsalis* (Hendel) was carried out during rainy and winter season guava crop over the period of 2018-2019 at the Department of Agricultural Entomology, BCKV, Mohanpur, West Bengal. Comparative bionomics data of *B. dorsalis* revealed that the egg, larval and pupal periods of *B. dorsalis* in the rainy season crop amounted to 1.56± 0.56, 10.14± 0.59 and 10.74± 0.42 days, respectively in the winter season these worked out to 2.11± 0.33, 11.0± 0.41 and 13.87± 0.82 days, respectively. The lifecycle got extended when reared with the winter season fruit crop compared to that of rainy season. This study revealed that short life cycle with more damage of oriental fruit fly, *B. dorsalis* was observed in the rainy season guava as compared to winter season.

Key words: *Bactrocera dorsalis*, guava fruit, fruit fly, lifecycle, egg, larval, pupal period, adult longevity, fecundity, rainy season, winter season

India is the world's largest producer of guavas (*Psidium guajava* L) and the third most grown fruit crop in West Bengal state, with guava trees blooming twice a year, in April-May and September-October, followed by ripening in the rainy and winter seasons, with a productivity of 15.2 tons per ha (Mitra et al., 2008; Anonymous, 2021). Due to its diverse adaptability, guava crop is threatened by a number of biotic stress including insect pests about 80 insect pest species were reported to infest the guava (Butani, 1979). Among them, Fruit flies are the one of the major pest that affect the yield and quality of guava fruits. Fruit flies belong to the family Tephritidae and order Diptera. It contains more than 4000 species in which about 700 species of sub family Dacinae has been presented all over the world (Fletcher, 1987). Among them, oriental fruit fly, *Bactrocera dorsalis* (Hendel) is a major pest and polyphagous in nature (Butani, 1979). In India, the yield loss due to *B. dorsalis* ranges from 1 to 31% with a mean of 16%. Being polyphagous, they breed profusely on guava as well as mango. A thorough knowledge of life history of an insect and its status during different seasons provide an important basis for developing efficient pest management strategies (Laskar, 2013). The present study assesses the comparative seasonal bionomics of *B. dorsalis* during different seasons in the guava growing tract in Indo-Gangetic alluvial plains of West Bengal.

MATERIALS AND METHODS

The study on the comparative seasonal bionomics of *B. dorsalis* was done during the rainy (July-September) and winter seasons (December-February) at BCKV, Mohanpur, Nadia district (23° 53´N, l88° 95´E, 9.75 masl) under laboratory conditions at Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya (BCKV), Mohanpur, West Bengal during 2018-2019. The guava variety L-49 was grown as per recommended practices without any insecticidal exposure. Laboratory conditions were not constant and maintained with surrounding weather conditions and checked using with digital temperature humidity meter. Mean temperature and relative humidity in rainy season as well as in winter season during 2018 and 2019 were 30.76°C, 24.93°C and 76.73%, 84.98%, respectively. Field collection of infested guava fruits were done from the Horticultural Research Station, Mondouri, BCKV, Mohanpur, West Bengal. Ten infested fruits were examined under laboratory conditions at Plant protection laboratory of Department of Agricultural Entomology. The fruits were kept singly in rearing glass jars (20 cm height with 14 cm diameter), provided 5-6 cm thick layer of sieved and sterilized sand as sites of pupation. The mouth of jars were covered with mosquitonet. This mosquito net is tightly wrapped with pair of rubber bands for avoiding the escape of last instar maggots as well as to extend the protection to maggots and pupae from predators and parasitoids. Moisture level inside the rearing glass jars were maintained by addition of distilled water in the sand at periodic intervals. This adds optimum moisture favouring the maggots to pupate inside sand kept in the rearing jars.

After eclosion of fruit fly adults, those were allowed to be there for a week and were provided with a diet of enzymatic yeast hydrolysate and sugar (1:3) together with water. After a week, among the sexually matured adult fruit flies, ten pairs of male and female flies were kept overnight separately in the vials for mating process and further used to study the life cycle studies of *B. dorsalis* on guava. Gravid females were kept in the cage provided with a piece of fresh fruits of guava having protein diet and 5% honey solution for egg laying. The eggs were detected by excavating the fruit just below the oviposition puncture through microscopic observations. The eggs were transferred in the Petri dishes containing pulp. The freshly laid eggs were collected daily and used for further studies.

Observations were taken on incubation period, larval duration, pupal period, oviposition period, pre and post oviposition period, adult longevity and total lifecycle. The adults which emerged on same day were paired in an insect proof net cage with 5 % honey and protein diet for egg laying and fecundity observed daily until the death of the female and male fruit flies. For observing the incubation period and egg hatchability %, 30 freshly laid eggs were observed in Petridishes having 10 eggs each as a replicate for the emergence of neonates. Emerging larvae were reared in glass jars having sand media and provided with half cut pieces of medium sized mature fruits of guava till pupation. Observations on moulting were made on three instars, which were easily visible. Similarly, pupal period was also observed. The newly emerged adults were separated as female and male on the basis of morphological features. The period from emergence of adults till death was also observed. Observations on biological parameters such as egg hatchability %, larval survival %, pupal recovery %, adult emergence %, sex ratio and fecundity/ female were made. For morphometrics, different life stages of *B. dorsalis* also were observed during two guava seasons under stereozoom microscope (n=10) and the measurements were made by using digital vernier caliper. The life history parameters were analysed with mean and standard deviation.

RESULTS AND DISCUSSION

The bionomics of *B. dorsalis* was studied in rainy and winter seasons of guava under laboratory conditions (Table 1). Fertilized females punctured the guava fruit with their long extendible ovipositor. A watery fluid oozed out from the puncture, later it transformed into a white or brown resinous deposit. Eggs were elliptical, smooth glistening white to creamy colour with elongate shape. During winter season guava, the egg period was maximum (2.11± 0.33 days) and minimum for rainy season crop (1.56± 0.56 days). The morphometric of life stages revealed that during rainy season, for egg, it measured 1.14± 0.08x 0.27± 0.01 mm, whereas during winter it was 1.12± 0.17x 0.2± 0.03 mm. This finding is in conformity with Sharma and Gupta (2018), Laskar (2013), Amur et al. (2017) and Vanitha (2015). Naik et al. (2017) found that egg incubation period was on an average of 1.85± 0.34 days. Ganesh (2009) reported that incubation period was 3.00± 0.71 days with a range of 2-4 days.

There were three larval instars, and these lasted for: first for 2.26± 0.20 days (measuring 4.74± 0.23x 0.57± 0.15 mm) during rainy season compared to winter one being 2.40± 0.24 days (4.32± 0.67x 0.54± 0.09 mm). These results were in conformity with Vanitha (2015) Second instar lasted for 3.42± 0.12 days during rainy season compared to winter season one being 4.2±0.37 days, with these being bigger when reared in rainy season and significantly differing from larvae reared on winter season. These findings are more or less concordant with Amur et al. (2017). Vanitha (2015) also found that duration of second instar as 2.20± 0.33 days. Third instar lasted for 3.45± 0.54 days (8.72± 0.33x 1.54± 0.74 mm) during rainy season, requiring less number of days compared to winter season. Vanitha (2015) found that length of third instar larvae was 8.60± 0.48 mm and breadth was 1.51± 0.17 mm. Amur et al. (2017) observed a duration of 2.75± 0.54 days, while Vanitha (2015) found it as 4.22± 0.32 days. Total larval period was minimum during rainy season- 10.14± 0.59 days and maximum being in winter season (11.56± 0.41 days). Prepupa creamy white to pale yellow lasting1.07± 0.44 days (6.68± 0.24x 2.08± 0.45 mm during rainy season, and as well as 1.18± 0.41 days (6.30± 0.13 x 2.03± 0.33 mm) in winter, respectively (Table 1).These results corroborate with those of Ganesh (2009), Singh and Sharma (2013), Vanitha (2015), Amur et al. (2017) and Sharma and Gupta (2018). Total pupal period observed in the rainy season was 10.74± 0.42 days (5.28± 0.16 x 2.12± 0.71 mm); and during winter it was 13.87± 0.82 days (4.79± 0.22 x 1.90± 0.16 mm), respectively. These observations conform with those given by Amur et al. (2017). Sharma and Gupta (2018) observed its size as 4.76± 0.02x 2.12± 0.03 mm. Singh and Sharma (2013) recorded the pupal duration to be 7.67± 0.27 days (Table 1).

Maximum number of adults emerged from the puparia between 7.00 am to 10.00 am, and during rainy

season, adult longevity of male was about 23.60± 3.49 days; and 27.10± 2.17 days in winter season. Male was comparatively large when reared in rainy season. Female was larger and lived longer, and during rainy season its longevity was about 34.98± 2.24 days, and 38.08± 3.06 days in the winter season. These results agree with those of Ganesh (2009), Singh and Sharma (2013), Vanitha (2015), Amur et al. (2017), Naik et al. (2017) and Sharma and Gupta (2018). Preoviposition period was observed to be 8.16± 0.81 days during rainy season which in winter was 9.01± 0.54 days. Ganesh (2009) recorded the preoviposition period as 8.32±

Table 1. Bionomics and morphometrics of *B. dorsalis* in different seasons on guava (n=10)

	Rainy season		Winter season	
Life stages	Range (days)	Mean± SD (days)	Range (days)	Mean± SD (days)
Egg (incubation period)	1.0-2.2	1.56± 0.56	1.6-2.2	2.11± 0.33
Larval period: 1st instar	2.0-2.5	2.26± 0.20	2.1-2.8	2.40± 0.24
Larval period: 2nd instar	3.0-4.4	3.42± 0.12	3.3-4.6	4.2± 0.37
Larval period: 3rd instar	3.1-4.3	3.45± 0.54	3.6-4.7	4.0± 0.30
Complete larval period	8.2-11.3	10.14± 0.59	9-12	11.0± 0.41
Prepupal period	0.5-1.5	1.07± 0.44	0.7-1.8	1.18± 0.42
Pupal period	9.0-12.0	10.74± 0.42	11-15	13.87± 0.82
Adult longevity (Male)	18.5-32.5	23.60± 3.49	19.4-36	27.10± 2.17
Adult longevity (Female)	26.1-45.8	34.98± 2.24	29.5-49.2	38.08± 3.06
Total life cycle (egg to adult emergence)	20.2-25.5	22.82± 1.65	21.3-30.5	26.37±1.24
Pre-oviposition period	7-13	8.16± 0.81	7-14	9.01± 0.54
Oviposition period	3-8.8	6.12± 0.76	3-6.5	5.46± 0.74
Post-oviposition period	1-4.5	2.82± 0.65	1-5	2.95± 0.13
Biological parameters	Range	Mean± SD	Range	Mean± SD
Fecundity (No.)	78-172	122.1± 17.15	56-131	82.3± 23.51
Egg hatchability %	90-95	91.66± 2.88	80-93.33	83.33± 1.65
Larval survival %	72-86	80.42± 6.73	70-85	71.62± 5.30
Pupal recovery %	70-85	78.50± 4.43	65-75	72.45± 2.31
Adult emergence %	76-92	83.2± 6.57	68-86	70.0± 2.15
Sex ratio (♂:♀)	1:1.10 -1:1.32	1:1.21± 0.57	1:1.03-1:1.15	1:1.08± 0.34
Morphometrics				

	Length (mm)		Breadth (mm)		Length (mm)		Breadth (mm)	
Life stages	Range	Mean± SD	Range	Mean± SD	Range	Mean± SD	Range	Mean± SD
Egg	0.97-1.34	1.14± 0.08	0.16-0.79	0.27± 0.01	0.88-1.30	1.12± 0.17	0.15-0.50	0.21± 0.03
1st instar larva	3.47-5.56	4.74± 0.23	0.39-0.69	0.57± 0.15	3.30-5.60	4.32± 0.67	0.40-0.60	0.54± 0.09
2nd instar larva	5.89-7.95	6.48± 0.41	0.87-1.04	0.90± 0.07	5.40-7.12	5.84± 0.09	0.80-0.92	0.84± 0.04
3rd instar larva	7.38-9.13	8.72± 0.33	1.06-1.79	1.54± 0.74	7.00-9.03	8.50± 0.83	1.10-1.80	1.49± 0.16
Prepupa	6.10-7.54	6.68± 0.24	1.83-2.62	2.08± 0.45	6.08-6.60	6.30± 0.13	1.5-2.51	2.03± 0.33
Pupa	5.10-5.40	5.28± 0.16	1.9-2.3	2.12± 0.71	4.31-5.19	4.79± 0.22	1.61-2.28	1.90± 0.16
Adult male (Expanded wing)	5.50-6.50	6.17 ± 0.41	7.4-9.87	9.32± 0.41	5.40-6.28	5.93± 0.22	7.10-9.43	8.94± 0.72
Adult female (Expanded wing)	5.84-6.63	6.57± 0.62	10.0-13.5	12.33± 0.14	5.90-6.80	6.28± 0.24	10.3-12.5	11.70± 1.30

SD = Standard deviation

1.11 days, and Amur et al. (2017) as 13.55 ± 1.33 days, while Naik et al. (2017) observed it as 12.10± 1.28 days. Oviposition period was 6.12± 0.76 days during rainy season whereas it was about 5.46± 0.74 during winter season. Vanitha (2015) observed this as 5.96± 1.65 day. Post-oviposition period during rainy season was 2.82± 0.65 days whereas during winter season, it was about 2.95± 0.13 days; Ganesh (2009) recorded it as 3.00± 0.76 days. Patel and Patel (2018) reported it as 1.60± 0.69 days. The total life cycle took 22.82± 1.65 days during rainy season, and comparatively longer i.e. 26.37± 1.24 days in winter. These results agree with those of Singh et al. (2010), Singh and Sharma (2013) and Mir et al. (2014) (Table 1).

Fecundity differed significantly between rainy and winter season, it was 122± 17.15 in rainy season, and less during winter of 82.3± 23.51. Ganesh (2009) observed the fecundity as 155± 34.32. Egg hatching % during rainy season was of 91.66± 2.88% whereas during winter season it was about 83.33± 1.65%. These results agree with those of Amur et al. (2017) and Ganesh (2009). Larval survival % was more and 80.42± 6.73% during rainy season compared to winter season (71.62± 5.43%); and pupal recovery was 78.50± 4.43% during rainy season, as against 72.45± 2.31% during winter season. Adult emergence was more when reared in rainy season crop (83.2± 6.57 %) than winter (70± 2.15%).These results corroborate with those of Sohail et al. (2015). Sex ratio (♂:♀) of male and female was 1:1.21± 0.57during rainy season, which was 1: 1.08± 0.34 during winter season, as observed by Singh and Sharma (2013), and Amur et al. (2017) observed it to be 1:1.17. Amur et al. (2017) and Sohail et al. (2015) brought out the variations in the bionomics of fruit fly, *B. dorsalis* during different seasons (Table 1).

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A NEW RECORD OF TERMITE *COPTOTERMES EMERSONI* AHMED

Bhanupriya[1], Nidhi Kakkar[1], Sanjeev K. Gupta[1]

Department of Zoology; [1]Department of Zoology, The Institute of Integrated and Honors studies (IIHS), Kurukshetra University, Kurukshetra 136119, Haryana, India
*Email: nidhikakkar12@yahoo.com (corresponding author)

ABSTRACT

The *Coptotermes* Wasmann (1896), is a highly scattered genus, which is represented by nine species. *Coptotermes emersoni* Ahmad (Isoptera: Rhinotermitidae: Coptotermitinae) is a species first time reported from Southern Haryana, India, with specimens trapped from banyan tree. Morphometric analysis of soldiers like body length, head length without mandibles, head length with mandibles, body pigmentation, antennae segments, tibial spur, tarsal segments, head width, and body width has been made. These reveals that *C. emersoni* has crenulations present on each of the mandibles, right mandible with two crenulation and left mandible with five crenulations which make it unique among other species of the genus *Coptotermes*.

Key words: *Coptotermes, emersoni*, Rhinotermitidae, Haryana, soldiers, morphometrics, mandible, tarsi, tibial spur, crenulations, head, antenna, body, pigmentation

Termites are ecosystematically dynamic insects belonging to the order Isoptera, of which 3106 species under 330 genera and 12 families are known (Krishna et al., 2013a; Singla et al., 2013; Singla et al., 2016; Kakkar et al., 2017; Paul et al., 2018; Murthy, 2020; Effowe et al., 2021). Of these, only 300 species are from India under 37 genera and 7 families (Saha et al., 2016; Vidhyashree et al., 2018; Amina et al., 2020). The termites of Haryana state are poorly known- its diversity reported varies, as 11 (Verma, 1989), 19 (Thakur, 1992), 15 (Kumar and Thakur, 2010) or 20 species, ranked under ten genera and three families (Thakur, 2007). The maximum of 37 species under 3 families (Termitidae, Rhinotermitidae and Kalotermitidae) and 11 genera were reported in the subsequent work (Poonia, 2019; Poonia, 2020). Of these *Coptotermes emersoni* (Ahmed) had not so far been reported in Haryana. According to ICZN (International Code of Zoological Nomenclature) genus *Coptotermes* Wasmann (Rhinotermitidae: Coptotermitinae) comprises of 110 subterranean species that are widely scattered in nature because they nest their colony in woody items (Krishna et al., 2013b). Out of these, only 9 species have been identified from India (*Coptotermes beckeri, C. ceylonicus, C. emersoni, C formosanus, C. gaurii, C. gestroi, C. heimi, C. kishori* and *C. travians*) (Roonwal and Chhotani, 1989), whereas, 4 species (*Coptotermes beckeri, C. ceylonicus, C heimi,* and *C. kishori*) are from the southern part of India and 4 are from the northern India (*C. kishori, C. gestroi, C. heimi* and *C. travians*) (Roonwal and Chhotani, 1989; Ranjith and Kalleshwaraswamy, 2021).

Systematic account of *Coptotermes emersoni* Ahmad reveals the chronology as follows: 1953. *Coptotermes emersoni* Ahmad, SpoL ZeyL, 21(1): 37-38. Type-locality: Colombo, Sri I.anka.

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MATERIALS AND METHODS

Termite samples were collected from Abhepur village, Sohna, Gurgaon district, Haryana (28°17' 38.39208" N, 77° 6' 10.28196" E). Specimens were picked up from banyan tree with forceps and tree trunk was explored with screwdriver, and preserved in 70% alcohol. These vials were carefully labeled with time, date of collection and site of collection (Takematsu and Vongkaluang, 2012; Murthy et al., 2015, 2016;

Kakker et al., 2016, Arif et al., 2019). During collection, main emphasis was given to soldiers, as soldiers are the basis of species identification, and these identified with morphometrics of body and head length with and without mandibles, body pigmentation, antennae segments, tibial spur, tarsal segments, and head and body width **(**Roonwal and Chhotani, 1989; Scheffrahn et al., 2006; Engle et al., 2009; Saha et al., 2016; Amina et al., 2016; Mahapatro et al., 2018**)**. Five individuals of the caste were used to calculate mean and standard deviation for species identification. The specimens were examined under a light compound microscope and dissecting microscope.

RESULTS AND DISCUSSION

The results revealed the presence of the subterranean genus *Coptotermes* having nine species in India (Roonwal and Chhotani, 1989) and 110 species globally (Krishna et al., 2013b). This genus contributes 8.18% of the world termite fauna, of which three species are from Haryan (Poonia, 2019). This genus is distributed over India, China, Africa, Southeast Asia, Australia, and the Neotropics (Chouvenc et al., 2016) due to their mound construction activity inside woody logs. Therefore, nest erection activity marks this genus as a most common invader in new locality on earth surface. A total of 30-50 individuals of termite were collected and these were identified as *Coptotermes emersoni* Ahmad using identification keys (Roonwal and Chootani, 1989). As a member of the subterranean termite family Rhinotermitidae, *C. emersoni* is unique termite species with two crenulations present on the right mandible found in India. This species was first reported in Sri Lanka (Roonwal and Chhotani, 1989; Krishna et al., 2013b). These identified individuals were placed under (Inward et al., 2007; Jones and Eggleton 2011).

The morphometrics reveal that total body length of the soldier caste is 4.5-6 mm) comparatively smaller than other species. It has a pale brown oval head with red to brown colored mandibles. Mandibles are less curved and smaller than the head with range of 0.8-0.9 mm. A total of 13 antennae segments are present with 3rd antennal segment smallest; labrum is subtriangular with a pointed apex; left mandible has 4 small crenulations and one large, whereas the right is denoted by only two crenulations, and number of crenulations on the right mandible makes this species unique from other *Coptotermes* species. Three pairs of moving legs having tibial spurs (3:2:2 ratio) and tarsal segments (4) are present (Fig. 1a-h). The measurements are as follows: Total body length 5.18±0.54; head length without mandibles 1.1±0.1; head + mandibles length 1.96±0.11; mandibles length 0.86±0.05; head width 0.96±0.11; and body width 1.08±0.08.

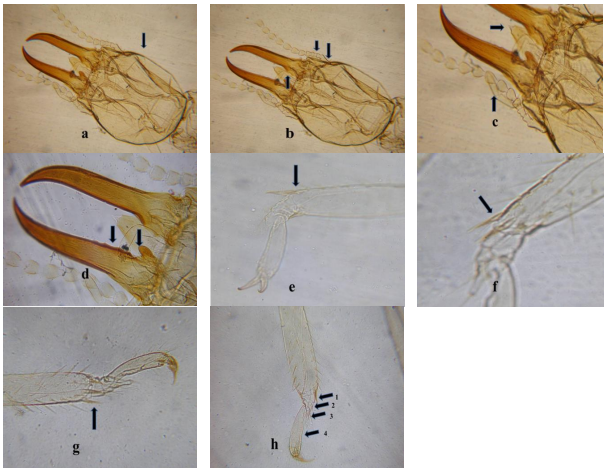

Fig. 1a-h. *Coptotermes emersoni* soldier: a) Head with oval shape, b) Right mandible with 2 crenulations, 1st largest and 3rd smallest antennal segments, c) Labrum with a pointed apex, 13 segmented antennae, d), left mandible with 4 short crenulations and 1 largest present at base, e) Foreleg with 3 tibial spur, f) Midleg with 2 tibial spur, g) Hind-leg with 2 tibial spur, h) Tarsal segments (4).

AUTHOR CONTRIBUTION STATEMENT

All authors contributed to the idea and design of this manuscript. Literature explorations, data study, and first manuscript draft were done by BP. The final manuscript was revised, edited and approved by all authors.

CONFLICT OF INTEREST

The authors declare that there is no competing interest.

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POPULATION DYNAMICS OF *HELICOVERPA ARMIGERA* ON SOYBEAN

Zuhaib Farooq, Mohd. Ayoob Mantoo, Munazah Yaqoob, *Liyaqat Ayoub, Sheikh Salma Irshad, Tauseef Ahmad Bhat[1], Fehim Jeelani Wani[2], Ishfaq Majeed Shah and Showkat Ahmad Sheikh

Division of Entomology; [1]Division of Agronomy,
[2]Division of Agricultural Economics and Statistics, Faculty of Agriculture, Wadura Sopore
Sher-e-Kashmir University of Agricultural Sciences and Tech. of Kashmir, Sopore 193201,
UT of Kashmir, India
*Email: liyaqatayoub@gmail.com (corresponding author)

ABSTRACT

This study on the population dynamites of pod borer *Helicoverpa armigera* (Hubn.) on soybean revealed that it appeared from 29th Standard meteorological week (SMW) (0.40± 0.10 three leaves/ plant). It increased and reached its peak level of 2.67± 0.17/ 3 leaves/ plant during 33rd SMW. The declining trend was observed and reached 0.60± 0.13/ 3 leaves/ plant during 40th SMW. The peak infestation was 48% during 35th SMW. The incidence exhibited non-significant positive correlation with maximum (r= 0.227) and minimum temperature (r= 0.335) and evening relative humidity (RH) (r=0.315); and a significant positive one with morning RH (r= 0.599) and significant negative one with rainfall (r= -0.42). The sunshine was found to be negatively and non-significantly correlated (r = -0.069).

Key words: *Helicoverpa armigera*, infestation, incidence, relative humidity, temperature, rainfall, sunshine hours, correlation coefficients, seasonal incidence

Soybean (*Glycine max* (L.) Merrill) is one of the most important and widely grown oil seed crops in the world. Successful production in soybean cropping systems is hampered due to the incidence of several insect pests. Among these pests, *Helicoverpa armigera* (Hubn.) is a major pest of soybean (Naseri et al., 2009) as with many crops attacking >60 plant species belonging to more than 47 families (such as soybean, cotton, sorghum, maize, sunflower, groundnuts, cowpea, tomato and green pepper) (Zalucki et al., 1994). *Helicoverpa* can attack soybeans at any stage from seedling to pod ripening but are most likely to attack flowering/ podding/ pod fill stages. This noctuid pest is distributed eastwards from southern Europe and Africa through the Indian subcontinent to Southeast Asia, and hence to China, Japan, Australia and the Pacific Islands. This study evaluates its population dynamics at Wadura, Sopore, Kashmir.

MATERIALS AND METHODS

The study was done with the soybean variety "Shalimar Soybean 1" at the FoA, Wadura, Sopore following standard package of practices except pest control. The larval incidence was recorded at weekly intervals from sowing (DAS) up to the last picking of pods. These observations were made from 25 randomly selected plants, and % plant infestation and pod damage was computed. Meteorological data for maximum and minimum temperature (^{0}C), morning and evening relative humidity (%), sunshine (hours) and rainfall (mm) were obtained from the Meteorological observatory of Division of Agronomy, FoA, Wadura Sopore. The larval incidence data were correlated with weather factors using SPSS software.

RESULTS AND DISCUSSION

The incidence of *H. armigera* on soybean during kharif 2020 commenced from 29th standard meteorological week (SMW) (0.40± 0.10/ 3 leaves/ plant); and this reached its peak of 2.67± 0.17/ 3 leaves/ plant during 33rd SMW. Thereafter it declined to 0.60± 0.13/ 3 leaves/ plant during 40th SMW. These results are in line with those of Shivaraju et al. (2011) that the larval activity commenced from 35-40 days after sowing. Motaphale et al. (2019) observed its peak incidence during August. The results revealed that incidence exhibited positive, non-significant correlation with maximum temperature (r= 0.227), minimum temperature (r= 0.335) and evening RH (r=0.315); while it was a positive, significant correlation with morning RH (r= 0.599) and a negative but significant one with rainfall (r= -0.42) while sunshine was found to be negatively correlated (r = -0.069). The regression analysis as depicted in Fig. 1 reveal that the weather

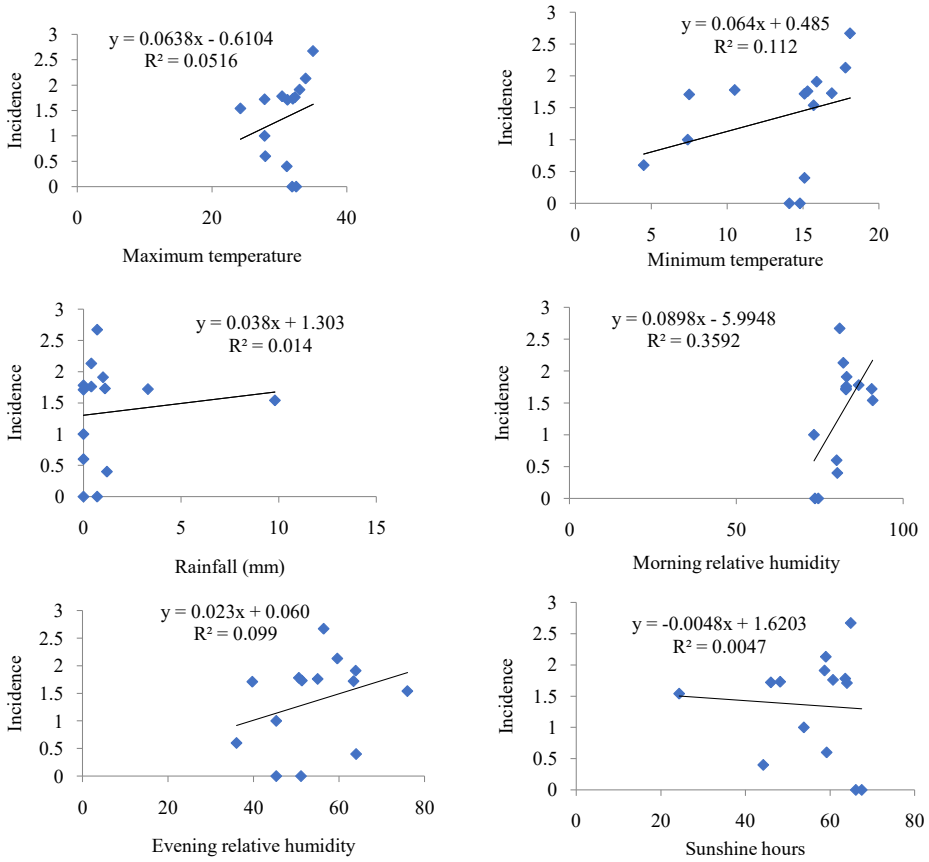

Fig. 1. Population dynamics of *H. armigera* on soybean

factors showed significant effect on the incidence, implying that factors contribute to 61% of incidence. Brahman et al. (2018) reported a positive correlation with maximum and minimum temperature, morning (r = 0.017) and evening RH (r = 0.339) and a non-significant negative one with rainfall. Bangale et al. (2019) observed that the incidence was positively correlated with RH and a negative one with sunshine hours. Mehto et al. (1985) reported a negative non-significant association with bright sunshine hours in cowpea. The pod damage by *H. armigera* in soybean started from 29th SMW and showed an increasing trend up to 35th SMW, and declined thereafter reaching a minimum at 40th SMW. Maximum pod damage (40%) was observed during 35th SMW and pod damage started declining and lowest pod damage (4%) was observed during 40th SMW (Fig. 1).

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NEW DISTRIBUTION RECORDS OF *BACTROCERA* SPP. FROM HIMACHAL PRADESH

Maneesh Pal Singh*, Divender Gupta and Isha Sharma

Department of Entomology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan 173230, Himachal Pradesh, India
*Email: khwww786@gmail.com (corresponding author)

ABSTRACT

Survey undertaken to assess the distribution of fruit fly fauna in Himachal Pradesh revealed new distribution records of two species viz., *Bactrocera watersi* (Hardy) and *Bactrocera zahadi* (Mahmood) observed on cucurbitaceous crops. *Bactrocera zahadi* a member of the *B. tau* complex is a serious pest in the mid and low hills of Himachal Pradesh covering the districts of Una, Hamirpur, Solan, Sirmaur, Chamba and Shimla. It was observed both on fruit and exfruit, while *B. watersi* was observed only from Solan region in traps.

Key words: *Bactrocera* spp., fauna, new distribution records, *Bactrocera zahadi*, *Bactrocera watersi*, cucurbits, Himachal Pradesh, fruit and exfruit, traps

Fruit flies belong to the family Tephritidae (Diptera) and these occur as pests on horticultural crops. *Bactorcera tau*, *B. cucurbitae*, *B. dorsalis*, *B.zonata* and *B. correcta* are the major pests of fruits and vegetables (Kapoor, 2002). *Bactrocera* Macquart is a diversified genus of tribe Dacini with several cryptic species which are pests. Cucurbits are infested by a number of fruit fly species, of which *B. tau* is observed as a major pest throughout the country and its incidence has been serious in Himachal Pradesh (Gupta and Verma, 1991); and *B. tau* and *B. zahadi* (Mahmood) are similar in their morphological features, and also in their host range and distribution, and hence are often confused with each other. This study explored the *Bactrocera* spp., from the mid and high hills of Himachal Pradesh, which resulted in bringing out the new distribution records of *B. zahadi* and *B. watersi* (Hardy) have been recorded.

MATERIALS AND METHODS

Flies were trapped using insecticide-based attractant (cuelure) fruit fly traps installed at Una, Hamirpur, Solan, Sirmaur, Chamba and Shimla. The trap consisted of a polyurethane bottle (250 ml), to which a metal canopy was attached with an aluminium wire; a wooden block of 7.5x 2.5x 2.5 cm size was impregnated with ethanol: methyl eugenol: malathion solution in the ratio 6:4:1 for 48 hr and placed inside the bottle. Another aluminium wire was used to install the bottle trap. In addition, cucurbits with fruit punctures were brought to the laboratory and reared up to adult emergence. The egg laying females were captured from the cucurbits and later the cucumber slices were provided in glass jar, for egg laying in the laboratory, and these were reared to adult. Specimens were side mounted on 00 size entomological pins using glue, and were identified based on keys provided by Drew and Raghu (2002), David and Ramani (2011; 2019), and Drew and Romig (2013). Images of the wings were obtained using ISH1000 camera mounted on Olympus SZX10 binocular microscope in the Department of Entomology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. Virgilo et al. (2015) uplifted this to genus level based on their molecular phylogenetic studies but this study follows Hancock and Drew (2018) and considers the *Zeugodacus* as subgenus of *Bactrocera*.

RESULT AND DISCUSSION

The two new records of the *Bactrocera* observed now are given below:

***Bactrocera (Zeugodacus) watersi* (Hardy, 1954)** (Fig. 1)

It is a large sized (9.1 mm) species, reddish-brown, and can be identified by a broad costal band and broad round apical spot on the wing apex. Scutum bears two lateral and one medial post sutural vittae, median vitta tapering toward both ends, black apical spot is present on scutellum. Narrow black T pattern is present on abdominal tergites, otherwise abdominal tergites red-brown. Only one specimen was captured from Solan district in cuelure trap. Earlier it was recorded from Karnataka and Tamil Nadu (Agarwal and Sueyoshi, 2005; David and Ramani, 2011)

Fig. 1. Habitus of *B. (Zeugodacus) watersi*

Fig. 2. Habitus of *B. (Zeugodacus) zahadi*

***Bactrocera (Zeugodacus) zahadi* (Mahmood, 1999)** (Fig. 2)

It is a medium sized (6.1± 0.062 mm) reddish brown species with irregular to round facial black spot. Scutum is reddish-brown, few specimen with dark patches at laterally. Both lateral and median postsutural vittae present. Supernumerary lobe is strong, depressed and keel shaped. *B. zahadi* is similar to *B. tau*, but can be differentiated by the presence of prominent black markings on apex of all femora and wing with depressed keel shapes strongly developed anal lobe while *B. tau* have round to keel shaped medium developed anal lobe (Fig. 1). Glans densely covered with vasica in case of *B. zahadi*. It has been trapped in large number from Himachal Pradesh with the maximum trap catch being from Solan district (32± 3.14) and minimum being from Chamba (8.4± 1.93) district, as compared to Una (22.4± 2.97), Hamirpur (13.8± 3.23), Shimla (8.4± 1.93) and Sirmaur (24.2± 1.98); *B. zahadi* can be easily mistaken as *B. tau* but can easily be differentiated by depressed keel shaped anal lobe in *B. zahadi* whereas the anal lobe is round keel like and weak in *B. tau* (Fig. 1). There is confusion between *B. tau* and *B. zahadi* but with the help of some peculiar characters such as wing and genitalia morphology (David Ramani, 2019) both the species can be differentiated. Infuscation of costal band below the vein R_{2+3} is considered as different from the *B. tau* but it is generally variable in both the species and the infuscation can be seen in both, it may depend on environment. Earlier it was recorded from Karnataka, Kerala, Tamil Nadu and Tripura (Agarwal and Sueyoshi, 2005; David and Ramani, 2011; David and Ramani, 2019).

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THRIPS VECTORS OF TOSPOVIRUSES ON TOMATO IN SOUTH INDIA

R Aravintharaj* and R Asokan

Division of Basic Sciences,
ICAR-Indian Institute of Horticultural Research, Bengaluru 560089, Karnataka, India
*Email: aaravindr@gmail.com (corresponding author)

ABSTRACT

The present study was undertaken to determine distribution of thrips species from major tomato growing regions in South India (Tamil Nadu, Karnataka, Maharashtra, Telangana, Andhra Pradesh). The thrips species were identified using molecular techniques employing universal barcoding primer (mt-COI). These revealed the presence of six species viz., *Thrips palmi* Karny, *Scirtothrips dorsalis* Hood, *Thrips tabaci* Lindeman, *Frankliniella schultzei* (Trybom), *Thrips apicatus* Priesner and *Tusothrips sumatrensis* (Karny). Of these, *T. palmi* was found to be predominant in all the states surveyed followed by *S. dorsalis*, *F. schultzei* and *T. tabaci*.

Key words: *Thrips palmi*, *Thrips tabaci*, *Thrips apicatus*, *Scirtothrips dorsalis*, *Frankliniella schultzei*, *Tusothrips sumatrensis*, species identity, mtCOI, phylogenetic analysis, tomato

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop in India, and in 2017 its production was 19.76 mt and a rise of 2% in production is expected in coming years (APEDA, 2017). Tomato cultivation is affected by biotic factors like insect pests, bacteria, fungus and viral diseases. Among the insect pests, thrips (Thysanoptera: Thripidae) cause significant damage and globally about 15 species are known, as pests or vectors (German et al., 1992). Thrips alone can transmit tospoviruses to 15 monocotyledonous and 69 dicotyledonous plants (Pappu et al., 2009). Tospoviruses are the major constraints in tomato production too, and of these *Groundnut Bud Necrosis Virus* (GBNV) has been found to be major constraint causing up to 100% damage (Kunkalikar et al., 2011). Other tospoviruses such as *Capsicum Chlorosis Virus* (CaCV), *Groundnut Bud Necrosis Virus* (GBNV) and *Watermelon Bud Necrosis Virus* (WBNV) have also been reported on tomato from the Indian subcontinent. These viruses can infect crops alone or as mixed infections (Kunkalikar et al., 2011). Of the 15 species that transmit tospovirus, only six species, *Frankliniella occidentalis* (Pergande), *F. schultzei* Moulton, *Ceratothripoides claratris* Shumsher, *Scirtothrips dorsalis* Hood, *Thrips palmi* Karny, and *T. tabaci* (Lindeman) are reported from India (Ullman 1997; Jones 2005; Pappu et al., 2009; Ciuffo et al., 2010; Hassani-Mehraban et al., 2010; Riley et al., 2011; Zhou and Tzanetakis 2013). Information on prevalence and species composition of thrips transmitting virus on tomato is still inadequate. Hence, the present study to determine the thrips species complex in tomato using DNA barcodes.

MATERIALS AND METHODS

Thrips were collected from Andhra Pradesh, Karnataka, Telangana, Maharashtra and Tamil Nadu during November 2018 to August 2019 in 70% ethanol and stored at 4^{O}C for further studies. Permanent slide mounts were prepared with digestion process using methodology of Mound and Kibby (1998). Photographs were taken in a compound microscope (Leica DM-1000) using Leica software application suite (LAS EZ 2.1.0). For molecular identification, DNA was isolated from single thrips employing CTAB method with little modification (Asokan et al., 2011). PCR was performed in 25 µl total reaction volume containing 5µl of isolated genomic DNA (50-100 ng/ µl) followed by 1.0 µl of forward primer and 1.0 µl of reverse primer of 20 p moles of each primer, 2.5 µl of 10 mMTris Buffer (pH-8.3), 0.5µl of 2.5 mM $MgCl_2$, 1.0 µl of dNTP mixture (0.25 mM of each dNTP) and 0.5 µl of (0.5 U concentration) Taq DNA polymerase (GeNei^{TM,} Genei laboratories Pvt ltd). PCR amplification performed in a thermal cycler (TECHNC,TC-512) with the following cycles: 94^{O}C for 2 min as initial denaturation followed by 35 cycles of 94^{O}C for 45 sec, 47^{O}C for 45 sec, 72^{O}C for 45 sec and final extension for 72^{O}C for 10 min. Universal Mitochondrial cytochrome oxidase I (CO-I) primers used as follows (LCO-1490- 5' - GGTCAACAAATC ATAAAGATATTGG -3'; HCO-2198- 5' - TAAACTTCAGGGTGACCAAAAAATCA

-3') (Hebert et al., 2003a and Hebert et al., 2003b) and resolved in 1.5% agarose gel, stained with 0.5µg/ ml ethidium bromide and documented in a gel documentation system (UVP). Amplified PCR Products were purified using gel extraction kit (Nucleospin® Extract II, Macherey Nagel, Germany) and cloned in to PTZ57R/T vector (Thermo Fisher Scientific, UK). Competent *Escherichia coli* (DH5α) cells were used to clone the PCR products and further blue-white selection carried out. Plasmids were isolated using GenJET™ plasmid MiniPrep kit (Fermentas Life Sciences, UK), as per manufacturers protocol. Three independent clones selected for each sample were sequenced using M13 forward and reverse primers (Ms. Medauxin, Bengaluru, India). NCBI-BLAST (Basic Local Alignment Search Tool) (http://blast.ncbi.nlm.nih.gov/) tool was used for analysing the sequence homology. Sequence alignment was done in BioEdit (version 7.0.9.0) (Hall et al., 1999) and phylogenetic tree was constructed in MEGA.7.0 software (Kumar et al., 1993).

RESULTS AND DISCUSSION

The genomic DNA of all six thrips were isolated. All the samples were amplified with amplicon size of ~ 700bp. Not all six species of thrips were present in a single location/ region on tomato. Five species (*T. palmi, S.dorsalis, F.schultzei, T.apicatus* and *T. sumatrensis*) were observed in Karnataka; only *T. palmi* was present in all the sampled locations of Telangana (Table 1) *Thrips palmi* mtCOI sequence analyzed via BLAST showed an identification of 99.85% with USA *T. Palmi* sequences (KX233569). *Scirtothrips dorsalis* was present in all the states except Telangana, and revealed 99.85% identity with KM355512 Indian isolate. *Thrips tabaci* was present only in Tamil Nadu and Maharashtra (Tamil Nadu-2 and Maharashtra-1), and KF036290 USA isolate was found to have 100% identity. *Frankliniella schultzei* occurs in Karnataka and Tamil Nadu (Karnatak-2; Tamil Nadu-4) and has 100% identity with Pakistan sequence (HQ990721); and 99.85% identity with Indian isolates (MK333280). *Thrips apicatus* and *Tusothrips sumatrensis* were observed only in Karnataka, and corresponding identity was of 100% (KX622321) and 97.37% (KX622448).

Phylogenetic tree was constructed by maximum likelihood (ML) tree method using mt-COI sequence obtained from all *Thrips* spp (Fig. 1). All thrips sequences are precisely grouped in three clades corresponding to three genera of Thysanoptera (*Thrips* spp., *Scirtothrips* spp. and *Frankliniella* spp.). The present results agree with earlier ones of Boykin et al. (2007). In all locations *T. palmi* stood out as single subgroup; in that five samples (Devarayapuram, Hosur, Oddanchatram, Shoolagiri and Mecheri of Tamil Nadu) along with one from Maharashtra (Narayanagaon) formed a separate clade; and *T. tabaci* and *T. apicatus* were also found associated in the same group; while *F. schultzei* went in separate group- in that two subgroups were formed (samples from Manaparai and Surandai locations of Tamil Nadu falls in one), while those from Bandigere, Kavalande, Mussenalu and ICAR-IIHR fell in another subgroup. Samples of *S. dorsalis* irrespective of locaztions formed a single group. *Tusothrips sumtrensis* (from Sivakotai) was in separate group as it was only found from Karnataka.

Earlier reports suggested that thrips like *S. dorsalis* (German et al., 1992; Meena et al., 2005), *T. palmi* (Lakshmi et al., 1995; Meena et al., 2005; Reddy et al., 1992) and *F. schultzei* (Meena et al., 2005) were observed as putative vectors for GBNV, whereas *T. tabaci* could transmit *Tomato spotted wilt virus* (TSWV) (Wijkamp et al., 1995). In NCBI few entries were available related to *Tusothrips sumatrensis and T. apicatus*. Tyagi and Kumar (2014) reported *T. apicatus* from Himachal Pradesh, India. In the present study majority were GBNV vectors like *T.palmi* followed by *S. dorsalis and F. schultzei*. Thus, all the five states surveyed stand a great risk of GBNV infection; whereas Tamil Nadu and Maharashtra need to be cautious about TSWV infection due to prevalence of *T. tabaci*.

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Table 1. Thrips spp. collected from major tomato regions in South India

S. No.	Location	Latitude and longitude	Thrips spp.	NCBI Acc. No
1.	Hosur, Krishnagiri, Tamil Nadu, India	12.4621.3°N 77.5200.5°E	*Thrips palmi*	MN972622
2.	Shoolagiri, Krishnagiri, Tamil Nadu, India	12.4003.4°N 78.0037.1°E	*Thrips palmi*	MN972623
3.	Devarayapuram, Coimbatore, Tamil Nadu, India	10.5948.8°N 76.4907.1°E	*Thrips palmi*	MN972624
4.	Kinathukadavu, Coimbatore, Tamil Nadu, India	10.4852.6°N 77.0133.0°E	*Thrips tabaci*	MN972625
5.	Mecheri, Salem, Tamil Nadu, India	11.4806.3°N 77.5836.6°E	*Thrips palmi*	MN972626
6.	Manapari, Trichy, Tamil Nadu, India	10.3707.9°N 78.2515.1°E	*Frankliniella schultzei*	MN972627
7.	Sembatti, Dindigul, Tamil Nadu, India	10.1818.6°N 77.5151.6°E	Nil	
8.	Oddanchatram, Dindigul, Tamil Nadu, India	10.3041.8°N 77.4442.8°E	*Thrips palmi*	MN972628
9.	Pavoorchatram, Thirunelveli, Tamil Nadu, India	8.5523.7°N 77.2256.5°E	*Scirtothrips dorsalis*	MN972629
10.	Kilapavoor, Thirunelveli, Tamil Nadu, India	8.5418.5°N 77.2356.3°E	*Thrips tabaci*	MN972630
11.	Surandai, Thirunelveli, Tamil Nadu, India	8.5850.9°N 77.2443.7°E	*Frankliniella schultzei*	MN972631
12.	Nyamathi, Shimogga ,Karnataka, India	14.0405.1°N 75.3617.3°E	*Thrips palmi*	MN972632
13.	Mussenalu, Shimogga, Karnataka, India	14.0353.2°N 75.3626.7°E	*Frankliniella schultzei*	MN972633
14.	Kadgamdoddi, Raichur, Karnataka, India	16.1354.5°N 77.2557.4°E	*Thrips palmi*	MN972634
15.	UAS-Raichur, Karnataka, India	16.1146.1°N 77.1850.7°E	*Scirtothrips dorsalis*	MN972635
16.	Mangasandra, Kolar, Karnataka, India	13.0606.3°N 78.0451.3°E	*Thrips palmi*	MN972636
17.	Chintamani, Kolar, Karnataka, India	13.2534.5°N 78.0426.7°E	*Scirtothrips dorsalis*	MN972637
18.	Budumanahalli, Bengaluru, Karnataka, India	13.1134.7°N 77.3144.7°E	*Thrips palmi*	MN972638
19.	Thambarsnhalli, Bengaluru, Karnataka, India	13.0717.8°N, 77.29392°E	Nil	
20.	Sivakottai, Bengaluru, Karnataka, India	13.0735.9°N 77.3058.2°E	*Tusothrips sumatrensis*	MN972639
21.	ICAR-IIHR, Bengaluru, Karnataka, India	13.0811.0°N 77.2952.6°E	*Frankliniella schultzei*	MN972640
22.	Shanthigrama, Hassan, Karnataka, India	12.5843.9°N 76.1245.2°E	Nil	
23.	Malali, Hassan, Karnataka, India	16.2057.1°N 75.1201.0°E	*Thrips palmi*	MN972641
24.	Kavalande, Mysuru, Karnataka, India	12.0150.6°N 76.4805.8°E	*Frankliniella schultzei*	MN972642
25.	Mulluru, Mysuru, Karnataka, India	12.1438.4°N 76.3321.2°E	Nil	
26.	Thagadooru, Mysuru, Karnataka, India	12.0554.8°N 76.4745.5°E	*Thrips palmi*	MN972643
27.	Chikkarasikere, Mandya, Karnataka, India	12.3041.8°N 77.0241.0°E	*Thrips apicatus*	MN972644

(contd.)

(Table 1 contd.)

28.	Doddegowdanakoppalu, Mandya, Karnataka, India	12.2617.6°N 76.3933.8°E	*Scirtothrips dorsalis*	MN972645
29.	Magala, Chamrajnagar, Karnataka, India	14.5950.4°N 75.4834.4°E	Nil	
30.	Bandigere, Chamrajnagar, Karnataka, India	11.5214.9°N 76.5721.1°E	*Frankliniella schultzei*	MN972646
31.	Narayanagov, Pune, Maharashtra, India	19.0801.3°N 73.5738.6°E	*Thrips palmi*	MN972647
32.	Saswad, Pune, Maharashtra, India	18.2113.0°N 74.0241.7°E	*Scirtothrips dorsalis*	MN972648
33.	Chondoli, Pune, Maharashtra, India	18.5049.6°N 73.5136.0°E	*Thrips palmi*	MN972649
34.	Rajgurunagar, Pune, Maharashtra, India	18.5102.8°N 73.5348.2°E	*Thrips tabaci*	MN972650
35.	Kowdipally, Medak, Telengana, India	17.5230.7°N 78.1214.6°E	Nil	
36.	Polepalle, Mahbubnagar, Telengana, India	16.4841.7°N 78.0830.6°E	*Thrips palmi*	MN972651
37.	Nuthimadugu, Anantapur, Andhra Pradesh, India	14.2914.9°N 77.1941.0°E	*Scirtothrips dorsalis*	MN972652
38.	Tekmal, Kurnool, Andhra Pradesh, India	17.5848.2°N 78.0146.0°E	*Thrips palmi*	MN972653

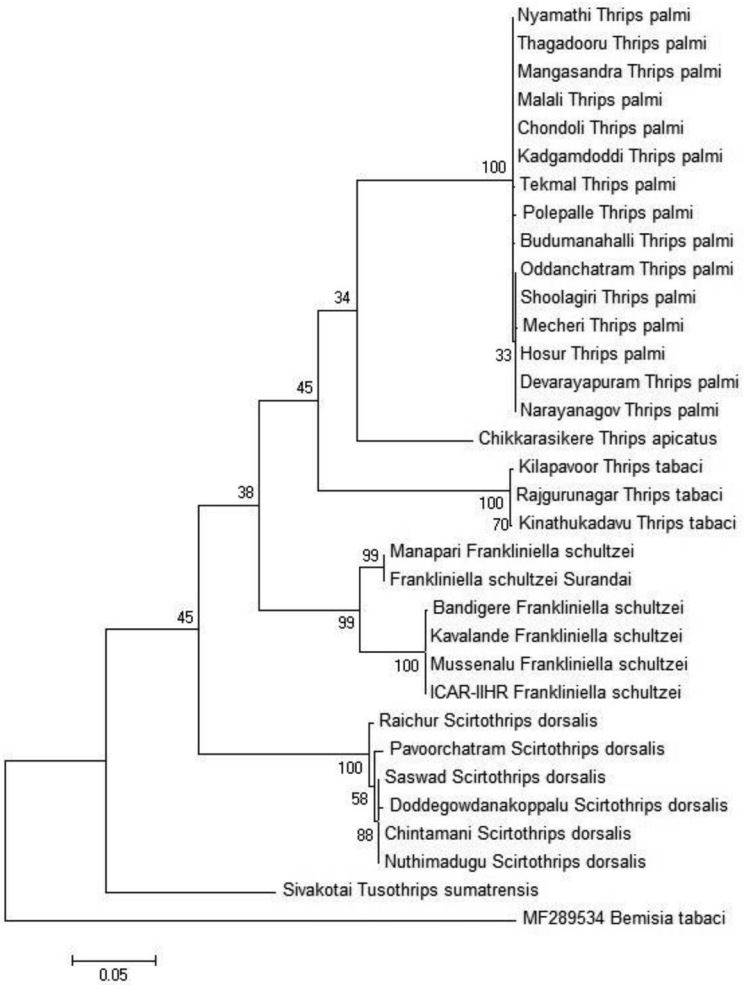

Fig. 1. Maximum-likelihood tree for *Thrips* spp., based on 655bp length fragment of the mt-COI gene. The tree was obtained by using the Kimura's 2 parameter (K2P) distance with 1000 bootstrap replicates. *Bemisia tabaci* is used as out-group

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SEASONAL INCIDENCE OF MAJOR INSECT PESTS OF JASMINE *JASMINUM SAMBAC* L.

U Pirithiraj*, R P Soundararajan[1] and C Gailce Leo Justin[2]

Department of Agricultural Entomology, Tamil Nadu Agricultural University (TNAU), Coimbatore 641003, Tamil Nadu, India
[1]Horticultural College and Research Institute (Women); [2]Anbil Dharmalingam Agricultural College and Research Institute (TNAU), Tiruchirappalli 620027, Tamil Nadu, India
*Email: u.pirithiraj@gmail.com (corresponding author)

ABSTRACT

Jasmine *Jasminum sambac* L. is an important ornamental crop that fetches recurrent income to farmers. The present study was carried out in three locations Sevandhanagar, Navalurkuttappattu and Horticulture farm, TNAU, Tiruchirappalli, Tamil Nadu, India from August 2019 to September 2020. The seasonal incidence of major insect pests such as *Hendecasis duplifascialis* Hampson, *Nausinoe geometralis* Guenee, *Contarinia maculipennis* Felt, *Frankliniella scultzei* Trybom and *Tetranychus urticae* Koch were studied. *Hendecasis duplifascialis* incidence was observed to be maximum (31.63% damaged buds) in second fortnight of October in Sevandhanagar; in Navalurkuttappattu, it was the incidence of *N. geometralis* (2.2 webs/ plant) that was maximum, and noticed in the second fortnight of December. In horticulture farm, maximum damage was of *C. maculipennis* (48.66% damaged buds) noticed in the second fortnight of September. Thrips population was significant and was observed positively correlated with maximum temperature in Sevandhanagar (r = 0.55).

Key words: *Jasminum sambac*, pest incidence, *Hendecasis duplifascialis*, *Nausinoe geometralis, Contarinia maculipennis, Frankliniella scultzei, Tetranychus urticae*, weather factors, correlation coefficient, linear regression

Jasmine is an important ornamental flower crop, known for its attractive and fragrant flowers (Rahman et al., 2011). Tamil Nadu ranks first with annual production of 1,38,280 mt. The first GI tag given to a flower in Tamil Nadu is Madurai Malli (jasmine) (Vandhana, 2013; Narasimhan, 2014). The genus *Jasminum* has more than 200 species, of which 40 are indigenous to India (Irulappan, 1994; Thakur et al., 2014). Among these, *Jasminum sambac*, *J. auriculatum* and *J. grandiflorum* are commercially cultivated (Green and Miller, 2009). The jasmine crops were habitually infested by bud worm *Hendecasis duplifascialis* Hampson, leaf web worm *Nausinoe geometralis* Guenee, blossom midge *Contarinia maculipennis* Felt, thrips *Frankliniella scultzei* Trybom and red spider mite *Tetranychus urticae* Koch. Conducive weather and the crop phenology of jasmine invite and favors the biology, growth and development of these pests. These pests are present in the crop during most of the cropping seasons with fluctuations in infestation due to weather factors. Studies on population dynamics of pests is essential not only to predict their severity but also to frame season based IPM practices (Harini et al., 2018; Kamala and Kennedy, 2018). Few attempts were made to explore the insect pest occurrence in jasmine. Hence, the present study focused on studying the influence of weather parameters on the incidence of major pests of jasmine.

MATERIALS AND METHODS

Field studies were conducted at three locations in Tiruchirappalli district of Tamil Nadu from August first fortnight, 2019 to September second fortnight, 2020. The locations include two villages namely Sevandhanagar (Location 1, Farmer's field, 10.78471°N,78.56833°E) and Navalurkuttappattu (Location 2, Farmer field, 10.755655°N 78.606448°E) and Horticultural farm (Location 3, TNAU, Tiruchirappalli, 10.75558°N 78.60280°E). Seasonal incidence of insect pests in jasmine plants was recorded in 10 randomly selected/ tagged plants. Fortnightly observations were made on the incidence of *H. duplifascialis*, *C. maculipennis*, *N. geometralis*, *T. urticae* and *F. scultzei*. Standard methodologies were followed to record the incidence of these (Sudhir, 2002; Neelima, 2005). The extent of damage by *H. duplifascialis* was assessed by recording number of total and bored buds in five randomly selected shoots/ plant, and expressed in %; *C. maculipennis* damage was also assessed by similar protocol and expressed in % bored buds; and *N. geometralis* was assessed by recording the total number of webbings made by the

larvae and expressed as number of webs/ plant. Total number of *T. urticae* present on apical three leaves of plant were collected and brought to laboratory. Then counted under microscope and expressed as number of mites/ leaf. Three flower clusters, each from the bottom, middle and top canopy were selected and beaten against white cardboard sheet and the thrips collected were counted. The incidence of *F. scultzei* was expressed as number of thrips/ flower cluster (Pirithiraj et al., 2020). The damage % with standard error was worked out for each fortnight data for all the insect pests. Cumulative incidence was worked out in three fields in Sevandhanagar. Weather data such as maximum and minimum temperature, morning and evening relative humidity, wind velocity, sunshine hours, evaporation and rainfall were obtained from the meteorological observatory, Department of Agronomy, Anbil Dharmalingam Agricultural College and Research Institute, Tamil Nadu Agricultural University, Tiruchirappalli, Tamil Nadu, India. Mean data on seasonal incidence of insect pests were used to correlate with weather parameters. Regression equation was worked out for each location to assess the influence of weather parameters.

RESULTS AND DISCUSSION

The onservations revealed a significant variation in the incidence of pests in three locations. Pirithiraj et al. (2021) recorded significant variation in population of herbivores in different fields of jasmine. *Hendecasis duplifascialis* incidence was maximum (31.63% damaged buds) in second fortnight of October at Sevandhanagar fields; in the same second fortnight, it was 11.50 and 0.00% in Navalurkuttapattu and Horticulture farm, respectively. Maximum incidence of *H. duplifascialis* (31.94%) was observed in February second fortnight (Neelima, 2005). Kiran et al. (2017) noticed its maximum occurrence in August first fortnight (31.87 %); while a maximum (21.50% bored buds) was recorded in September, and minimum was in November 2001 (Vanitha, 2001). Bud borer of sapota crop was recorded throughout the year and maximum was in March (Sathish et al., 2014). With sapota bud borer *Anarsia achrasella*, maximum damage was 53% (Jayanthi et al., 2006); and with *Maruca vitrata* it was second week of July in pigeon pea (Jat et al., 2017). In Navalurkuttappattu, maximum incidence of *N. geometralis* (2.2 webs/ plant) was in the second fortnight of December (Fig. 1). Kiran et al. (2017) reported the nil incidence of *N. geometralis* during December to April and maximum was observed during first fortnight of November (4.6 webs/ plant). In Navalurkuttappattu, the regression equation fitted with weather parameter was $Y = 11.38 - 0.03X_1 - 0.15X_2 - 0.08X_4 - 0.02X_5 - 0.11X_6 - 0.26X_7$. The R^2 obtained in Navalurkuttappattu was 0.6388 which indicates that the weather parameters influence the pest by 63.88%.

In College horticulture farm, the highest mean damage of *C. maculipennis* (48.66% damaged buds) was noticed in the second fortnight of September. Whereas in the same second fortnight of September, Sevandhanagar and Navalurkuttappattu had a bud damage of 40.33 and 15.64 % respectively. Maximum incidence of blossom midge was recorded in Madurai district of Tamil Nadu (Kamala, 2020a). Jayasheelan and Allwin (2018) reported the maximum occurrence

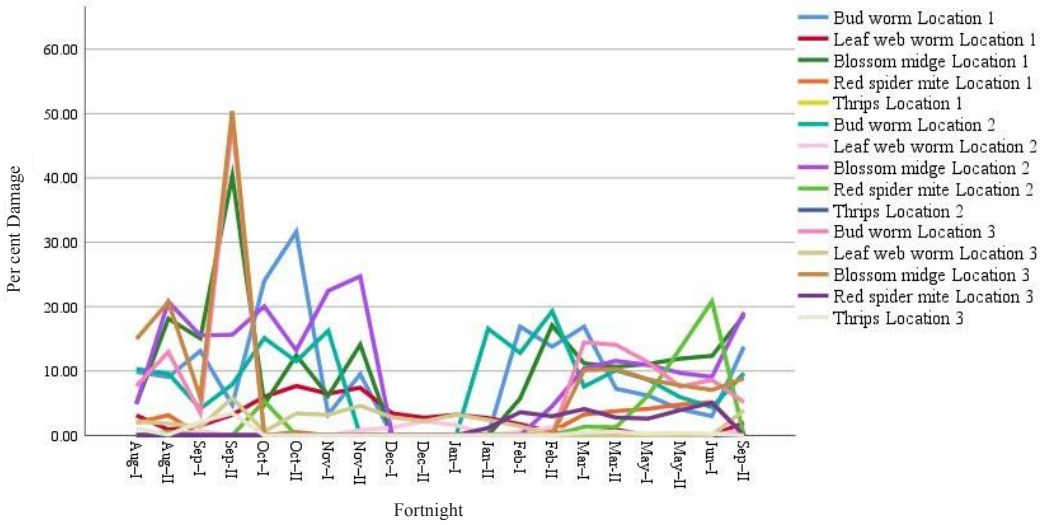

Fig. 1. Seasonal incidence of major insect pests of jasmine

of the midge in April and minimum was in November. However, the midge, *Asphondylia capsici* was maximum of 62% in chilli crop during the period (Divya et al., 2018); and maximum in chilli was 63.79% during 50th standard mean week of 2008-09 (Pathipati et al., 2014). In Navalurkuttappattu the midge damage has a significant positive correlation (r = 0.47*) with minimum temperature. However, in Navalurkuttappattu and Sevandhanagar the blossom midge damage was comparatively less than the damage of *H. duplifascialis* in certain fortnights and vice-versa. There is limited evidence for interspecific competition while comparing intraspecific competition (Jermy, 1985). Competition between phytophagous insect occurs if they were closely related, sessile and feed on discrete resource. Wang et al. (2011) reported the displacement of one species of thrips by other by means of interspecific interaction in purple cabbage.

In Navalurkuttappattu, maximum incidence of *T. urticae* was noticed during first fortnight of June (20.83 mites/ leaf), while it was 5.15 and 5.06 mites/ leaf in Sevandhanagar and Horticulture farm, respectively. Neelima (2005) studied the seasonal occurrence of red spider mite and reported no population in July (second fortnight) to March (second fortnight). Shah et al., 2014 reported maximum incidence of red spider mite in July, also in the 12th standard week on rose plants (Norboo et al., 2017). Maximum mite population density of 11.72/ 2 cm^2 was recorded in 2015 on tomato plants (Premalatha et al., 2016). In Sevandhanagar, the regression equation fitted with weather parameter was $Y = -24.28+1.11X_1-0.57X_2+0.03X_3+0.02X_4-0.23X_5-0.59X_6+0.46X_7-0.01X_8$. This indicates one unit rise in maximum temperature will increase the number of mites by 1.11/ leaf. Shukla et al. (2015) recorded significant and positive correlation between mites and average temperature. Putri et al. (2021) reported an increase in 1°C of maximum temperature would lead to an increase of 1.342 numbers of two spotted spider mite. In Sevandhanagar and Navalurkuttappattu, no incidence of mite was observed during the first fortnight of September whereas in horticulture farm, thrips population was maximum during (4.12 thrips/ flower cluster). Kiran et al. (2017) observed maximum thrips incidence during May first fortnight and no incidence during June- September. Gopal et al. (2018) noticed maximum thrips incidence in chilli crop during 3rd standard week. Thrips population was significant and positively correlated with maximum temperature in Sevandhanagar (r = 0.55**).

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AUTHOR CONTRIBUTION STATEMENT

UP conducted the experiment and drafted the manuscript. RPS conceptualized the research idea and fine-tuned the manuscript. CGLJ succour throughout the research work and publication. All authors read and approved the manuscript.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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BIONOMICS OF *CRYPTOPHLEBIA OMBRODELTA* LOWER A MAJOR PEST OF TAMARIND

Rajesh Kumar Patel*, Vandana Chadar, N C Mandawi and Y P S Nirala

Department of Entomology, S G College of Agriculture and Research Station, Jagdalpur
Indira Gandhi Krishi Vishwavidyalaya, Raipur 492012, Chhattisgarh, India
*Email: patelrk337@gmail.com (corresponding author)

ABSTRACT

The moth C*ryptophlebia ombrodelta* (Lower) is a destructive pest on tamarind, *Tamarindus indica*. Its biology and morphometrics are presented herein with rearing done in the laboratory. The mature larva measures about 1.7 to 2.14 cm (2.12 cm), with pinkish body. The moth is grey, with female laying pale yellowish to white, flat and rounded eggs near the peduncle joint of pod (fruit) or on the pod surface. The eggs hatch 6 to 9 days. The affected pods can be recognized by the entrance hole packed with excreta. It causes about 42% loss to tamarind fruits and completes 3 to 4 generations/ year.

Key words: *Cryptophlebia ombrodelta*, Lepidoptera, Tortricidae, tamarind, pest, loss, biology, lifestages, morphometrics, eggs, larva, pupa, adult

The eucosmid (olethreutid) moth *Cryptophlebia ombrodelta* Lower was described from Sydney by Oswald B Lower in 1898 under the name *Arotrophora ombrodelta* Lower (Tindale, 1955). The synonyms of *C. ombrodelta* are: *Arotrophora ombrodelta* (Lower); *C. carpophaga* (Walshingham, 1900); *Pogonozada* (Hampson 1905); and *Thaumatotibia* (Zacher 1915). Twenty two species of this genus are known so far, of which *C. illepida* (Butler), *C. ombrodelta* (Lower) and *C. peltastica* are considered to be major pests (Bradley, 1953). *Cryptophlebia ombrodelta* is reported from India, Sri Lanka, Nepal, Indonesia, China, Taiwan, Vietnam, Thailand, western Malaysia, New Guinea, Philippines, Japan, Guam, Australia and Hawaii. It is considered a pest of legumes. It has been reported to be an important pest of macadamia, litchi, and longan fruit in Asia, Australia and Hawaii (Jones, 1995). The pest is commonly known as tortrix moth, litchi fruit moth, macadamia nut borer and tamarind fruit borer. This study provides some details of its biology and morphometrics.

MATERIALS AND METHODS

Biology of *C. ombrodelta* was studied in the laboratory (21-32^{o}C, 68-80%RH) in Shaheed Gundadhoor College of Agriculture and Research Station, Jagdalpur (Bastar). Mature pupae were collected from infested fruits of tamarind and reared in plastic cages of size 26 x 15 x7.5 cm. Emerged adults were allowed to lay eggs in the rearing cage. The open end of the rearing cage were covered with fine cloth and tightened with rubber bands. Egg hatchability was studied in petridishes. The larval, pupal and adult durations were also recorded with rearing done under petridishes. Observations from egg to adult stages were recorded at 24 hr interval.

RESULTS AND DISCUSSION

The adults of *C. ombrodelta* mate in shady and cool places during day time, and lays eggs singly. These egg are pale yellowish white, flat and rounded, with irregular lines on their chorion. After 3-4 days, these have their chorion beautifully sculptured with pinkish red spots, and finally become blackish, and measure 1 mm in dia. These are laid in small groups of about 15 eggs on surface of the pod. Newly emerged larva is about 0.4-0.6 cm long, with average of 0.6 cm. It is creamy-white, with black head, and enters into the fruit from pedicel joint and rarely from middle of the fruit. Larvae feed up to 3-5 cm length of fruit to attain its maturity. Mature larva measure about 1.7- 2.14 cm long (2.12 cm) and are pinkish, with head dark reddish and partly retractable in the prothorax. The antennae are small and 3-joineted. Thorax bears 3-jointed legs and the prolegs are borne by the 3rd, 4th, 5th, 6th and 10th abdominal segments. Pupa is obtect, adecticous type and dark reddish, covered within the silken cocoon. It measures about 0.8-1.1 cm long (0.96 cm), 0.25-0.35 cm broad. About 10 segments are distinct from above. The eyes are small and dark black, antennae and legs are fused ventrally. Anus lies ventrally on the 10th segment. Three to four generations are completed till maturity of the fruit, and it is more fertile from July to September, with eggs laid singly or in group of 1-3 near the peduncle joint of fruit.

1 2 3 4 5 6

Figs. 1-6. *Cryptophlebia ombrodelta* 1. Newly laid egg, 2. First instar larva, 3. Mature larva, 4. Pupa, 5. Female moth, 6. Male moth

The eggs hatch in 6 - 9 days, with embryo when fully developed within the chorion making a hole and thrusts its body slowly through this opening. Newly emerged tiny larva bites a small hole into the fruit and begins to feed. The larva as it grows continues to make tunnels within the fruit. In general, one larva is seen in a single fruit but 1-3 larvae may be present. The larval instars are from five to six, occupying 18- 23 days, with fully fed larva pupating in the larval tunnel under a silken cocoon covered with its excreta. Pupal period lasts for 12-16 days, with moth emerging by rupturing the pupal coat of silken covering, and flying away (Fig. 1-6). It is distributed in India, Sri Lanka, Nepal, Indonesia, China, Taiwan, Vietnam, Thailand, West Malaysia, New Guinea, Philippines, Japan, Guam, Caroline Is., Australia and Hawaii (Robinson et al. 1994). In India, it is distributed all over the tamarind growing area of Chhattisgarh such as Bastar, Dantewada, Narayanpur, Bijapur, Kondagaon, Dhamtari and some parts of Rajnandgaon, Sarguja and Raigarh. It can cause severe damage up to 42%, with a single larva damaging about 3-5 cm length of fruit prior to pupation. Larvae are polyphagous and have been observed feeding on plants in several families. Recorded food plants are *Tamarindus indica, Parkinsonia aculeata*, *Cassia fistula*, *Cassia occidentalis*, *Senna occidentalis*, *Cassia alata*, *Cassia sophera*, *Cassia bicapsularis*, *Nephelium litchi*, *Acacia* sp, *Aegle marmelos*, *Sesbania aculeata*, *Sesbania grandiflora*, *Feronia*, *Adenanthera pavonia*, *Filicium decipiens*, *Bauhinia hirsuta*, *Bauhinia purpurea*, *Bauhinia malabarica*, *Parkia*, *Prosopis juliflora*, *Cocoloba uvifera*, *Phaseolus lunatus*, *Poinciana pulcherrima* and *Pithecellobium dulce,* citrus, coconut.

Singh (2014) reported that the damage of borer started at the green fruit stage and went up almost till the maturity stage in bael and tamarind. The females lay eggs on the fruits surface and larvae bore into the fruit. Inside the fruit, the larvae feed on the pulp and seed and remained in until adult emergence. Pupation occurred in the fruit near the rind and the adult emerged through an already made borehole leaving behind the puparium attached to exit hole on the fruit surface. Adults are brown to reddish brown with a dark-brown pretornal spot that was more pronounced in females. Late instar larvae were approximately 13-20 mm long. The abdomen is yellowish white, turning reddish in the final instar. The head and prothoracic shield were black or dark brown in the early instars, turning pale or yellowish brown in the final instar. These observations corroborate with the present findings. Sinclair (1974) reported that the *C. ombrodelta* was reared satisfactorily on an artificial medium. The use of head capsule widths to identify larval instars was complicated by the variable number of instars (five to six).

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DIVERSITY OF INSECT POLLINATORS ON SESAME

Selvakumari G, B Usha Rani[1]*, K Suresh[2], G Anand[2] and M Shanthi

Department of Agricultural Entomology; [1]ICAR- Krishi Vigyan Kendra, Agricultural College and Research Institute, Madurai 625104, Tamil Nadu, India
[2]Cotton Research Station, TNAU, Srivilliputhur 626135, Tamil Nadu, India
*Email: ushateja@yahoo.com (corresponding author)

ABSTRACT

Field experiment was carried out to explore the pollinator fauna and their abundance and diversity on sesamum. The results revealed 19 pollinators belonging to six families from three orders viz., Hymenoptera, Diptera and Coleoptera. Among these the order Hymenoptera was predominant having 15 species with maximum relative abundance. Foraging behaviour of *Apis* sp. was more (4.19 individuals/ m^2/ 5 min) and non *Apis* sp. was less (1.12 individuals/ m^2/ 5 min). Eventhough Diptera and Coleoptera shared equal number of species, the foraging behaviour and abundance was maximum with Diptera (1.02 individuals/ m^2/ 5 min). The sesamum ecosystem flourished with pollinators during 0800- 1000 and 1000- 1200 hr with higher diversity indices of Shannon's H (2.52) during 1000- 1200 hr and Simpson's D index (0.22) between 1600- 1800 hr. Shannon's E index was higher (0.85) during 1000-1200 and 1600 -1800 hr.

Key words: *Sesamum indicum*, pollinators, insects, abundance, diversity, foraging behaviour, Hymenoptera, Diptera, Coleoptera, diversity indices, dominance, diurnal variations

Sesame *Sesamum indicum* L. is one of the important oilseeds. It is indigenous to Africa due to the preponderance of wild species in that region (Azeez et al*.,* 2017). Among its wild relatives *Sesamum orientale* var. *malabaricum* is restricted to the Indian subcontinent. Bees are excellent pollinators and the flowers attract these to visit them for pollen and nectar. Commercial production of >90% of crops rely on bee pollination. Cross pollination in entomophilous crops based on the coevolution of flowering and activity of insect pollinators serves as the effective source for enhancing the crop yield both qualitatively and quantitatively (Patidar et al*.,* 2017). It is estimated that global annual economic value of insect pollination is €153 billion (Das and Jha, 2018). Being a self-pollinated crop, the tubular floral structure of sesame facilitates cross pollination up to an extent of 65%. The complimentary pollination carried out by honey bees in sesame improves seed germination, vigour of seeds and augments the crop yield. The present study focuses on the relationship of insect pollinators, and investigate their diversity in relation to flowering phenology of sesame and also during different hours of the day.

MATERIALS AND METHODS

The experimental trial was laid out in the farmer's field at Thoppilikuppam (11.56°N, 79.46°E), Cuddalore district, Tamil Nadu during May- July 2021. The experimental plot was laid out in randomized block design in an area of 1.62 ha with plots divided into five subplots of 1 m^2 area as replication plots. The number of insect pollinators from each species visiting the flowers was recorded from 10% flowering stage to flowering cessation period. The insects foraging on the flowers were collected using sweep net, subsequently killed and preserved in ethanol for identification with the help of taxonomist and literature. The foraging behaviour and relative abundance of insect pollinators were observed for 5 min from 0600 - 1800 hr at two hours interval in five plants during alternate flowering days and expressed as mean no. of individuals/ m^2/ 5 min (Das and Jha, 2019). To estimate the rareness and commonness of pollinator species, the diversity indices were computed (Madhuvandhi, 2021).

RESULTS AND DISCUSSION

On observing the foraging activity of floral visitors on sesame a sum of 19 insect pollinators were identified based on their role involved in pollen and nectar collection (Table 1). Among them, 15 species are of Hymenoptera followed by two species each from Diptera and Coleoptera. In Hymenoptera, Apidae is the dominant family with six species and 4 from Halictidae, followed by Megachilidae (3) and Xylocopidae (2). The order Diptera is with two species from family

Table 1. Foraging behaviour of pollinators on sesamum (Thoppilikuppam, Cuddalore)

S. No.	Pollinators/ time of a day	*Mean no. of individuals / m^2/ 5 min						Mean
		0600-0800	0800-1000	1000-1200	1200-1400	1400-1600	1600-1800	
Apis bees		Hymenoptera						
1	*A. c. indica*	8.49± 0.02^{a}	12.21± 0.10^{a}	14.83± 0.07^{a}	10.57± 0.13^{a}	7.50± 0.04^{a}	5.46± 0.07^{a}	9.84
2	*A. dorsata*	5.98± 0.29^{b}	8.21± 0.11^{b}	12.18± 0.08^{b}	7.85± 0.08^{b}	4.49± 0.14^{b}	2.81± 0.06^{b}	6.83
3	*Apis florea*	3.05± 0.06^{c}	5.60± 0.19^{c}	8.39± 0.12^{c}	4.38± 0.12^{c}	2.16± 0.05^{c}	0.87± 0.02^{c}	4.07
4	*Braunsapis* sp.	0.00± 0.00^{f}	1.95± 0.03^{gh}	2.46± 0.08^{g}	1.45± 0.04^{g}	0. 48± 0.02^{h}	0.21± 0.02^{h}	1.09
5	*A. zonata*	1.49± 0.04^{d}	3.06± 0.08^{d}	4.14± 0.12^{de}	2.14± 0.03^{e}	0.03± 0.00^{i}	0.46± 0.14^{g}	1.88
6	*Ceratina* sp.	1.58± 0.14^{d}	2.75± 0.14^{de}	2.25± 0.05^{g}	0.19± 0.06^{k}	0.78± 0.02^{f}	0.52± 0.03^{f}	1.34
Mean		3.43	5.63	7.37	4.43	2.57	1.72	4.19
Non *Apis* bees								
7	*Halictus* sp.	1.35± 0.21^{d}	2.64± 0.06^{e}	4.81± 0.03^{d}	3.28± 0.16^{d}	1.24± 0.23^{e}	0.74± 0.08^{cd}	2.34
8	*Augochlora* sp.	0.80± 0.03^{e}	2.85± 0.02^{d}	3.18± 0.04^{f}	3.44± 0.04^{d}	1.54± 0.05^{d}	0.53± 0.03^{ef}	2.06
9	*Lasioglossum* sp.	0.86± 0.19^{e}	2.31± 0.08^{f}	3.35± 0.07^{f}	1.73± 0.03^{f}	0.42± 0.02^{h}	0.00± 0.00^{i}	1.44
10	*Nomia* sp.	0.86± 0.03^{e}	2.40± 0.04^{f}	4.45± 0.07^{d}	1.38± 0.03^{g}	0.00± 0.00^{i}	0.46± 0.07^{g}	1.59
11	*Xylocopa* sp. 1	0.00± 0.00^{f}	0.51± 0.03^{i}	1.14± 0.07^{j}	1.48± 0.04^{g}	0.00± 0.00^{i}	0.00± 0.00^{i}	0.52
12	*Xylocopa* sp. 2	0.00± 0.00^{f}	1.02± 0.06^{h}	1.42± 0.17^{i}	1.35± 0.32^{h}	0.00± 0.00^{i}	0.00± 0.00^{i}	0.63
13	*Anthidium* sp.	0.00± 0.00^{f}	1.04± 0.08^{h}	2.07± 0.08^{gh}	0.00± 0.00^{l}	0.00± 0.00^{i}	0.00± 0.00^{i}	0.78
14	*Megachile disjuncta*	0.00± 0.00^{f}	0.82± 0.02^{i}	1.33± 0.09^{i}	0.22± 0.03^{k}	0.00± 0.00^{i}	0.00± 0.00^{i}	0.39
15	*Megachile lanata*	0.00± 0.00^{f}	0.52± 0.03^{i}	1.18± 0.05^{j}	0.82± 0.06^{i}	0.00± 0.00^{i}	0.00± 0.00^{i}	0.42
Mean		0.43	1.56	2.54	1.70	0.35	0.19	1.12
Diptera								
16	*Episyrphus* sp.	0.68± 0.04^{e}	2.43± 0.04^{e}	1.79± 0.03^{h}	1.10± 0.0^{h}	0.52± 0.03^{g}	0. 00± 0.00^{i}	1.09
17	*Eristalmus* sp.	1.40± 0.05^{d}	2.04± 0.07^{f}	1.05± 0.08^{k}	0.78± 0.04^{i}	0.52± 0.02^{g}	0.00± 0.00^{i}	0.96
Mean		1.04	2.23	1.42	0.94	0.52	0.00	1.02
Coleoptera								
18	*O. versicolor*	0.00± 0.00^{f}	0.15± 0.02^{j}	0.37± 0.03^{l}	0.72± 0.03^{ij}	0.50± 0.02^{g}	0.64± 0.02^{de}	0.40
19	*Aulocophora foveocolis*	0.00± 0.00^{f}	0.21± 0.02^{j}	0.44± 0.03^{l}	0.56± 0.34^{j}	0.64± 0.02^{g}	0.75± 0.04^{cd}	0.43
Mean		0.00	0.18	0.40	0.64	0.57	0.69	0.41
P Value		0.00	0.00	0.00	0.00	0.00	0.00	
F value		329.67	836.09	901.48	357.86	648.12	424.29	
Species richness (S)		11	19	19	18	13	9	
Shannon's H index		2.00	2.50	2.52	2.45	1.97	1.88	
Shannon's E index		0.83	0.84	0.85	0.84	0.76	0.85	
Simpson's D index		0.18	0.11	0.10	0.12	0.20	0.22	
Simpson Index of biodiversity		0.82	0.89	0.90	0.88	0.80	0.78	
Simpson Reciprocal Index		5.55	9.09	10	8.33	5	4.54	

*Each value mean of five observations with five replications; in a column means followed by same letter(s) not significant with each other (DMRT, $p \leq 0.05$); Mean± Standard Error

Syrphidae. Two coleopterans from family Scarabaeidae and Chrysomelidae were also observed. During the flowering period, Pashte et al. (2013) observed 22 species of insect pollinators, with 17 species from Hymenoptera 3 from Diptera and 2 species of Lepidoptera. Similarly, Ngongolo et al. (2015) at Kichi forest reserve recorded 24 species of floral visitors in three sesame cultivated community farms.

In *Apis* hymenopterans, *A. c. indica* was the dominant forager followed by *A. dorsata* and *A. florea* (Table 2). The activity of *A. c. indica* (14.83 individuals/ m^2/ 5 min) and *A. dorsata* (12.18 individuals/ m^2/ 5 min) was the dominant at 1000-1200 hr while the activity of *A. florea* was maximum during 0800- 1000 hr (8.39 individuals/m^2/ 5 min). The abundance of total *Apis* hymenopterans peaked (7.37 individuals/ m^2/ 5 min) during 1000-1200 hr, whereas their activity was less (1.72 individuals/ m^2/ 5 min) during 1600- 1800 hr. Among the non-*Apis* hymenopterans, *Halictus* sp. was the predominant followed by *Augochlora* sp., *Nomia* sp., *Lasioglossum* sp., *Anthidum* sp., *Xylocopa* sp. 1, *Xylocopa* sp. 2, *M. lanata* and *M. disjuncta.* About Diptera, *Episyrphus* sp. and *Eristalinus* sp. were abundant during 0800- 1000 hr with 2.43 and 2.04 individuals/ m^2/ 5 min, respectively and they wind

Table 2. Relative abundance of pollinators during different flowering periods in sesamum *n=7

S. No.	Pollinators	Abundance of pollinators vs flowering % (No. of individuals/ m^2/ 5 min)*					Abundance (%)
		15 %	50 %	100 %	< 50 %	Mean	
1	*A. c. indica*	6.86	10.74	15.89	5.88	9.84	25.78
2	*A. dorsata*	4.86	7.23	8.67	6.56	6.83	17.89
3	*A. florea*	3.65	4.78	5.14	2.72	4.07	10.66
4	*Ceratina* sp.	0.82	1.04	1,74	0.76	1.09	2.85
5	*A. zonata*	1.19	1.91	2.89	1.53	1.88	4.92
6	*Braunsapis* sp.	0.82	1.57	2.08	0.91	1.3	3.52
7	*Halictus* sp.	1.78	2.62	3.59	1.39	2.35	6.14
8	*Augochlora* sp.	1.61	2.23	3.24	1.18	2.07	5.40
9	*Lasioglossum* sp.	0.63	1.61	2.48	1.05	1.44	3.77
10	*Nomia* sp.	0.74	1.68	2.64	1.32	1.60	4.17
11	*Xylocopa* sp. 1	0.28	0.63	1.06	0.13	0.53	1.37
12	*Xylocopa* sp. 2	0.37	0.72	1.19	0.26	0.64	1.66
13	*Anthidim* sp.	0.48	0.85	1.48	0.34	0.79	2.06
14	*M. lanata*	0.23	0.34	0.94	0.19	0.43	1.11
15	*M. disjuncta*	0.12	0.36	1.0	0.11	0.40	1.04
16	*Eristalinus* sp.	0.78	1.14	1.72	0.75	1.10	2.87
17	*Episyrphus* sp.	0.63	0.94	1.45	0.82	0.96	2.51
18	*O. versicolor*	0.15	0.40	0.94	0.14	0.41	1.06
19	*Aulocophora foveicollis*	0.13	0.51	0.86	0.23	0.43	1.13
Mean		26.13	41.30	59	26.27	38.18	100

up their activity during 1600- 1800 hr. These findings are similar to those of Mahfouz et al. (2012), with maximum and minimum activity of honey bees being at 0900- 1100 and 1500- 1600 hr, respectively; they also observed that abundance of bee activity decreases with diminishing flowers/ plant and with increase in age of the crop.

The studies on foraging behaviour of *A. cerana* on sesame revealed that 0900-1000 hr was the peak period to visit the sesamum flowers (Bhagawati et al., 2016). It was observed that *A. c. indica* revealed maximum abundance (25.78%) followed by *A. dorsata* (17.89%) and *A. florea* (10.66%); and *Ceratina* sp. was the less abundant (2.85%) among *Apis* hymenopterans. In non-*Apis* hymenopterans the maximum share (6.14%) was of *Halictus* sp. with mean population of 2.35 individuals/ m^2/ 5 min. Among Diptera, *Episyrphus* sp. was most abundant (2.87%) with an average of 1.10 individuals/ m^2/ 5 min. With a mean population of 0.43 individuals/ m^2/ 5 min, *A. foveicollis* shared an abundance of 1.13% (Table 2). Similar results were obtained by Pashte and Shylesha (2013) that honey bee species form the dominant pollinators (77.67%) compared to other species of insect pollinators (6.79%).

Species richness (S) was maximum during two consecutive sunshine hours 0800-1000, 1000- 1200 hr with 19 species and minimum (9 species) during 1600-1800 hr. The maximum values of diversity indices Shannon's H (2.52), Simpson's D (0.22) and evenness Index of Shannon's E index (0.85) were observed. Simpson's biodiversity and reciprocal Index were also higher during two consecutive sunshine hours 1000-1400 hr (Table 1).

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PREFERENCE OF RED FLOUR BEETLE *TRIBOLIUM CASTANEUM* (HERBST) TOWARDS COLOUR CUES

V Yamini Prakashini, G Srinivasan*, M Shanthi and K Prabakaran[1]

Department of Agricultural Entomology, Agricultural College and Research Institute (AC&RI), Tamil Nadu Agricultural University (TNAU), Madurai 625104, Tamil Nadu, India
[1]Department of Social Sciences, AC&RI, TNAU, Killikulam 628252, Tamil Nadu, India
*Email: mshanthiento@tnau.ac.in (corresponding author)

ABSTRACT

Behavioural response of the red flour beetle *Tribolium castaneum* towards various colour cues was evaluated and preference was assessed. Among the coloured surfaces, dark pink was observed to be the most preferred one (27.78, 28.39 and 29.33% at 24, 48 and 72 hrs after release, respectively). Blue, black and yellow revealed moderate preference. Influence of coloured lights on *T. castaneum* revealed that violet coloured LEDs had superior effect on attraction. The trend on preference of colour cues did not vary with increase in time period and red was the most avoided colour indicating its repellency nature.

Key words: *Tribolium castaneum*, *Corcyra cephalonica*, visual stimuli, coloured discs, coloured LEDs, distribution, dark pink, violet, red, blue, black, yellow.

In India, the losses due to insect pests have been decreasing over the years from 23.3 to 15.7% owing to the advancements in biocontrol techniques and strategies (Dhaliwal et al., 2015). In India, the rice moth *Corcyra cephalonic*a (Stainton) despite being a notorious pest is being used and mass produced as a factitious host for rearing parasitoids like *Bracon hebator*, *B. krikpatricki*, *B. brevicornis*, *Chelonus blackburni* and *Goniozous nephantidis*, trichogrammatids and predators like anthocorid bugs and chrysopid larvae (Lalitha and Ballal, 2015). This is because of its adaptability, amenability and beneficial impact (Gauraha and Deole, 2016). *Corcyra cephalonica* rearing is influenced by biotic and abiotic factors and among the biotic ones, contamination with red flour beetle *Tribolium castaneum* (Herbst) is a major one. In addition to food competition, predatory habit of *T. castaneum* leads to reduction in moth emergence which ultimately affects the *C. cephalonica* egg production. In the absence of food, the adults and larvae of *T. castaneum* feed on the eggs and larvae of *C. cephalonica* voraciously (Murugesan et al., 1997); and thus, it has a significant negative impact on the early developmental stages of *Corcyra* (Nagalakshmi and Balaji, 1999). Control of this insect pest in *Corcyra* rearing will demand excluding chemical control options and thus will require new approaches, especially those which alter their behavioural or locomotory responses. Using colour cues can be an option as these play a crucial role in the process of locating the host (Briscoe and Chittka, 2001). It is observed that when multimodal cues such as odour and colour gets combined, greater attraction is ensured (Arnold et al., 2015). Light sources emitting different colours influence the behaviour of insects (Nirmal et al., 2017). The present study evaluates the possibilities of managing *T. castaneum* using visual stimuli.

MATERIALS AND METHODS

The experiments were conducted in the *C. cephalonica* mass rearing room, Insectary, Department of Agricultural Entomology, Agricultural College and Research institute, Madurai during 2020- 2021. Preference of colours by *T. castaneum* was assessed using LED lights and paper discs of different colours. Paper discs of size 7.5 cm painted with various poster colours such as green, red, yellow, blue, dark pink, violet, black, white and transparent paper were kept over the *Corcyra* rearing trays artificially infested with *T. castaneum* (Shelja et al., 2019) and 600 adults of *T. castaneum* were released into the rearing trays. Transparent disc served as control. Beetles aggregated above and below the paper discs were counted at 24, 48 and 72 hr after release. In other set of experiment, differently coloured small electric LED bulbs were set in a plastic chamber with seven arms made up of glass tubes (Sheribha et al., 2010). In each arm, a coloured light viz., green, red, yellow, blue, violet and white was provided and electrical source was given with the help of batteries. The arm without light was treated as control. 10 g of *Corcyra* rearing diet was provided as

food source inside each of the arms. Totally 300 adults were released at the centre and beetles attracted to each colour was counted after 24, 48 and 72 hr. The beetles were discarded from the arms after taking observations on 24 and 48 hr after release. Both the experiments were laid in completely randomized design with three replications. Distribution % was calculated according to Reza and Parween (2006). The experimental data were subjected to arc sine transformation and the means separated using DMRT (Duncan's Multiple Range Test, p=0.05) with SPSS 16.0 software.

RESULTS AND DISCUSSION

The results of variation in responses from *T. castaneum* adults to different colour cues revealed the preference of *T. castaneum* adults to specific visual stimuli (Table 1); maximum preference was observed in dark pink colour- 27.78, 28.39 and 29.33% at 24, 48 and 72 hr after release (HAR), respectively; this increased with time period and the preference to other coloured discs varied. Dark pink was followed by violet (14.11%) and blue (12.39%) at 24 HAR. After 48 HAR, the preference towards green, violet and white got increased when compared with the preference at 24 HAR. Evaluation of coloured LED lights revealed violet as the most attractive one- 24.22, 5.78 and 2.00% at 24, 48 and 72 HAR, respectively; at 48 and 72 HAR, the beetles tend to response equally to violet and blue, and statistically on par with each other. At 48 HAR, yellow (4.33%), green (2.11%) and white (2.33%) revealed a moderate distribution of *T. castaneum,* meanwhile at 72 HAR it was yellow (1.33%) and green (0.89%) LEDs which were preferred next to violet and blue. Distribution on arms with red LED was meagre indicating the avoidance by adults.

Thus, the dark pink and violet are the most attractive cues and red colour is a repellent for *T. castaneum*. These observations corroborate with earlier ones- violet and green exhibiting the maximum and least preference, respectively (Shelja et al., 2019). Higher attraction in dark pink colour is in conflict with the reports of Reza and Parween (2006). Least preference of red colour observed now is in agreement with those of Arab and Salem (2018); also, with those of Sheribha et al (2010). Park and Lee (2017) observed that preference of red LED by *T. castaneum* was low in comparison with other LEDs. Song et al. (2016) evaluated the attractiveness of *T. castaneum* towards LEDs and BLB (black light bulb) traps and observed that red LED trap was more attractive which is in contrast with present study.

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Table 1. Distribution of *T. castaneum* adults in coloured paper discs and coloured lights

	24 HAR	48 HAR	72 HAR		24 HAR	48 HAR	72 HAR
Green	5.33 (13.35)^{e}	6.11 (14.31)^{ef}	5.61 (13.70)^{f}	Green	4.67 (12.48)^{d}	2.11 (8.35)^{c}	0.89 (5.41)^{cd}
Red	4.22 (11.86)^{f}	3.50 (10.78)^{g}	3.83 (11.29)^{g}	Red	2.67 (9.40)^{e}	1.00 (5.74)^{d}	0.67 (4.68)^{de}
Yellow	7.67 (16.07)^{d}	6.78 (15.09)^{e}	7.17 (15.53)^{d}	Yellow	13.44 (21.51)^{c}	4.33 (12.01)^{b}	1.33 (6.63)^{bc}
Blue	12.39 (20.61)^{c}	10.61 (19.01)^{c}	12.89 (21.04)^{c}	Blue	15.67 (23.32)^{b}	4.78 (12.63)^{ab}	1.67 (7.42)^{ab}
Dark pink	27.78 (31.81)^{a}	28.39 (32.20)^{a}	29.33 (32.79)^{a}	Violet	24.22 (29.48)^{a}	5.78 (13.91)^{a}	2.00 (8.13)^{a}
Violet	14.11 (22.06)^{b}	15.83 (23.45)^{b}	14.39 (22.29)^{b}	White	3.78 (11.21)^{d}	2.33 (8.79)^{c}	0.45 (3.83)^{e}
Black	7.39 (15.77)^{d}	7.83 (16.25)^{d}	6.83 (15.15)^{de}	Control	1.33 (6.63)^{f}	0.78 (5.06)^{d}	0.33 (3.30)^{e}
White	5.00 (12.92)^{e}	5.78 (13.91)^{f}	6.28 (14.51)^{ef}	-	-	-	-
Transparent	0.78 (5.06)^{g}	0.72 (4.88)^{h}	0.67 (4.68)^{h}	-	-	-	-
SEd	0.44	0.43	0.44	-	0.70	0.64	0.63
p value	0.00	0.00	0.00	-	0.00	0.00	0.00
F value	581.33	647.29	626.52	-	294.24	56.91	16.71

HAR – Hours After Release;* Mean values of three replications; Figures in parentheses arcsine transformed values; Mean followed by same letter (s) in a column not significantly different by DMRT (p =0.05)

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INCIDENCE OF MANGO STEM MINER *SPULERINA ISONOMA* (MEYRICK) AND FIRST RECORD OF ITS PARASITOID

J Poorani* and R Thanigairaj

ICAR-National Research Centre for Banana, Thogamalai Road,
Thayanur Post, Tiruchirappalli 620102, Tamil Nadu, India
*Email: pooranij@outlook.com (corresponding author)

ABSTRACT

Incidence of mango stem miner *Spulerina isonoma* (Meyrick) (Lepidoptera: Gracillariidae), a poorly known pest, is recorded from Tamil Nadu, India. Details on the symptoms of damage and life stages of the pest are given and illustrated. *Chelonus* sp. (Hymenoptera: Braconidae) is recorded as its parasitoid for the first time.

Key words: Mango, stem miner, Lepidoptera, symptoms, diagnosis, life stages, distribution, parasitoid, new record, India

Mango is attacked by over 400 species of insects in India (Tandon and Verghese, 1985; Reddy et al., 2018). Of these, only a few attain pest status and are economically important and several of them are obscure pests. During surveys for pests of mango in Tamil Nadu, the incidence of mango stem miner *Spulerina isonoma* (Meyrick) (=*Acrocercops isonoma* Meyrick) (Lepidoptera: Gracillariidae: Acrocercopinae) was observed on a low to moderate scale on some mango cultivars. This insect was originally described under the genus *Acrocercops* by Meyrick (1916) and *Acrocercops isonoma* Meyrick is listed as its current valid name by LepIndex (Beccaloni et al., 2003), the database hosted by the Natural History Museum, London. In the Global Taxonomic Database of Gracillariidae (De Prins and De Prins, 2020), *Spulerina isonoma* (Meyrick) is cited as its current valid name. It was originally described from "Pusa, Bengal", and it is also known to occur in Southeast Asia (Malaysia, Thailand) and Australia (Eastern Australia, Northern Territory) (Chin et al., 2010). Incidence of this pest on mango was recorded from Tamil Nadu, India, during 2016-18. A brief account of the symptoms of damage and developmental stages of the pest is given here in view of the rarity of the pest. There is no record of any natural enemies of this pest from India at present. Herein, parasitization by *Chelonus* sp. (Hymenoptera: Braconidae) for the first time on this host.

MATERIALS AND METHODS

The specimens were collected during surveys conducted for pests of mango during 2016-18 in Tamil Nadu. Lifestages were brought to the laboratory and natural enemies, if any, were documented. Photographs of the symptoms of damage and lifestages were taken with a Nikon D750 DSLR camera and Leica DMC 4500 digital camera attached to Leica M205A stereomicroscope. The adult moths were identified by comparison with the description given by Meyrick (1916).

RESULTS AND DISCUSSION

The pest was found on the mango cultivars Imam Pasand and Totapuri in the research farm of the National Research Centre for Banana, Trichy. The symptoms of damage and the life stages are briefly described and illustrated below. The infested trees can be identified by the presence of characteristic, dirty white or creamy white blisters at the bases of young shoots and emerging flushes of mango (Fig. 1a-d). These blisters (Fig. 1e-g) could be observed on mango stem long after the emergence of adult moths and layers of the blisters peel off easily when disturbed. The original description by Meyrick (1916) indicates it was "bred from larva mining in the leaf of *Mangifera indica*", but mining on the leaf was not observed in any plants we surveyed.

The larvae are yellowish white and have a distinctive, segmented appearance (Fig. 1h, i). They feed under the epidermis at the bases of young shoots and flushes of mango resulting in the formation of characteristic whitish, papery thin blisters or mines. The larvae remain hidden inside the mines and continue to feed and come out just before pupation. Pupation takes place inside transparent silken cocoons on leaves (Fig. 1j, k),

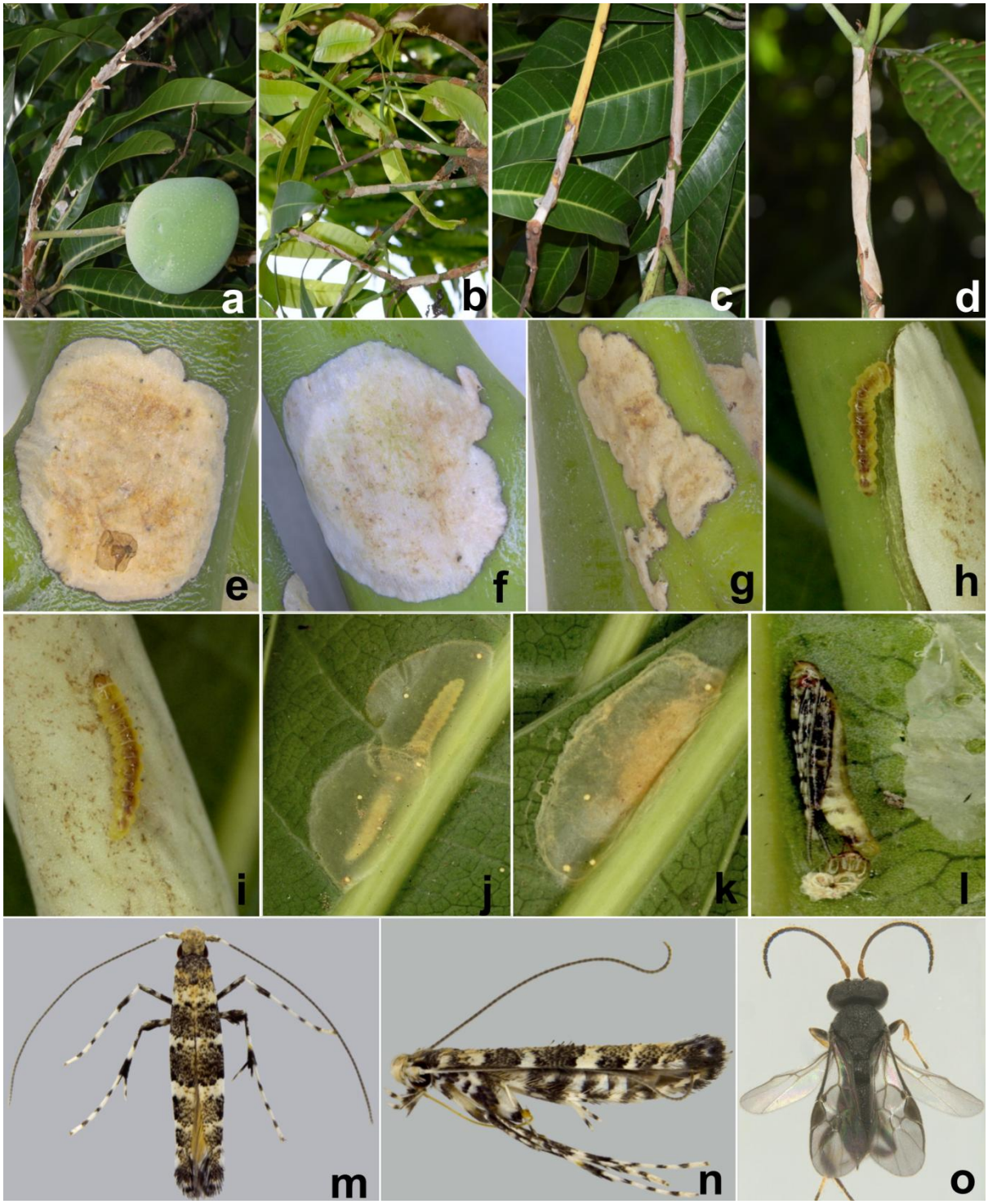

Fig. 1. *Spulerina isonoma*: a-g. Symptoms of damage; h, i. Larva; j, k. Pupation in silken cocoon; l. Pupa, exposed; m. Adult, dorsal view; n. Adult, lateral view; o. *Chelonus* sp., a parasitoid of *S. isonoma.*

usually around the leaf midrib and the pupa (Fig. 1l) is thin, elongate and white with black markings and very long antennae reaching up to the apex. The adult moth (Fig. 1m, n) is narrow and elongate with lanceolate wings. The forewings are covered with brownish scales irrorated with black and have transverse whitish fasciae and a much smaller, crescentic white spot near apex, with elongate, grayish yellow marginal cilia. One egg parasitoid, *Ooencyrtus ooii* Noyes (Hymenoptera: Encyrtidae) has been recorded on this pest in Malaysia (De Prins and De Prins, 2019). Here *Chelonus* sp. (Fig. 1o) (Hymenoptera: Braconidae) is reported as a parasitoid of *S. isonoma* for the first time. The stage of parasitization could not be observed, but *Chelonus* spp. are usually known to be egg-larval parasitoids.

At present, mango is the only known host plant of this insect and very little information is available about it in the Indian literature on mango pests. It does not cause economically significant levels of damage on flowering and fruiting as feeding does not kill the shoots and mango fruit production is unaffected (AGDAWR, 2015). Studies from Thailand do not indicate any adverse effects on mango production (Kuroko and Lewvanich, 1993). Reports from Australia indicate its potential for further spread through propagating material is low to nil as usually the oldest portion of shoots is mined by the larvae and the infestation in the form of papery blisters is easy to detect (AGDAWR, 2015). The absence of published information on this insect from India, its native home, is also indicative of its minor importance as a pest of mango.

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BEHAVIOURAL RESPONSE OF STORED PRODUCT INSECTS TO LIGHT AND BAIT SOURCES IN PADDY STORAGE GODOWN

M Sathiyaseelan, J Jayaraj*, M Shanthi and K Sujatha[1]

Department of Agricultural Entomology; [1]Department of Seed Science and Technology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai 625104, Tamil Nadu, India
*Email: vu2jrj@rediffmail.com (corresponding author)

ABSTRACT

This study was carried out at the Central Farm, Agricultural College and Research Institute, Madurai, from July to August 2021. Behavioural response of lesser grain borer *Rhyzopertha dominica,* red flour beetle *Tribolium* spp. and Angoumois grain moth *Sitotroga cerealella* to different light and bait sources revealed that the incandescent light 25W was effective with *R. dominica* (17.08%), *Tribolium* spp. (9.28%) and *S. cerealella* (2.98%) followed by compact fluorescent light (CFL) 18W attracting *R. dominica*, *Tribolium* spp. and *S. cerealella*. The least trapping efficiency was observed with CFL 15W and light emitting diodes (LED) 20W lights. The behavioural response to bait when analysed revealed that maximum attraction was observed in wheat flour 41.41% followed by cracked sorghum (32.14%), sorghum flour (24.09%) and pearl millet flour (24.08%).

Key words: Paddy godown, bait and light trap, *Rhyzopertha dominica*, *Tribolium* spp., *Sitotroga cerealella*, incandescent, CFL and LED lights, wheat flour, attraction, monitoring

Phototactic response is an important tool in IPM programme (Nirmal, 2015). Insect pest control in stored grains is critical for the management of food products, post-harvest grains and processed foods (Kim et al., 2010). These insects have the potential to severely degrade the quality, commercial value, weight and seed viability of stored grains (Dal Bello et al., 2000). The most destructive insects of cereals in storage are the lesser grain borer *Rhyzopertha dominica*, rice weevil *Sitophilus oryzae*, red flour beetle *Tribolium* spp. and Angoumois grain moth *Sitotroga cerealella* (Kim et al., 2010; Ahamed and Raza, 2010; Duehl et al., 2011; Ahmad et al., 2013). Light traps are used to control insects in other stored product insects such as the cigarette beetle *Lasioderma serricorne*, and the Indian meal moth *Plodia interpunctella* (Samburaj and Phillips, 2008). Incandescent and black lights have wide wavelength and low electric efficiency, while more efficient light sources such as light-emitting diodes (LED) could be used for making insect light traps (Cohnstaedt et al., 2008). Detection of insect incidence using bait traps with pheromones or food attractants or a combination of pheromone and food attractants may influence IPM (Barak, 1989). Therefore, in the present study, the behavioural response of *R. dominica*, *Tribolium* spp. and *S. cerealella* to LED, CFL and incandescent lights and food baits was evaluated under storage condition.

MATERIALS AND METHODS

The study was conducted at the Central Farm storage godown (14.5x 6.5x 3.5 m), Agricultural College and Research Institute, Madurai during July to August 2021. The light trap setup consisted of a plastic plate (35 cm dia) on top and a plastic funnel on the bottom, which was linked to the top plate via PVC pipes fastened to it. The light source was positioned in the centre of the top plate. To secure the insects, a polythene cover was tied to the funnel. The entire setup was hung upside down in the godown. The experiment was done using LED, CFL and incandescent light traps of different electrical power of 15, 18, 20 and 25W with an untreated control of trap without light. The light traps were operated for 12 hr from 6 pm to 6 am in all the week days and observed for the number of insects trapped. The trap catches were recorded for 35 days (5 standard weeks). All the light traps were installed at 2 m above the ground level. Insects attracted in each trap were observed and sorted out based on major species. The insects collected in the collection bag were killed by exposure to ethyl acetate. The number of *S. cerealella*, *R. dominica* and *Tribolium* spp. were counted and the trapping efficiency of light sources was calculated using the formula (Dangi, 2004)-

$$\text{Trapping efficiency (\%)} = \frac{\text{Number of a particular species}}{\text{Total number of all species}} \text{ x } 100$$

Food materials were cracked and crushed grains

and flours of sorghum, wheat, groundnut, rice, maize pearl millet and rice bran were taken and filled in the polythene receptacles of probe trap-like structure which was made of rustproof metal, hollow cylinders of 23 and 5 cm long and dia, respectively; and with 280 evenly spaced 4 mm hole which can hold 50 g food bait, with one end closed by a removable cap. The bait traps filled with 50 g of materials were inserted into the interspace between the staked bags for the insects to drop into the bottom part of the polyethene receptacle attached with traps. The trap catches were recorded for 25 days and the attraction index was calculated using the formula (Smith et al., 1993): Attraction Index (%) = ((T-C)/N) x100, where T- no. of insects attracted in treatment; C- No. of insects trapped in the control; and N- Total no. of individuals. The attraction index and the difference in the behavioural response/ orientation of the insects were analysed using completely randomized design (CRD) by one-way ANOVA subjecting the data to arcsine transformation and were separated by using Duncan's Multiple Range Test (DMRT) with SPSS 22.0 software and the differences were regarded as significant at $p < 0.05$ (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Trapping of insect pests of stored paddy observed using different light and bait sources and the relative insect trapping efficiency of various light sources was analysed. The weekly insect trapping efficiency of incandescent light 25W was found to be the maximum for *R. dominica* (17.08%), *Tribolium* spp., (9.28%) and *S. cerealella* (2.98%) followed by CFL 18W 14.98%, 8.60% and 2.32% of *R. dominica*, *Tribolium* spp. and *S. cerealella*, respectively; the lower attraction was due to CFL 15W viz., 3.91, 2.41 and 1.87% of *R. dominica*, *Tribolium* spp. and *S. cerealella,* respectively; while due to LED 20W the attraction was 3.44, 2.54 and 1.33% of *R. dominica*, *Tribolium* spp. and *S. cerealella,* respectively (Table 1). The results indicate varied attraction indices of insects in bait sources. The attraction of *S. cerealella* towards wheat flour was 23.44% followed by pearl millet flour (9.81%) and rice bran + rice flour (9.55%). A least attraction of *S. cerealella* was observed in sorghum flour (4.80%); *R. dominica* was attracted more in cracked sorghum bait (11.72%) followed by pearl millet flour (9.95%) and rice flour (4.23%). For *Tribolium* spp. higher attraction

Table 1. Trappings of storage pests in light sources

Light sources	Insects collected	No. of insects trapped/trap/week*					Total	Trapping efficiency (%)
		28 SW	29 SW	30 SW	31 SW	32 SW		
LED 15W	*Rhyzopertha dominica*	22.67	24.33	97.00	75.33	66.00	285.33	7.05
	Tribolium spp.	13.67	21.67	28.00	31.67	25.67	120.68	2.98
	Sitotroga cerealella	4.67	6.33	15.00	13.00	13.67	52.67	1.30
CFL 15W	*Rhyzopertha dominica*	13.67	15.67	34.33	51.67	42.67	158.01	3.91
	Tribolium spp.	9.00	10.33	23.67	29.00	25.67	97.67	2.41
	Sitotroga cerealella	19.00	14.67	10.00	16.00	16.00	75.67	1.87
Incandescent	*Rhyzopertha dominica*	96.33	88.00	71.00	74.33	64.00	393.66	9.73
15W	*Tribolium* spp.	13.00	29.67	40.67	40.00	34.33	157.67	3.90
	Sitotroga cerealella	10.00	4.67	14.00	17.67	16.67	63.01	1.56
LED 20W	*Rhyzopertha dominica*	9.00	14.00	26.67	45.00	44.33	139	3.44
	Tribolium spp.	8.33	15.67	24.67	30.00	24.00	102.67	2.54
	Sitotroga cerealella	3.00	7.33	12.00	14.33	17.33	53.99	1.33
CFL 18W	*Rhyzopertha dominica*	128.33	120.67	121.00	117.00	119.00	606	14.98
	Tribolium spp.	79.67	73.00	73.33	61.00	61.00	348	8.60
	Sitotroga cerealella	14.33	9.33	16.33	23.67	30.00	93.66	2.32
Incandescent	*Rhyzopertha dominica*	90.33	139.67	172.67	150.67	137.67	691.01	17.08
25W	*Tribolium* spp.	62.67	68.33	89.67	82.33	72.33	375.33	9.28
	Sitotroga cerealella	13.67	13.33	22.67	32.00	39.00	120.67	2.98
Control	*Rhyzopertha dominica*	5.33	8.00	14.67	13.00	13.33	54.33	1.34
(No light)	*Tribolium* spp.	3.00	5.33	7.00	9.33	9.00	33.66	0.83
	Sitotroga cerealella	1.67	3.00	5.00	5.67	6.67	22.01	0.54
Grand total							4044.7	100.00

*Mean of three replications; SW-Standard week

index to cracked sorghum was 13.72% followed by sorghum flour (11.72%) and the least attraction of *Tribolium* spp. was observed in rice flour (3.66%) (Table 2).

Jeon et al. (2011) observed the behavioural response of the rice weevil *Sitophilus oryzae* to LED at different intensities and wavelength and observed greater number of weevils getting attracted to blue wavelength (84.3%) followed by green, red, UV and IR. In the present study, LED attracted the least number of insects compared with incandescent and CFL lights. Ultraviolet light 4W installed 1.5 m above ground level in the corners and alleyways of a rice warehouse, combined with the use of a bait trap, accurately detected the presence of lesser grain borer, resulting in timely insecticidal treatment (Mohan et al., 1994). The attraction of *R. dominica*, *S. cerealella*, *T. castaneum* and *S. zeamais* to light traps (6W blacklight-blue) was evaluated by Nualvatna et al. (2003). The blacklight was preferred by *R. dominica* over the blacklight-blue and green incandescent lamps. The incandescent 25W was attractive to *R. dominica*, *Tribolium* spp. and *S. cerealella* (29.69, 30.37 and 25.05% respectively), followed by CFL 18W (with attraction of 26.04, 28.16 and 19.45%, respectively) (Table 2).

Phototactic response of *T. castaneum*, *S. zeamais Lasioderma serricorne* and *Tyrophagus putrescentiae* to red LED, and *S. cerealella* and *S. oryzae* to blue LED was reported by Park et al. (2017). Present study is in conformity with the findings of Song et al. (2016) who studied the attraction of *T. castaneum* and *S. zeamais* to LED in the granary and the attraction with black light bulb (BLB) trap and red LED attracted more *T. castaneum* and *S. zeamais* than BLB. Phototactic behavioural responses of the Indian meal moth *Plodia interpunctella* to seven wavelengths of light-emitting diodes (LEDs); the green LED to *P. interpunctella* adults was approximately 1.81x more attractive than black light bulb (BLB) as reported by Park and Lee (2016). The attractiveness of wheat flour to *S. cerealella* observed now is comparable with earlier studies indicating that larger grain borer *Protephanus truncatus* and *R. dominica* were attracted towards cereal host odour (Bashir et al., 2001; Edde and Phillips, 2006). Cracked wheat alone had attracted *S. zeamais* six times more than *S. oryzae* (Likhayo and Hodges, 2000). Maximum attraction of *R. dominica* (11.72%) and *Tribolium* spp. (13.72%) was observed due to some attractive compounds present in the cracked sorghum and *S. cerealella* to wheat flour (23.44%) and pearl

Table 2. Response of stored product insects to bait and light sources

Attractants	*Relative attraction index (%)			Total attraction index (%)	Light sources	*Relative attraction index (%)			Insect response (%)
	S. cerealella	*R. dominica*	*Tribolium* spp.			*R. dominica*	*Tribolium* spp.	*S. cerealella*	
Crushed groundnut	5.00 (12.92) [f]	8.46 (16.91) [d]	9.11 (17.57) [d]	22.57	LED 15W	12.26 (20.50) [d]	9.77 (18.21) [d]	10.93 (19.31) [e]	32.96
Wheat flour	23.44 (28.96) [a]	7.53 (15.93) [ef]	10.44 (18.85) [c]	41.41	CFL 15W	6.79 (15.10) [e]	7.90 (16.33) [e]	15.71 (23.35) [c]	30.40
Cracked corn	7.82 (16.24) [c]	9.62 (18.07) [c]	4.32 (11.99) [g]	21.4	Incandescent 15W	16.92 (24.29) [c]	12.76 (20.93) [c]	13.08 (21.20) [d]	42.75
Sorghum flour	4.80 (12.65) [f]	7.57 (15.97) [e]	11.72 (20.02) [b]	24.09	LED 20W	5.97 (14.15) [e]	8.31 (16.75) [e]	11.21 (19.56) [e]	25.49
Rice flour	5.75 (13.87) [e]	4.23 (11.87) [h]	3.66 (11.02) [h]	13.64	CFL 18W	26.04 (30.68) [b]	28.16 (32.05) [b]	19.45 (26.17) [b]	73.65
Pearl millet flour	9.81 (18.25) [b]	9.95 (18.39) [b]	4.32 (11.99) [g]	24.08	Incandescent 25W	29.69 (33.02) [a]	30.37 (33.44) [a]	25.05 (30.03) [a]	85.12
Rice bran	7.72 (16.13) [c]	5.52 (13.58) [g]	6.98 (15.32) [e]	20.22	Control	2.33 (8.79) [f]	2.72 (9.50) [f]	4.57 (12.34) [f]	9.63
Rice bran + Rice flour	9.55 (18.00) [b]	7.21 (15.58) [f]	5.36 (13.39) [f]	22.12	-	-	-	-	-
Cracked sorghum	6.70 (15.01) [d]	11.72 (20.02) [a]	13.72 (21.74) [a]	32.14	-	-	-	-	-
Control	0.00** (0.52) [g]	0.00 (0.52) [i]	0.00 (0.52) [i]	0.00	-	-	-	-	-
SEd	0.297	0.153	0.159	-	-	0.558	0.347	0.283	-

*Mean of three replications; **Figures in parentheses arc sine transformed values with formula: 1/4n for 0%; Mean followed by same letter (s) in a column not significantly different by DMRT (p=0.05)

millet flour (11.65%). These results are in line with earlier findings in which *R. dominica* was getting attracted to wheat flour (Ahmad et al., 2013). The trapping efficiency of different light sources observed now demonstrate that these sources can be used as a tool in IPM, and sorghum and pearl millet flour can be exploited for monitoring and mass trapping of insect pests in rice godowns.

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ROLE OF PROTEIN AND FOOD BAITS IN ATTRACTION OF MELON FRUIT FLY *ZEUGODACUS CUCURBITAE* IN BITTER GOURD

Sruthi A B, Zadda Kavitha*, M Shanthi and A Beaulah[1]

Department of Agricultural Entomology Agricultural College and Research Institute, TNAU, Madurai 625104, Tamil Nadu, India
[1]Department of Horticulture, Agricultural College and Research Institute, TNAU, Killikulam 628252, Tamil Nadu, India
*Email: zaddakavitha@gmail.com (corresponding author)

ABSTRACT

A field experiment was conducted to evaluate the attractiveness of various protein and food baits against cucurbit fruit fly (*Zeugodacus cucurbitae*) (Coquillet) in bitter gourd fields. Protein baits evaluated were soybean, yeast, casein and Proteinex baits. Food baits evaluated were banana, guava, tomato, pineapple and bitter gourd juice baits. The incidence of *Z. cucurbitae* was also observed. Among the evaluated protein baits, Proteinex bait trapped more i.e., 8.05/ trap/ week (female-4.94 and male-3.11), and showing 44.45% reduction incidence. Of the food baits assessed, tomato juice bait was the best, trapping 3.35 fruit flies/ trap/ week (female-2.09 and male-1.26) with 37.16% damage reduction. From the present investigation it can be concluded that among protein and food baits evaluated, Proteinex and tomato respectively with attractant materials @ 12 nos/ ha with weekly replenishment may effectively attract both sexes of adult fruit flies and thereby act as reliable management strategy against fruit flies in horticultural crops.

Key words: *Zeugodacus cucurbitae*, bitter gourd, protein bait, Proteinex, food bait, fruit juice, banana, guava, tomato, pineapple, attraction, efficiency, attraction enhancers

In India, vegetable crops are cultivated in 1,03,16,000 ha with productivity of 18,94,64,000 mt (Anonymous, 2020-21). Of these, cucurbits are the most important summer vegetables, and these are affected by the fruit flies. Because of the polyphagous, frugivorous and florivorous nature, fruit flies are serious in many horticultural crops causing economic loss (Dhillon et al., 2005). In India, bitter gourd is cultivated in 1,07,000 ha with a production of 12,92,000 mt (Anonymous, 2020-21). The fruit fly family, Tephritidae with about 4500 species, is one of the largest families of Diptera (David, 2011), of which 250 species are economically important. Fruit flies are widely distributed in tropical, subtropical and temperate regions. Several measures are deployed to reduce these pests including isnecticides (Sen et al., 2019). Application of insecticides not only poses harmful effects on beneficial arthropods but also contaminates the environment, increases the cost of production as well as raises MRL issues (Gogi et al., 2010). There is need to develop alternatives for insecticides for management of fruit flies. At present, pheromone traps using cuelure as the active ingredient are commercially available which can attract only male fruit flies. However, this male lure has limited effectiveness because they are sex-specific. Attracting female fruit flies is very important because they are the dominant factor for the multiplication of the pest (Epsky et al., 1999). The present study compares the efficiency of several protein and food baits to attract the *Zeugodacus cucurbitae* (Coquillet) relying on two facts about the females i.e. protein source is important for the sexual maturation (Biasazin et al., 2018) and egg development (Manrakhan and Lux, 2006) and their preference for host fruit odour when searching for oviposition.

MATERIALS AND METHODS

A field experiment was conducted in bitter gourd fields (Abhishek variety) during February, 2021 to April, 2021 in Ayyur village, Alanganallur block, Madurai district (10°4'N,78°5'E). There was minimum 50 m distance between the treatments, and among protein baits, four protein baits with negative control and untreated control were evaluated. Thus, there were seven treatments including control, replicated four times in randomized block design. The protein baits evaluated were soybean powder (10%), yeast powder (10%), casein powder (10%) and Proteinex (10%). All the treatments were mixed with attraction enhancers and insecticide viz., jaggery (10%), ammonium acetate (5%), malathion (0.001%) and borax (2%). In the

negative control, attraction enhancers and insecticide alone were used. Seven food baits treatments were evaluated which included elaichi banana, guava, pineapple, tomato and bitter gourd pulps @10% with the jaggery (10%), citric acid (5 g), malathion (0.001%), yeast 10 g and borax (2%) a negative control and an untreated control. The negative control contained only the attraction enhancers and insecticide.

Bait traps were prepared with the plastic containers of 10 cm dia, 20 cm height and 1 l capacity in which four holes of 20 mm size were made in the middle part. Prepared baits were poured in these traps @ 200 ml/ trap and were hung to the iron wires of pandal in bitter gourd ecosystem at a height of 1.5 to 2 m under shade. Traps were installed @ 1 trap/ 1000 m^2 and baits were kept in the field at the time of initiation of flowering @ 15/ha. Baits were maintained in semi liquid state by adding approximately 10-15 ml water in alternate days. In all the treatments, borax was added to avoid the decomposition of trapped flies (Lasa and Williams, 2021) and to raise the alkalinity of the bait (Heath et al., 1994). Jaggery was used to increase the attractiveness of bait (Thomas and Mangan, 2005). Yeast was used as a fermentation stimulator and ammonium acetate was a female fruit fly attractant enhancer (Pinero et al., 2020). Baits were changed once in a week and maintained up to the harvest of the crop. In each treatment, observations on total number of fruit flies, number of female and male fruit flies trapped was recorded at weekly intervals. After the weekly observation, site of the trap was changed to maintain uniform distribution in field. Observations were also taken on incidence and level of fruit infestation. For this, ten bitter gourd fruits were collected randomly, cut opened, and observed for infestation and number of larvae counted under the microscope. The data were subjected to appropriate transformations before analysis. Means were separated by Tukey's HSD test. Statistical analyses were performed using the software IBM SPSS Statistics version 22.0 (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The results revealed significant variation in the fruit flies trapped with protein and natural food baits. Protein as a critical source of component of food baits for *Z. cucurbitae* is well known (Fabre et al., 2003). Wood (2001) stated that when mixed with killer compounds, protein-bait sprays paved a way to blast the flies. In bitter gourd, among the protein baited traps, Proteinex was found to be superior (72.50 fruit flies/ trap/ 9 weeks), and female fruit flies were more i.e., 51.75/ trap/ week (Table 1). Proteinex had been observed to trap Oriental fruit flies in guava in Punjab by Mann (1996), with soybean powder found to be the next best, and both equally effective in attracting the male flies. Cornelius et al. (2000), and Ravikumar and Viraktamath, (2007) also observed that the combination of Proteinex in bait significantly attracted more flies. Sunandita and Gupta (2001 found that protein hydrolysate and boric acid bait mixtures were effective with *B. tau*. Pinero et al. (2015) stated that the attraction of females towards the protein baits was enhanced by ammonium acetate. Iqbal et al. (2020) revealed that in field as well as in laboratory studies protein hydrolysate, yeast and ammonium acetate-based lures captured comparatively more adults of *Z. cucurbitae.* Guava pulp when added with Proteinex yeast, cane sugar and alcohol attracted more flies in snake gourd and ridge gourd (Abinaya et al., 2020). Trapped male and female ratio in the protein baits ranged from 0.35:1 to 0.51:1 clearly indicating that the traps attracted more females than the males. In guava and mango orchards, Rajitha and Viraktamath (2005) observed that protein baits attracted female fruit flies effectively. Malathion as effective killer agent in protein baits against fruit flies was observed by Khosravi et al. (2018).

Among the food baited traps, tomato juice bait was the more preferred (30.25/ trap/ 9 weeks), with majority being females (19.51); banana juice bait was the next best. Pandey et al. (2010) concluded that banana bait - banana (1 kg) + carbofuron (10 g) + yeast (10 g) + citric acid (5 g) showed a consistent superiority in fruit fly catches. Food baits containing banana pulp as base attracted significantly more (Bharathi et al., 2004; Rajitha and Viraktamath, 2005). Satpathy and Samarjit Rai (2002) reported that melon fruit flies are lured to bait with over ripped banana, citric acid and furadan during peak activity periods. Pandey et al. (2008) observed that melon fruit fly is effectively controlled by bait of 1 kg rotten banana + 10 g carbofuran + 5 g yeast + 5 g citric acid. Pujar et al. (2020) observed that banana pulp with food grade alcohol and vinegar attracted more fruit flies. Male and female ratio in the catches with the food baits ranged from 0.36:1 to 0.57:1 indicating that the traps attracted more females. Level of incidence was the lowest in the tomato bait treatments (3.53 larvae/ fruit) and this was on par with the banana and bitter gourd baited treatments; incidence was minimum in the tomato baited treatment (20.56), and % reduction was more (37.16) in tomato baited treatment followed by banana baited treatment (30.37) (Table 2). Thus, it

Table 1. Attraction of fruit flies to the protein baits and their incidence

Treatments	Week after trap placement* No. of fruit flies/ trap/ week									Total No. of fruit flies attracted/ trap/ 9 weeks			Mean no. of fruit flies/ trap/ week			Male female ratio	Mean Level of incidence	Mean % incidence	Mean % reduction over control
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	Male	Female	Total	Male	Female	Total				
Soybean bait	6.00 (2.55)^{b}	8.00 (2.92)^{a}	7.00 (2.74)^{b}	13.00 (3.67)^{a}	4.75 (2.29)^{b}	5.50 (2.45)^{ab}	4.50 (2.24)^{bc}	7.25 (2.78)^{b}	3.00 (1.87)^{b}	17.15 (4.27)^{a}	41.25 (6.46)^{b}	59.00 (7.71)^{b}	1.97 (1.57)^{a}	4.58 (2.25)^{b}	6.56 (2.66)^{b}	0.43:1	3.40 (1.97)^{ab}	19.44 (26.17)^{a}	44.45
Caesin bait	3.75 (2.06)^{c}	4.00 (2.12)^{b}	7.25 (2.78)^{ab}	5.25 (2.40)^{b}	3.75 (2.06)^{b}	2.00 (1.58)^{c}	3.50 (2.00)^{c}	4.50 (2.24)^{c}	1.50 (1.41)^{c}	14.00 (3.74)^{b}	25.50 (5.04)^{d}	39.44 (6.00)^{d}	1.33 (1.35)^{b}	2.61 (1.76)^{d}	3.95 (2.11)^{d}	0.51:1	4.47 (2.22)^{c}	27.22 (31.45)^{ab}	22.23
Proteinex bait	8.25 (2.96)^{a}	6.25 (2.60)^{ab}	9.50 (3.16)^{a}	5.50 (2.45)^{b}	8.75 (3.04)^{a}	6.75 (2.69)^{a}	11.50 (3.46)^{a}	11.00 (3.39)^{a}	5.00 (2.35)^{a}	21.50 (4.61)^{a}	51.75 (7.22)^{a}	72.50 (8.54)^{a}	2.31 (1.67)^{a}	5.75 (2.50)^{a}	8.06 (2.92)^{a}	0.41:1	2.87 (1.82)^{a}	18.33 (25.35)^{a}	47.63
Yeast bait	4.25 (2.18)^{bc}	4.50 (2.24)^{b}	4.00 (2.12)^{c}	4.00 (2.12)^{b}	7.00 (2.74)^{a}	5.00 (2.35)^{b}	5.75 (2.50)^{b}	4.50 (2.24)^{c}	3.25 (1.94)^{b}	11.00 (3.38)^{b}	31.25 (5.62)^{c}	42.25 (6.53)^{c}	1.22 (1.31)^{b}	3.47 (1.99)^{c}	4.69 (2.28)^{c}	0.35:1	4.13 (2.14)^{bc}	28.33 (32.16)^{ab}	19.06
Negative control	0.25 (0.87)^{d}	0.50 (1.00)^{c}	0.50 (1.00)^{d}	0.50 (1.00)^{c}	0.75 (1.12)^{c}	0.75 (1.12)^{c}	0.50 (1.00)^{d}	1.25 (1.32)^{d}	0.75 (1.12)^{c}	1.75 (1.48)^{c}	4.00 (2.11)^{e}	5.75 (2.50)^{e}	0.19 (0.83)^{c}	0.44 (0.97)^{e}	0.64 (1.07)^{e}	0.43:1	5.91 (2.53)^{d}	34.44 (35.94)^{bc}	1.60
Untreated control	0.0 (0.71)^{d}	0.0 (0.71)^{d}	0.0 (0.71)^{e}	0.0 (0.71)^{d}	0.0 (0.71)^{d}	0.0 (0.71)^{d}	0.0 (0.71)^{e}	0.0 (0.71)^{e}	0.0 (0.71)^{d}	0.0 (0.71)^{c}	0.0 (0.71)^{f}	0.0 (0.71)^{e}	0.0 (0.71)^{c}	0.0 (0.71)^{e}	0.0 (0.71)^{f}	0:0	6.96 (2.73)^{e}	35.00 (36.27)^{c}	-
CD (p=0.05)	0.26	0.30	0.32	0.28	0.33	0.24	0.25	0.30	0.29	0.08	0.14	0.26	0.06	0.11	0.28	-	0.42	0.84	-
SE (d)	0.61	0.71	0.75	0.61	0.70	0.50	0.54	0.79	0.46	1.00	2.37	2.02	0.04	0.06	0.04	-	0.56	1.41	-

*Mean of three replications; Values in parentheses √x+0.5 transformed values; % data arsine transformed; Mean followed by same letter in a column not significantly different by Tukey's HSD test (p=0.05)

Table 2. Attraction of fruit flies to the food baits

Treatments	Week after trap placement* No. of fruit flies/ trap/ week									Total no. of fruit flies attracted/ 9weeks			Mean no. of fruit flies/ trap/ week			Male female ratio	Mean Level of incidence	Mean % incidence	Mean % reduction over control
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week	Male	Female	Total	Male	Female	Total				
Tomato bait	2 (1.58)^{a}	2.25 (1.66)^{a}	2.5 (1.73)^{a}	2 (1.58)^{a}	3.5 (2.00)^{a}	4.5 (2.24)^{b}	6.25 (2.60)^{a}	4.25 (2.18)^{a}	3 (1.87)^{a}	10.75 (3.35)^{a}	19.51 (4.47)^{a}	30.25 (5.54)^{a}	1.19 (1.30)^{a}	2.17 (1.63)^{a}	3.36 (1.96)^{a}	0.55:1	3.53 (1.99)^{a}	20.56 (26.96)^{a}	37.16
Banana bait	0.5 (1.00)^{b}	1 (1.22)^{b}	0.75 (1.12)^{b}	0.75 (1.12)^{b}	0.75 (1.12)^{b}	7.25 (2.78)^{a}	3 (1.87)^{a}	4 (2.12)^{a}	1.25 (1.32)^{b}	5.25 (2.36)^{b}	14 (3.80)^{b}	19.25 (4.44)^{b}	0.58 (1.04)^{b}	1.56 (1.43)^{b}	2.14 (1.62)^{b}	0.37:1	4.35 (2.17)^{ab}	22.22 (28.13)^{ab}	30.37
Bitter gourd bait	0.25 (0.87)^{b}	0.5 (1.00)^{b}	0.75 (1.12)^{b}	1.5 (1.41)^{ab}	1.25 (1.32)^{b}	2.75 (1.80)^{c}	0.75 (1.12)^{b}	0.75 (1.12)^{b}	0.25 (0.87)^{b}	2.50 (1.70)^{bc}	6.25 (2.60)^{c}	8.75 (3.04)^{c}	0.19 (0.85)^{b}	0.67 (1.05)^{c}	0.84 (1.15)^{cd}	0.4:1	4.43 (2.21)^{ab}	28.33 (32.16)^{cd}	13.42
Guava bait	1 (1.22)^{ab}	0.5 (1.00)^{b}	1 (1.22)^{b}	0.75 (1.12)^{b}	1.5 (1.41)^{b}	1 (1.22)^{d}	0.75 (1.12)^{b}	0.75 (1.12)^{b}	0.25 (0.87)^{b}	2 (1.54)^{bc}	5.5 (2.44)^{c}	7.50 (2.83)^{cd}	0.22 (0.85)^{b}	0.44 (0.97)^{c}	0.67 (1.08)^{d}	0.36:1	4.83 (2.31)^{b}	26.11 (30.73)^{bc}	20.20
Pine apple bait	0.75 (1.12)^{ab}	1 (1.22)^{b}	0.75 (1.12)^{b}	0.75 (1.12)^{b}	0.75 (1.12)^{b}	0.5 (1.00)^{d}	0.75 (1.12)^{b}	0.75 (1.12)^{b}	0 (0.71)^{b}	2.5 (1.73)^{bc}	3.5 (2.09)^{c}	6 (2.55)^{cd}	0.28 (0.88)^{b}	0.69 (1.09)^{c}	0.97 (1.21)^{c}	0.57:1	5.88 (2.53)^{c}	27.78 (31.81)^{cd}	16.96
Negative control	0.50 (1.00)^{ab}	0.50 (1.00)^{b}	0.50 (1.00)^{b}	0.50 (1.00)^{b}	0.75 (1.12)^{b}	0.50 (1.00)^{d}	0.50 (1.00)^{b}	0.50 (1.00)^{b}	0.50 (1.00)^{b}	1.75 (1.41)^{c}	3 (2.10)^{c}	4.75 (2.50)^{d}	0.19 (0.83)^{b}	0.33 (0.91)^{c}	0.53 (1.01)^{d}	0.58:1	6.48 (2.63)^{c}	32.22 (34.59)^{de}	10.19
Untreated control	0 (0.71)^{c}	0 (0.71)^{c}	0 (0.71)^{c}	0 (0.71)^{c}	0 (0.71)^{c}	0 (0.71)^{e}	0 (0.71)^{c}	0 (0.71)^{c}	0 (0.71)^{b}	0 (0.71)^{c}	0 (0.71)^{d}	0 (0.71)^{e}	0 (0.71)^{b}	0 (0.71)^{d}	0 (0.71)^{e}	-	6.00 (2.56)^{c}	35.56 (36.60)^{e}	-
CD(p=0.05)	0.33	0.28	0.27	0.26	0.31	0.22	0.29	0.26	0.27	0.43	0.32	0.45	0.41	0.30	0.51	-	0.43	0.63	-
SE(d)	0.45	0.38	0.37	0.37	0.45	0.41	0.43	0.41	0.39	1.05	1.16	0.83	0.06	0.05	0.03	-	0.32	0.32	-

*Mean of three replications; Values in parentheses √x+0.5 transformed values; % data arsine transformed; Mean followed by the same letter in a column not significantly different by Tukey's HSD test (p=0.05)

is concluded that, Proteinex bait replenished at a week interval gave efficient control of fruit flies when placed @ 12 traps/ ha. Among the food baits, tomato bait @ 12 traps/ ha led to effective management.

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SEASONAL INCIDENCE OF FALL ARMY WORM *SPODOPTERA FRUGIPERDA* IN MAIZE

Darshan R* and Prasanna P M[1]

Department of Agricultural Entomology, College of Agriculture, University of Agricultural Sciences- Dharwad (UAS-D), Dharwad 580005, Karnataka, India
[1]Department of Agricultural Entomology, College of Agriculture (UAS-D), Hanumanamatti 581115, Karnataka, India
*Email: darshanr703@gmail.com (corresponding author)

ABSTRACT

The fall army worm *Spodoptera frugiperda* (J E Smith) is a polyphagous invasive pest, initially reported from Karnataka. A roving survey was conducted during two cropping seasons at fortnightly interval during kharif and rabi of 2019-20 to know the status of the pest in Haveri district. The results revealed that the larval counts and % infestation was 0.30 to 0.44 larvae/ plant and 23.10 to 33.77%, respectively. Parasitisation by two larval parasitoids viz., *Campoletis chlorideae* (Hymenoptera: Ichneumonidae) and *Exorista xanthaspis* (Diptera: Tachinidae) and infection by an entomopathogenic fungi, *Metarhizium rileyi* were also observed.

Key words: *Spodoptera frugiperda*, maize, Karnataka, natural enemies, parasitoids, entomopathogenic fungi, kharif, rabi, population dynamics, correlation coefficients

Maize (*Zea mays*) is an important cereal crop equally known for its use as food for man and fodder for animals. Yields of cereals are lower in India due to various factors, among which, insect pests are the most important as constraint. As many as 141 insect pests cause damage to maize from sowing to harvesting (Reddy and Trivedi, 2008). The fall army worm *Spodoptera frugiperda* has been very recently reported on maize from Karnataka as invasive in India (Sharanabasappa et al., 2018). There is chance that this pest may migrate to neighboring states in India as well as other Asian countries. The main explanation for its rapid spread may be its efficient ability to travel and migrate long distances in short time. The invasion of this pest may contribute to serious losses. The present study evaluates the status of *S. frugiperda* in the major maize growing areas of Haveri district in which maize is being cultivated under rainfed condition.

MATERIALS AND METHODS

Roving surveys were conducted in four villages in Haveri district, and from each village five randomly selected fields were observed at fortnightly interval to record infestation of *S. frugiperda* in maize. In each field, twenty plants were randomly selected and observations on the number of plants damaged as well as number of larvae/ plant were recorded. Mean no. of larvae/ plant and % infestation were worked out, and the incidence data were subjected for correlation coefficient and regression analysis with weather data. Twenty number of *S. frugiperda* larvae were collected randomly from each field for the observation of larval parasitisation after rearing under laboratory conditions. Further, these parasitoids were preserved in 70% ethyl alcohol and got identified, with % parasitisation computed for these. Also the cadaver of larvae were collected in butter paper covers, preserved under cold storage, before diluted in distilled water and smeared over suitable growth media for pathological studies of fungi. The fungi involved were got identified.

RESULTS AND DISCUSSION

The survey was conducted on two cropping seasons at fortnightly intervals in seven talukas of Haveri district during kharif and rabi 2019-20. The larval load and % infestation was observed to range between 0.30 to 0.44 larvae/ plant and 23.10 to 33.77%, respectively. Maximum larval load and % infestation was noticed in Savanur taluka and the least in Hirekerur taluka (Fig. 1). Waddill et al. (1981) observed that heavy rainfall was lethal to the pest as rain drops accumulates in whorls which creates suffocation to larvae. Kumar et al. (2020) also observed a significant negative correlation of rainfall with incidence. The late sown maize crop (last week of July) suffered more as compared to the early sown (last week of May) or timely sown crop

(first week of June). The infestation ranged from 6.00 to 100% in Karnataka (Mallapur et al., 2018a) and 35 to 70% in Chhattisgarh (Painkra et al., 2019). Two species of parasitoids viz., *Campoletis chlorideae* and *Exorista xanthaspis* were observed with maximum parasitization being observed in Savanur taluka (1.21 and 0.29%, respectively), and the least in Hirekerur taluka (0.83 and 0.22%, respectively). however, the peak % parasitization coincided with peak *S. frugiperda* infestation. There are other egg parasitoids viz., *Telenomus* sp., *Trichogramma* sp. (Shylesha et al., 2018); and larval parasitoids, *C. chlorideae* (Shylesha et al., 2018), *Coccygidium melleum, C. chlorideae, Eriborus* sp., *E. sorbillans*, *Odontepyris* sp. (Sharanabasappa et al., 2018) and *E. xanthaspis* (Navik et al., 2020) known on *S. frugiperda.* An entomopathogenic fungi *Metarhizium rileyi* was also observed during kharif, and not during rabi, with maximum infection being in Hirekerur taluka (3.56 %). The infection of *M. rileyi* ranged from 1.87 to 18.30% in northern Karnataka (Mallapur et al., 2018b) and 10 to 15% in August (Sharanabasappa et al., 2019). The incidence of larvae showed positive correlation with the maximum and minimum temperature in all the seven talukas during kharif; relative humidity and rainfall were negatively correlated, while the rainfall (r = -0.889) was only parameter having significantly negative effect (Fig. 2). In rabi all the weather parameters correlated negatively except maximum temperature which was

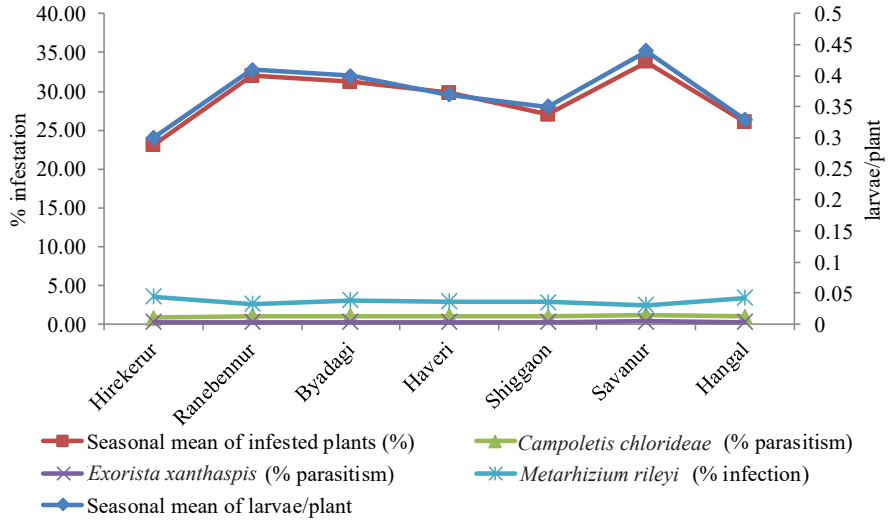

Fig. 1. Incidence of *S. frugiperda* and its natural enemies (Haveri district)

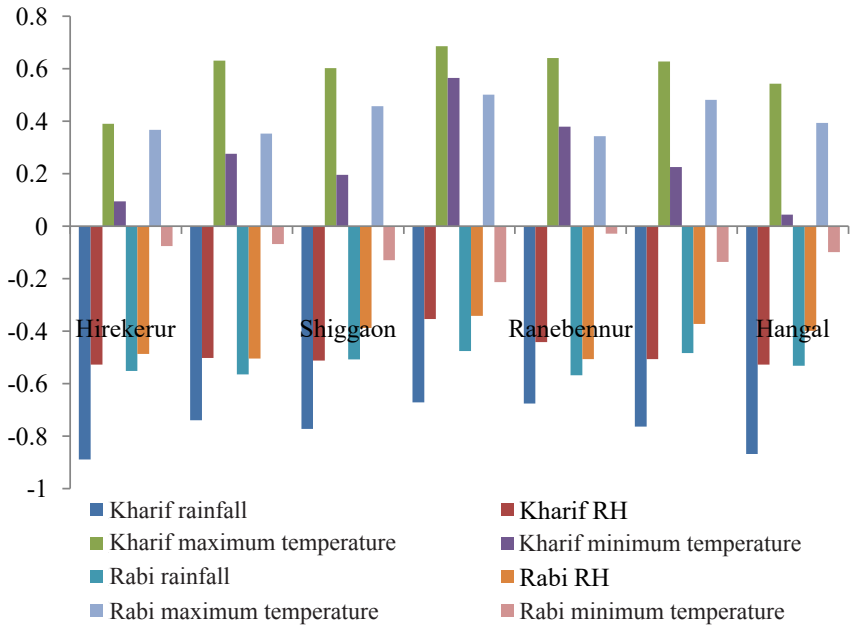

Fig. 2. Population dynamics of *S. frugiperda* (Haveri district- kharif and rabi, 2019-2020)

positively correlated. These observations corroborate with those of Waddill et al. (1981) and Kumar et al. (2020) on the effect of heavy rainfall.

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MANAGEMENT OF *CHILO PARTELLUS* SWINHOE AND *STENACHROIA ELONGELLA* HAMPSON IN MIDHILLS OF MEGHALAYA

Sandip Patra*, Rachna Pande[1], Rumki H. Ch. Sangma, Pankaj Baiswar and Bijoya Bhattacharjee

ICAR Research Complex for NEH Region, Umiam 793103, Meghalaya, India
[1]ICAR-Central Institute for Cotton Research, Nagpur 440010, Maharashtra, India
*Email: sandippatra47@gmail.com (corresponding author)

ABSTRACT

A field experiment was conducted at the ICAR Research Complex for NEH Region, Umiam, Meghalaya to evaluate nine pesticides applied in two phenological stages of maize (variety Vijay composite) against stem borer *Chilo partellus* (Swinhoe), and cob borer *Stenachroia elongella* Hampson. Deadheart due to stem borer recorded after 30 and 45 days after emergence and cob borer infestation recorded during harvesting of cobs revealed that flubendiamide was superior with 80.09% reduction in infestation of deadheart and 80.38% reduction of cob borer over untreated control. Similarly, among the biopesticides, *Bacillus thuringiensis* was effective against both the pests.

Key words: Maize, Meghalaya, *Chilo partellus*, *Stenachroia elongella*, flubendiamide, spinosad, *Bacillus thuringiensis*, neem oil, fipronil

Maize is the third most important cereal crops in India after rice and wheat, and it can be grown in all crop seasons (Kumar et al., 2014). Maize is cultivated in 9.2 m ha with production of 28.75 mt in India (Rakshit et al., 2019). Maize is the second most important cereal crop of Meghalaya with productivity of 2150 kg/ ha (Babu et al., 2019), and productivity is very low due to insect pest problems. Maize is attacked by 139 species of insect pests with varying degree of damage; though, few are only most destructive (Sarup et al., 1987; Siddiqui and Marwaha, 1993). In Meghalaya, stem borer (*Chilo partellus* Swinhoe) and cob borer (*Stenachroia elongella* Hampson) are the most important, with deadhearts up to 33.33 and 18.88%, respectively (Patra et al., 2013a). Yield loss due to stem borer was estimated between 24.3-36.3% (Bhanukiran and Panwar, 2000) and 13.45-15.67% in Meghalaya (Patra et al., 2013b), while cob damage due to cob borer ranged from 6.5 to 11.95% (Patra et al., 2013b) and 5 to 39% (Shylesha, 1996). The cob borer is difficult to manage with insecticides, due to problems like resistance, residue and adverse effects on non-target organisms. This necessitates alternative safe and ecofriendly IPM practices, and hence the present study to evaluate some pesticides against stem borer and cob borer in maize under mid hills of Meghalaya.

MATERIALS AND METHODS

A field experiment was conducted at the Entomology Research Farm, ICAR Research Complex for NEH Region, Umiam, Meghalaya, during 2010-11 with variety Vijay composite. The crop was sown during mid April in randomized block design (RBD) with four replications, in 3x 4 m plots with spacing of 60 cm (R-R) × 30cm (P-P). Recommended management practices were followed except plant protection measures. Neem oil 0.03EC (3 ml/ l), karanjin 2EC (2 ml/ l), annonin 1EC (2 ml/ l), *Beauveria bassiana* (*Bb*) (5 g/ l), *Bacillus thuringiensis* (*Bt*) (2 g/ l) spinosad 45SC (0.75 ml/ l), flubendiamide 480SC (0.3 ml/ l), clothianidin 50WDG (0.25 g/ l) and fipronil 5SC (1 ml/ l) were applied when infestation of *C.partellus* was noticed and second spraying was applied at the time of silking stage for *S. elongella*. Deadheart due to *C. partellus* was recorded after 30 and 45 days after emergence and *S. elongella* was recorded during harvesting. Yield data were recorded separately for each replication. The mean data were subjected to ANOVA after angular transformation.

RESULTS AND DISCUSSION

Efficacy of treatments against *C. partellus* presented in Table 1 reveal that during season I, the least deadhearts (3.14%) were found in flubendiamide 480SC treated plots which was statistically at par with spinosad 45SC (3.32%) and fipronil 5SC (4.98%). Among the biopesticides, neem oil 0.03EC led to minimum deadheart (6.39%) which was closely at par with *B. thuringiensis* (6.45%) and *B. bassiana* (6.80%) while in untreated control it was 11.44%. Similar pattern of efficacy was observed in season II. Mean of two years

data revealed that flubendiamide 480SC was the best (2.58% deadheart and 80.09% reduction) which was statistically at par with spinosad 45SC (2.73% deadheart) with 78.95% reduction over untreated control (12.95%); *B. thuringiensis* (5.53%) was also effective followed by neem oil 0.03EC. Against *S. elongella*, during season I, the least infestation was in spinosad 45SC treated plots (2.72%) which was at par with flubendiamide 480SC (2.75%), clothianidin 50WDG (4.17%) and fipronil 5SC (4.28%); *B. thuringiensis* (4.71%) was the best

Table 1. Efficacy of pesticides against *C.partellus* and *S. elongella* in maize

Treatments	Dose (ml or g/ l)	% deadhearts due to *C. partellus**			Reduction over control (%)	Maize grain yield* (t/ ha)		% increase in yield over control	
		Season II	Season II	Mean		Season I	Season II	Season I	Season II
Neem oil 0.03EC	3.0	6.39 (15.76)	5.45 (14.68)	5.92 (15.24)	54.30	2.76	2.62	28.37	24.20
Karanjin 2EC	2.0	8.68 (18.01)	6.79 (16.14)	7.73 (17.16)	40.27	2.58	2.52	20.00	19.34
Annonin 1EC	2.0	9.06 (18.47)	6.21 (15.51)	7.63 (17.07)	41.04	2.61	2.59	21.40	23.01
Beauveria bassiana	5.0	6.80 (16.18)	6.87 (16.23)	6.83 (16.22)	47.23	2.65	2.68	23.26	26.93
Bacillus thuringiensis	2.0	6.45 (15.78)	4.61 (13.54)	5.53 (14.79)	57.29	2.79	2.67	29.77	26.81
Spinosad 45SC	0.75	3.32 (11.91)	2.13 (10.09)	2.73 (11.08)	78.95	3.05	2.98	41.86	41.40
Flubendiamide 480SC	0.30	3.14 (11.61)	2.02 (9.96)	2.58 (10.85)	80.09	3.14	3.02	46.05	43.30
Clothianindin 50WDG	0.25	5.72 (14.98)	3.23 (11.79)	4.47 (13.49)	65.46	2.81	2.76	30.70	31.08
Fipronil 5SC	1.0	4.98 (14.14)	3.72 (12.48)	4.35 (13.36)	66.41	2.86	2.79	33.02	32.15
Control	-	11.44 (20.53)	14.45 (23.12)	12.95 (21.87)	-	2.15	2.11	-	-
SE. m (±)	-	0.8	0.74	0.53	-	0.14	0.10	-	-
CD (p=0.05)	-	2.33	2.15	1.54	-	0.41	0.28	-	-

Treatments	Dose (ml or g/ l)	*S. elongella* infestation* (%)			Reduction over control (%)	Grain damage* (%)			Reduction over control (%)
		Season I	Season II	Mean		Season I	Season II	Mean	
Neem oil 0.03EC	3.0	5.75 (15.03)	7.90 (17.26)	6.82 (16.19)	40.71	3.56 (12.19)	4.90 (14.01)	4.23 (13.16)	36.88
Karanjin 2EC	2.0	6.90 (16.29)	8.35 (17.76)	7.62 (17.07)	33.78	4.39 (13.41)	5.46 (14.65)	4.93 (14.05)	26.46
Annonin 1EC	2.0	7.21 (16.63)	7.96 (17.37)	7.58 (17.02)	34.13	4.77 (13.85)	4.88 (13.98)	4.83 (13.92)	27.99
Beauveria bassiana	5.0	6.48 (15.78)	7.51 (16.93)	6.99 (16.37)	39.26	3.42 (12.06)	4.67 (13.72)	4.04 (12.94)	39.66
Bacillus thuringiensis	2.0	4.71 (13.80)	6.22 (15.55)	5.46 (14.71)	52.52	1.98 (9.92)	3.48 (12.16)	2.73 (11.12)	59.31
Spinosad 45SC	0.75	2.72 (11.07)	2.20 (10.24)	2.46 (10.68)	78.61	1.43 (8.95)	1.85 (9.13)	1.64 (9.21)	75.56
Flubendiamide 480SC	0.30	2.75 (11.13)	1.76 (9.53)	2.26 (10.36)	80.38	1.21 (8.55)	1.12 (8.21)	1.17 (842)	82.59
Clothianindin 50WDG	0.25	4.17 (13.10)	6.71 (16.04)	5.44 (14.65)	52.73	2.44 (10.67)	3.63 (12.42)	3.04 (11.59)	54.66
Fipronil 5SC	1.0	4.28 (13.24)	5.75 (15.01)	5.02 (14.19)	56.42	2.51 (10.75)	2.77 (11.18)	2.64 (10.98)	60.63
Control	-	12.40 (19.56)	10.62 (19.91)	11.51 (20.71)	-	6.88 (16.21)	6.52 (15.90)	6.70 (16.08)	-
SE. m (±)	-	0.64	0.75	0.55	-	0.66	0.86	0.55	-
CD (p=0.05)	-	1.85	2.17	1.59	-	1.92	2.49	1.60	-

Figures in parentheses angular transformed values; *Mean of four replications.

among the biopesticides, at par with neem oil (5.75%) and *B. bassiana* (6.48%). Similar results were obtained in season II. Pooled data of two seasons showed that flubendiamide 480SC was very effective treatment against cob borer with the lowest cob infestation (2.26%) which was closely at par with spinosad 45SC (2.46%) with 80.38 and 78.61% reduction, respectively over untreated control (11.51%). Two seasons data indicated that *B. thuringiensis* was the effective biopesticide. The effect of treatments on grain damage indicate that all the treatments were effective; in season I, the least damage was in flubendiamide 480SC (1.21%), statistically at par with spinosad 45SC (1.43%), *B. thuringiensis* (1.98%), clothianidin 50WDG (2.44%) and fipronil 5SC (2.51%), with similar trend found in season II; two seasons' data showed that flubendiamide 480SC was the most effective. The yield data revealed that maximum yield was obtained with flubendiamide 480SC (3.14 t/ ha), and among the biopesticides *B. thuringiensis* gave maximum yield (Table 1).

Thus, flubendiamide 480SC was very effective against both the pests giving highest grain yield, and spinosad 45SC was also effective. These findings are in agreement with those of Kumar and Alam (2017) and Reddy et al. (2018) on flubendiamide against *C. partellus;* and on spinosad (Ahmed et al., 2002; Neupane et al., 2016; Devananda et al., 2018; Bhandari et al., 2020); effectiveness of fipronil was reported by Iqbal et al. (2017). The biopesticides, neem oil, *B. thuringiensis* and *B. bassiana* were also effective against both pests, which corroborates with the results of Rani et al. (2018) on azadirachtin, *Bt* and *Bb* against *C. partellus*; efficacy of *Bt* is in agreement with the results of Dhaliwal et al. (2018). Sarkar et al. (2015) showed the effectiveness of spinosad, annonin, karanjin, azadirachtin, *Bt* and *Bb* against red cotton bug and fruit borer in okra.

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AN ATTEMPT TO EXPLORE BUMBLE BEES IN NAGALAND

Avinash Chauhan* and H K Singh

Department of Entomology, School of Agricultural Sciences and Rural Development,
Nagaland University, Medziphema 797106, Nagaland, India
*Email: avi_shimla@hotmail.com (corresponding author)

ABSTRACT

A survey was conducted in five districts of Nagaland viz., Dimapur, Peren, Kohima, Phek and Kiphire to know the presence of bumble bees and their diversity. A total of 93 bumble bees were collected from forest and cultivated areas. These were got identified and their flora was recorded along with their activity. Bumble bees were observed in Khonoma region in Kohima and Pfutsero in Phek district, while these were not observed in Dimapur, Kiphire and Peren district of Nagaland. *Bombus orientalis* Smith was the species observed, with some differences in their morphology. Morphometrics revealed difference in various studied parameters of queens and workers.

Key words: *Bombus orientalis*, survey, bee flora, foraging activity, abundance, morphology, morphometrics, queen, workers rearing, brood

Bumble bees (*Bombus* spp.) are efficient pollinators, especially under protected cultivation (Velthuis and Doorn, 2006; Shipp et al., 1994; Chauhan, 2011) considered as alternate pollinators to the honeybees. These belong to order Hymenoptera, tribe Bombini and genus *Bombus* having more than 250 species in temperate, sub-temperate and sub-tropical regions. The behaviour, physiology and morphology of bumble bees make them ideal pollinators because of the speed at which they transfer pollen, the efficiency with which they gather pollen within various crops, and the increased endurance to fly in adverse weather for longer periods of time (Corbet et al., 1988; Erikson and Buchmann, 1983). The bumble bee also has the ability to buzz pollinate the flower for pollen, a pollination technique not reported in honeybees. Buzz pollination occurs by bumble bees vibrating the flower by pumping their wings at a certain frequency, to dislodge pollen. These are widely used for the pollination of greenhouse crops in Holland, New Zealand, China, Japan, Bulgaria, UK and Germany (Free, 1993; Stanghellini et al., 1997).

Different species of bumble bees like *Bombus haemorrhoidalis* Smith*, B. trifasciatus* Smith*, B. rufofasciatus* Richards *, B. monticolans* Richards, *B. simillimus* Smith, *B. eximius* Smith, *B. mimeticus* Richards, *B. tunicatus* Smith, *B. orichalceus* Fries, *B. oculatus* Frison, *B. waterstoni* Richards are reported from different parts of Himachal Pradesh, Uttra-Khand, North Bengal and North Eastern India especially Meghalaya and Arunachal Pradesh but till now no attempt was made to explore the bumble bees in Nagaland. *Bombus haemorrhoidalis* is a dominant species in Himachal Pradesh found mainly under sub-tropical and subtemperate region (Chauhan and Thakur, 2014; Yankit et al., 2018; Taye et al., 2021). Artificial rearing methods for this bumble bee species has been developed for round the year rearing (Chauhan et al., 2014) but still the efforts to commercialize this species is not yielding expected outcomes from last two decades. Knowing the importance of bumble bees and hindrances in commercialization of *Bombus haemorrhoidalis* Smith in spite of regular efforts by researchers, attempts are required to explore other species of bumble bees from other regions in India for domestication and their utilization for the pollination of crops commercially. Keeping in view the importance of bumble bees, and the problems in commercialization of bombiculture in the country, present study observed the dominant bumble bee fauna in Nagaland.

MATERIALS AND METHODS

A survey was conducted in five different districts of Nagaland during October- December 2019 and 2020, varying in their altitudes from 370 to 2100 masl. Foraging bees were collected during early morning hours (0530 hr) till late evening (1630 hr) from various wild, fruit, vegetable and ornamental plants. The bees were identified in the field on the basis of their big size, black thorax with coloured yellow and orange banded abdomen. Samples were collected with insect nets and then shifted in plastic vials (3.5 x 9 cm) with perforated

lids, and fed with 50% sugar solution to keep them alive. These were brought to the laboratory at School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema. The dead bees were transferred to 70% ethyl alcohol in plastic vials. The flora was also recorded while collection with foraging activity recorded on dahlia at Khonoma village under Kohima district and lupin flowers at Pfutsero village area under Phek district, every two hours interval consecutively for 3 days. Seven samples each of small and large size bumble bees were used for morphology and morphometric studies. Samples were got identified by the Division of Entomology, IARI, New Delhi. Five large size bumble bees (supposed as new queens) were shifted in separate wooden box and rearing experiments were laid as per Chauhan et al. (2014). The bumble bee queens were kept in incubator at 27± 1°C fed with 50% sugar solution and corbicular pollen. The sucrose solution was replaced every day while the pollen was replaced thrice in a week. Feeding was given in bottle lids (2.5x 1.75 cm). The queens were observed daily in night time for growth and development. The data obtained was subjected to statistical analysis.

RESULTS AND DISCUSSION

A total of 93 bumble bee samples were collected from five districts viz., Dimapur, Peren, Kohima, Phek and Kiphire. Of the districts, bumble bee samples were obtained only in hilly areas of Kohima (25° 40′ 18.147″ N, 94° 0′ 54.837″ E; 25° 39′ 14.106″ N, 94° 1′ 21.331″ E) and Phek districts (25° 33′ 45.681″ N, 94° 8′ 44.447″ E and 25° 34′ 15.6″ N, 94° 18′ 3.6″ E, 901- 2133 masl). The major flora observed include- *Lupinus* sp., *Rosa macrophylla*, *Dahlia* sp., *Calendula* sp., and *Dombeya spectabilis* (Table 1). During the month of October, the foraging bees were collected from *Cosmos bipinnatus, Dahlia* sp., *Lupinus* sp., *Dombeya spectabilis* and *Costus speciosus*. Similarly, in the month of November, the bees were caught while foraging on *Ziziphus mauritiana, Lageneria vulgaris*, *Dombeya spectabilis, Lupinus* sp., *Dahlia* sp., *Calendula* sp., *Binicasa hispida*, *Averrhoa carambola,*

Table 1. Important flora for collection of bumble bee, *B. orientalis* Smith

Month	Botanical Name	Common name	Place of collection
October	*Cosmos bipinnatus,*	Aster	Khonoma and Pfutsero
	Dahlia sp.,	Dailia	
	Lupinus sp.,	Lupin	
	Dombeya spectabilis	Pink ball	
	Costus speciosus	Crepe ginger	
	Chrysanthemum spp.	Asters	
	Lupinus sp.	Lupin	
November	*Ziziphus mauritiana,*	Ber	Khonoma and Pfutsero
	Lageneria vulgaris,	Bottle gourd	
	Dombeya spectabilis,	Pink ball	
	Lupinus sp.,	Lupin	
	Dahlia sp.,	Dailia	
	Calendula sp.,	Ruddles	
	Binicasa hispida,	Ash gourd	
	Averrhoa carambola,	Star fruit	
	Aeginetia indica	Forest ghost flower	
	Rosa macrophylla	Wild rose	
December	*Prunus cerasoides,*	Wild cherry	Khonoma and Pfutsero
	Dombeya spectabilis,	Pink ball	
	Lycopersicon esculentum,	Tomato	
	Rosa macrophylla,	Rose	
	Cajanus cajan,	Red gram	
	Calendula sp.	Ruddles	
	Allium hookeri,	Wild onion	
	Euphorbia sp.	Poinsettia	
	Prunus persica	Peach	
	Carica papaya	Papaya	

Table 2. Foraging activity of bumble bees, honey bees/ other pollinators on *Dahlia* sp. and *Lupinus* sp.

Day hour (hr)	Relative abundance (number/ 10min/ m^2)							
	Bumble bees		Honey bees		Other insects		Mean	
	Dahlia	Lupin	Dahlia	Lupin	Dahlia	Lupin	Dahlia	Lupin
0530	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0730	2.24	2.00	1.67	1.11	0.00	0.00	1.30	1.03
0930	6.63	4.67	7.33	4.11	1.67	1.00	5.21	3.26
1130	7.33	8.33	9.36	4.33	3.22	1.33	6.63	4.66
1330	5.67	5.46	6.66	2.33	3.67	2.33	5.33	3.37
1530	2.33	3.11	2.33	0.00	1.00	0.00	1.88	1.03
1630	1.33	0.00	0.00	0.00	0.00	0.00	0.44	0.00
Mean	3.65	3.37	3.91	1.70	1.37	0.67		

$CD_{p=0.05}$: Day hour: 0.43; Pollinator: 0.51; Pollinator x Day hour: 0.91

Aeginetia indica and *Rosa macrophylla*. In the month of December, *Prunus cerasoides, Dombeya spectabilis, Lycopersicon esculentum*, *Rosa macrophylla*, *Cajanus cajan, Calendula* sp., *Allium hookeri, Euphorbia* sp*., Prunus persica and Carica papaya* etc., were the sources of bumble bee samples collection. Earlier, different researchers (Saini and Ghattor, 2007; Kashyap, 2008; Chauhan et al., 2010; Chauhan, 2011; Chauhan and Thakur, 2014; Chauhan et al., 2014; Chauhan, 2015; Chauhan et al., 2016a, b; Nayak, 2018; Yankit et al., 2018; Sharma et al., 2018; Nayak et al., 2022) also observed the bumble bees on different flora and altitudes and concluded that the bumble bees can be collected while foraging for pollen and nectar. The activity of bumble bees started at 0605 hrs in the morning and ceased at 1623 hr on *Dahlia* sp. at Khonoma while the activity of bumble bees initiated at 0625hr and ceased at 1538 hr on *Lupinus* sp. during the month of November. The maximum activity of bumble bees was observed in late morning hours (1000-1300 hrs) and the minimum activity was recorded in early morning and late evening hours of the day at both locations (Table 2). Kashyap (2007); Chauhan (2011); Nayak (2018); Nayak et al. (2020); Nayak et al. (2022) observed maximum activity of *Bombus haemorrhoidalis* during late morning hours of the day and minimum activity was recorded in late evening hours in same species.

The morphological characters revealed that bumble bees were bigger in size as compared to honey bees, with black and yellow bands on the abdomen; abdomen covered with hairs, but less so on ventral side; thorax was also covered with hairs. Head and face elongate, slightly pubescent, space between eyes and base of mandibles and the clypeus was bare and shining, mesosoma and metasoma were densely pubescent. Head, thorax, upper parts of the legs and third abdominal segment clothes with black, basal two segments bright yellow and the apical three segments having brick red pubescence. Morphometrically, body, tongue, antenna, mandible, femur of hind leg, forewing and hind wing of small ones measured 19.78 mm ± 0.33, 10.44 mm ± 0.11, 5.95 mm ± 0.09, 1.53 mm ± 0.07, 4.14 mm ± 0.10, 15.64 mm ± 0.14, 10.56 mm ± 0.14, respectively. But for large size ones it was 25.49 mm ± 0.13, 12.84 mm ± 0.18, 6.89 mm ± 0.07, 2.24 mm ± 0.05, 5.96 mm ± 0.12, 21.11 mm ± 0.14 and 14.52 mm ± 0.11, respectively. *Bombus haemorrhoidalis* and *B. rufofasciatus* described by Chauhan et al. (2016a,b) differs with these, which were identified as *Bombus orientalis* Smith. Large size bumble bees kept in incubator did not secrete wax and eggs were not laid in any of the domicile. Jie et al. (2005) described methods for successful rearing of bumble bees, and revealed ambient temperature and humidity are important factors. Chauhan (2015) stated that unmated queens do not survive in winters.

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OUTBREAK OF DEFOLIATOR *COCONYMPHA IRIARCHA* MEYRICK ON COCONUT

Sujithra M*, Shashank P R[1], Santhosh Naik[1] and Rajkumar M

Division of Crop Protection, ICAR- Central Plantation Crop Research Institute (CPCRI), Kasaragod 671124, Kerala, India
[1]Division of Entomology, ICAR- Indian Agricultural Research Institute, New Delhi 110012, India
*Email: amitysuji@gmail.com (corresponding author)

ABSTRACT

A sporadic outbreak of the rare lepidopteran insect pest *Coconympha iriarcha* Meyrick (Gelechiidae: Lepidoptera) was recorded on the coconut palm (*Cocos nucifera* L.) (Arecales: Arecaceae). The larvae of these can be differentiated from the larvae of *Opisina arenosella*, the black headed caterpillar, by its size and colour. The former is with yellowish cream body with a pale brown head and is small (< 4 mm); latter is with a greenish body with red dorsal lines and a black head, and >11 mm long. In this study, reoccurrence of *C. iriarcha* is documented and it is redescribed with illustrations and damage symptoms.

Key words: Coconut, *Coconympha iriarcha*, *Opisina arenosella*, damage, defoliator, reoccurrence, redescription, illustrations, larva, differences

Coconut (*Cocos nucifera* L.) (Arecales: Arecaceae) is susceptible to >830 insect and mite species, 173 fungi, and 78 nematode species (CPCRI, 1979; Josephrajkumar et al., 2018). Of these, red palm weevil (Rhynchophorus ferrugineus Olivier), rhinoceros beetle (Oryctes rhinoceros L.), and coconut black-headed caterpillar (Opisina arenosella Walker) are the most important. Nevertheless, owing of their small size, lack of regularity in occurrence, and limited damage, certain minor pests go unnoticed. *Coconympha iriarcha* Meyrick (Lepidoptera: Gelechiidae) is one of the palm defoliators which was reported way back in 1928 on coconut fronds from Kozhikode, Kerala, India with specimens deposited in the Natural History Museum (NHM), London. However, it was described only in 1931 with erection of the genus *Coconympha*. Later, its incidence as a minor pest was reported on coconut from Malabar Coast (Lepesme, 1947), Kayamkulam (ICAR- CPCRI, 1956-57), *Calamus manan* Miq. from Malaysia (Steiner, 2001), rattan palm from Southeast Asia (Dransfield, 1979). During regular survey on monitoring of insect pests on coconut palms, incidence of *C. iriarcha* Meyrick (Lepidoptera: Gelechiidae) was observed in association with black headed caterpillar (BHC) *Opisina arenosella* in the coconut gardens (8- 10 years old) in the research farm at ICAR-Central Plantation Crops Research Institute (CPCRI), Kasaragod, Kerala (12°30'N,75°00'E) during February 2020. The details of its incidence, nature of damage on coconut along with taxonomic redescription are provided herein.

MATERIALS AND METHODS

Cocconympha iriarcha larvae collected from the infested coconut palm at the research farm were brought to the Entomology laboratory, CPCRI, Kasaragod. Larvae were placed in plastic containers and coconut leaflets were provided as food on daily basis until adult emergence. Biology was studied in the laboratory conditions at 26± 2°C, 65± 5%RH. Developmental stages were observed under Nikon SMZ 800 N stereozoom microscope and images were captured. ded. The emerged adults were collected, processed and identified using Clarke (1963) and the voucher specimens were deposited in the National Pusa Collection (NPC), Indian Agricultural Research Institute (IARI), New Delhi.

RESULTS AND DISCUSSION

The first negligible instance of *C. iriarcha* was found at the ICAR - CPCRI research farm in the nursery seedlings in the second fortnight of August 2019; later in February 2020, it was noticed in the dwarf coconut gardens (8- 10 years old) in association with *Opisina arenosella.* During February 2020, with high temperature coupled with the relative humidity, localized pest outbreak was observed. The damage symptoms include dried patches on the upper epidermis of the leaves and presence of larva and pupal stages in silken galleries made up of excreta and copious frass materials on the adaxial surface of leaflets (Fig. 1); thus symptoms are quite similar to that of *O. arenosella,* with

Fig. 1-4. *Coconympha iriarcha*; 1, 2. early larval instars; 3. Late larval instar covered with silken galleries; 4. Pupa

which symptom is initially noticed in only the older leaves. Feeding by scrapping off the under surfaces of the leaflets and later necrosis are observed as the primary mode of damage. During the outbreak all the developmental stages were observed, with large number of larvae, pupae and adults seen inside the silken galleries on the infested leaves. Nearly 38% of the coconut palms had the infestation in the affected garden (0.6 ha) and on an average, 9.06 ± 3.42 larva/ leaflet was noticed. Freshly emerged instar was yellowish (0.4- 0.6± 0.3 mm long), which turned greenish in the third and fourth instar (2.4- 3.8± 0.6 mm). Grown up larvae had two rows of prominent red patches running dorsally and with radiating spines on the lateral sides (Fig. 1-3). Pupa is obtect with chestnut to dark brown (2.6 ± 0.4 mm) (Fig. 4). Adult moth was small, grey coloured with a silvery median transverse, dorsal line. Duration from first instar to adult emergence took around 11- 17± 2.02 days.

Adult head with ocelli absent, having silvery yellowish rough scales on vertex and frons; labial palpus long, three segmented, porrect; basal segment small covered with whitish yellow, second segment narrow anteriorly and wider posteriorly, third segment long, curved, clothed with pale brown scales interspersed with black and silvery scales. Antennae long, filiform furnished with darkish brown scales. Thorax silvery brownish interspersed with yellowish scale. Unmodified three pairs of legs clothed with dark greyish scales. Hind femur with a pair of tibial spurs covered with dark gray scales. Wingspan 10-11 mm (n=5) in female and 8- 9 mm (n= 6) in male, half of the forewing olive-green interspersed with small grey scales with a metallic blue patch extending along the basal third of the costa, median transverse line silvery-white, followed by a metallic blue streak, area beyond this black with a coppery-purple-metallic fascia just before the termen, silvery white scales all along the apical margin; hindwings are dark fuscous with the basal half rather lighter. Abdomen with its first three segments clothed with metallic bluish interspersed with olive green colored scales, remaining abdomen with metallic bluish grey scales and anal tuft metallic blue scales (Fig. 5-7).

Male genitalia with uncus short; tegumen distinctly broadened at middle, tapering terminally and rounded apically. Socius small with 5- 6 needle like spines. Gnathos reduced. Valva oblong, hairy, terminally bifurcated. Sacculus sclerotized basely and membranous

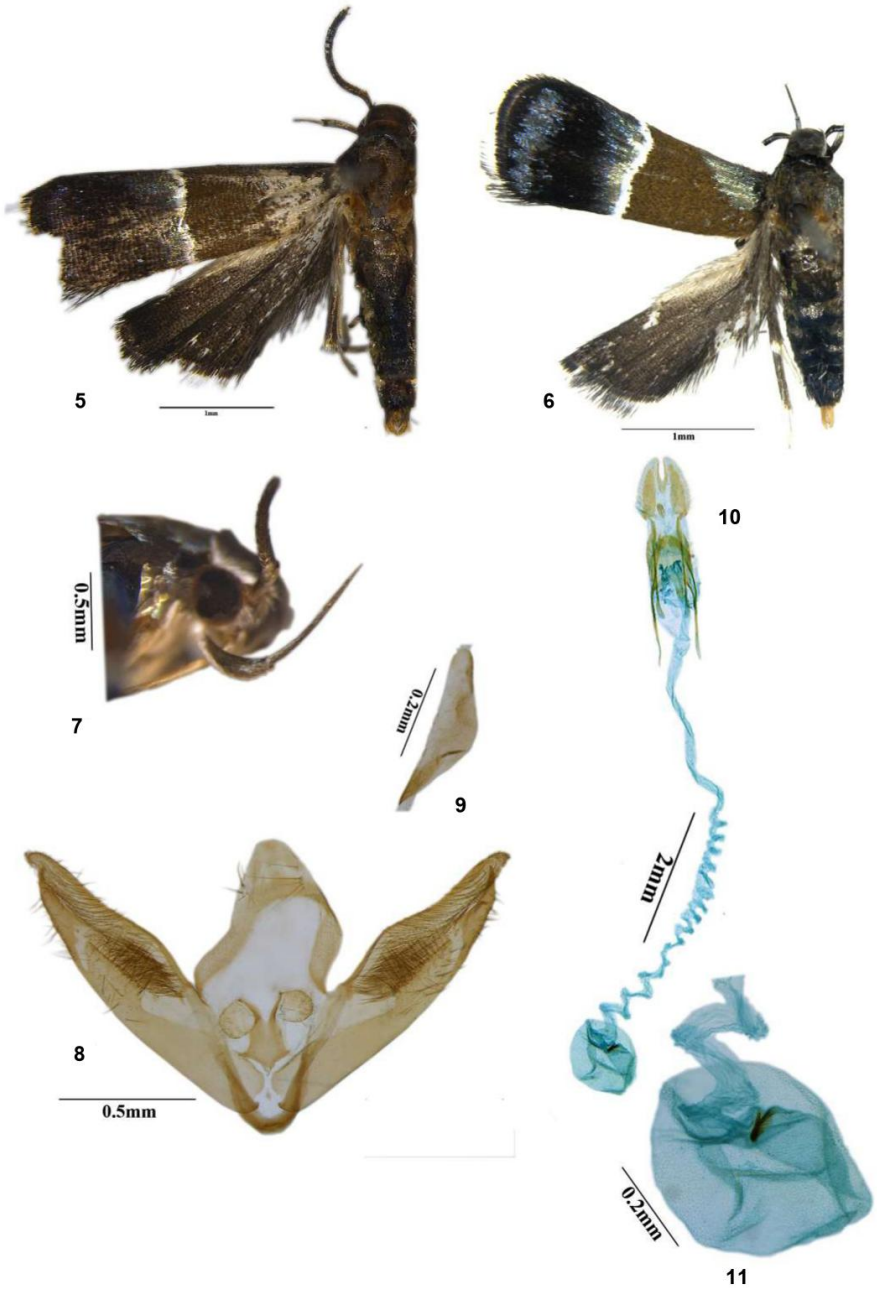

Fig. 5-11. *Coconympha iriarcha* Male, female, genitalia: 5. Male; 6. Female; 7. Labial palp; 8. Male genitalia; 9. Aedeagus; 10. Female genitalia; 11. Corpus bursae

towards anterior. Juxta well developed and district. Vinculum well sclerotized. Aedeagus short, broad at middle, rounded apically (Fig. 8, 9). Female genitalia with papilla analis medium sized, lightly setosed with micro setae. Posterior apophyses longer than anterior apophyses. Corpus bursae small to medium, spherical, dilated, signum present and elongated. Ductus bursae very long, basal half spiraled and 6x times the width of corpus bursae (Fig. 10, 11).

Although its damage to coconut fronds had been reported long ago in 1928 from Malabar Coast, Kerala, and reported as minor pest from Kayamkulam during 1956-57, information about its damage symptoms, existence and description are very scarce. In fact, it is among the least studied species that affect coconuts. It was observed that the larvae were able to infest 38% of the palms in an acre of coconut garden, indicating its ability to cause significant damage if not managed.

Profuse feeding on the coconut fronds by scrapping the green matter and inhabiting inside the silken galleries with frass material are the characteristic symptoms of C. iriarcha infestation which corroborates with the findings of Binoy et al. (2021) and Steiner (2001). Binoy et al., (2021) observed *C. iriarcha* infestation from Kozhikode, Kerala along with parasitic wasps viz*., Pediobius coconymphagus* Binoy and Sureshan, and *Goniozus coconymphagus* Santhosh, from its pupae and larvae. The occurrence of *C. iriarcha* incidence on coconut got overlooked because of its cooccurrence with a dominant defoliator, *O. arenosella* in the past years. However, detailed studies on its distribution pattern, biology and management strategies are required.

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FIRST REPORT OF *ACANTHOCORIS SCABRATOR* (COREIDAE) AS A PEST OF VEGETABLES IN INDIA

K M Shameem, S R Hiremath[1&] and K D Prathapan[1]*

Department of Zoology, Government College Chittur, Chittur, Palakkad 678104, Kerala, India
[1]Department of Agricultural Entomology, Kerala Agricultural University,
Vellayani PO, Trivandrum 695522, Kerala, India
[&]Present address: Department of Agricultural Entomology, Karunya Institute of Technology and Sciences,
Karunya Nagar, Coimbatore, Tamil Nadu- 641114, India
*Email: prathapankd@gmail.com (corresponding author): ORCID ID: 0000-0001-8493-1555

ABSTRACT

In this study, a coreid bug *Acanthocoris scabrator* (Heteropera: Coreidae) is reported as a pest of *Capsicum annuum, C. frutescens, Ipomoea aquatica, I. batatas* and *Solanum melongena* from Kerala, India. No acute symptoms such as drying up or wilting was observed either on *Solanum melongena* or *Capsicum* spp.; however, on *I. aquatica* and *I. batatas*, water-soaked lesions were observed around the feeding punctures on the tender stem. This is a new record of this pest from Andaman and Nicobar Islands.

Key words: *Acanthocoris scabrator*, Coreidae, host plants, *Capsicum annuum*, *Capsicum frutescens*, *Ipomoea aquatica*, *Ipomoea batatas*, *Solanum melongena*, Andaman Islands, new record, Kerala, vegetables, pest

Acanthocoris scabrator (Heteroptera: Coreidae) was described by Fabricius in 1803 based on specimens from Malaysia and Sumatra. It is widely distributed in the Oriental region and adjoining areas such as Sri Lanka, India, Myanmar, Malaysia, Indonesia, the Philippines, south China and Japan (Distant, 1902; Hoffman, 1928; Dolling, 2006). Dolling (2006) opined that "records of *Acanthocoris scabrator* from China are possibly erroneous and referable to *Acanthocoris scaber* if the species are truly distinct." Plants reported as host for *A. scabrator* include *Punica granatum* L. in Japan (Hoffman, 1928); *Capsicum annuum* L., *Capsicum* sp., *Cestrum nocturnum* L., *Cucurbita maxima* Duschesne, *Ipomoea* sp. (morning glory), *Physalis peruviana* L., *Solanum melongena* L., *Solanum nigrum* L. and *S. torvum* in China (Hoffman, 1931); *S. aculeatissifolium* Jack (?*Solanum aculeatissimum* Jacq.) (Miller, 1931), *I. palmata* Forsk., *I. batatas* Lam. (Miller, 1931, 1932) and *Vigna unguiculata* (L.) Walp. (Cowpea) (Miller, 1932) in Malaysia; and *Lantana* (Rao, 1920), *I. carnea* Jacq. and *Mangifera indica* L. (Koshy et al., 1977, 1978) in India. Biology of the insect was studied by Hoffman (1928) in China, Miller (1931) in Malaysia and Koshy et al. (1977) in India. Herein, this coreid is reported as a pest on vegetables from Kerala for the first time in India.

MATERIALS AND METHODS

Infestation of *A. scabrator* on different species of vegetables was observed by the first author in 2012 in Kerala, India. The insect was identified based on the description provided by Distant (1902). This was further confirmed based on the images of a syntype. Specimens of *A. scabrator* were collected from different states in mainland India as well as the Andaman & Nicobar Islands. Symptoms and nature of damage due to the pest were recorded on different vegetable crops. Intensity of infestation was recorded on *Capsicum annuum* at Manacaud, Trivandrum, Kerala in 2020. Voucher specimens of the bug are deposited in the Travancore Insect Collection, College of Agriculture, Vellayani, University of Agricultural Sciences, Bengaluru (UASB) and the National Bureau of Agriculturally Important Insects (NBAIR), Bengaluru (Accession no. NBAIR/HET-COR/5121 to NBAIR/HET-COR/5125). Plant vouchers of *C. annuum* (Accession no. 6761), *C. frutescens* L. (Accession no. 6760), *I. aquatica* Forssk. (Accession no. 7017, 7018) and *S. torvum* (Accession no. 6473) are deposited in the Calicut University Herbarium.

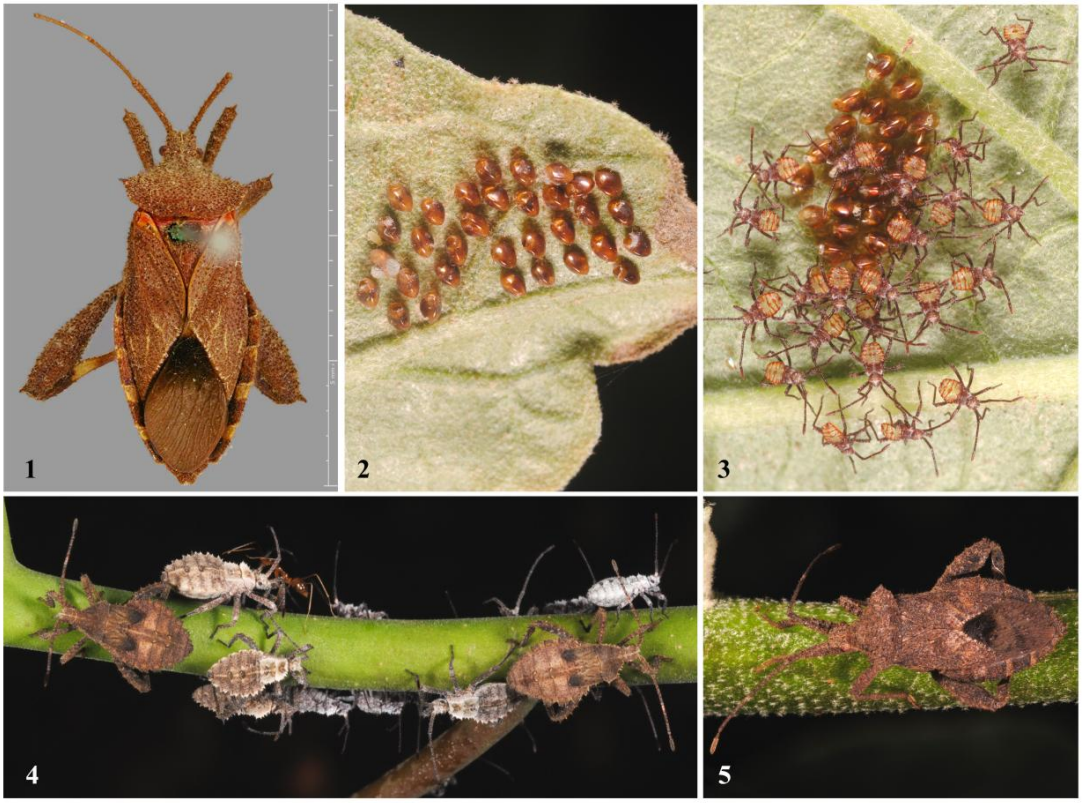
RESULTS AND DISCUSSION

Infestation of *A. scabrator* was observed on brinjal *S. melongena*, chilli *C. annuum*, Tabasco Pepper (Cayenne pepper) *C. frutescens* L., sweet potato *I. batatas* and water spinach *I. aquatica* in Kerala, south India. Infestation on *C. annuum* and *C. fruitescens* has been noticed at Tirurangadi (N 11° 02' 14.3" E 75° 55' 27.8"), Kerala since 2012. Heavy population of the bug was

observed on brinjal at Malayinkeezhu in Trivandrum (8° 30' 34.8" N 76° 59' 48.5" E) in April 2018. On 25 May 2020, *A. scabrator* was observed on *C. annuum* at Manacaud in Trivandrum District (N 8° 27' 32.62572" E 76° 56' 51.02664"). Infestation was observed on six plants of *C. annuum* ranging from 5 to 27 adults and nymphs (mean 15.3). The maximum infestation observed on a plant was 9 adults and 18 nymphs. Bugs were also collected on *I. carnea* at Tirurangadi (N 11° 02' 14.3" E 75° 55' 27.8") and on *S. torvum* Sw. at Pampadumpara (N 09° 48′ 23.7″ E 77° 10′ 04.9″). The bug was observed breeding on *I. batatas* and *I. aquatica* at Vellayani (N 08° 25′ 47.5″ E76° 59′ 8.3″). A single specimen was collected in the Little Andaman Island, Andaman and Nicobar Islands (N 10° 41' 47.0", E 92° 33' 25.8" 56 m). Specimens have also been collected from Karnataka in South India and Arunachal Pradesh and Manipur in northeast India.

Adults and nymphs congregated on the stem and sucked sap. (Fig. 1-5). Apparently, no acute symptom, such as drying up or wilting, was observed on either brinjal or chillies. On *I. aquatica* and *I. batatas*, water-soaked lesions were observed around the feeding punctures on the tender stem. *Acanthocoris scabrator* is known as a pest of *S. melongena* and *Capsicum annuum* in China and *I. batatas* in Malaysia, however, this is the first report of the bug on these vegetables in India. This is also the first ever record of *A. scabrator* on *C. frutescens,* and *I. aquatica*. Chen (1983) reported the closely related *A. scaber* (L.) on *C. frutescens* in China. Presence of the bug in the Andaman and Nicobar Islands is recorded for the first time.

Material examined: India. Kerala: 1♂, 3♀ Vellayani, N 08° 25' 47.5", E 76° 59' 8.3", 27.viii.2018, Prathapan & Sangamesh Coll., Ex *Ipomoea* sp.; 1♀, same data except host *Ipomoea batatas;* 5♂, 9♀ Malayankeezhu, 8° 30' 34.8" N 76° 59' 48.5" E, 28.iv.2018, SR Hiremath & Prathapan, Ex Brinjal; 2♂, 2♀ same data except host Chilli; 2♂, 2♀ Pampadumpara, 24.x.2015, Prathapan KD Coll., Ex *Solanum torvum*; 1♂ same data except host *Ipomoea*; 1♂, 2♀ same data without host (sweep net); 1♂, 2♀ Chittur, 10° 41' 19.1"N 76° 43' 25.1"E, 15.v.2018 112 m, Shameem KM Coll., Ex *Ipomoea carnea*; 2♂, 1♀ Tirurangadi, 28.ix.2012, Shameem K Coll., Ex Chilli; 2♀ same data except date 19.x.2012; 2♂, 1♀ same data except date 1.xi.2012; 1♀ same data except date 20.xi.2012; 3♂ same data except date 29.xi.2013; 1♀



Figs. 1-5. *Acanthocoris scabrator*. 1. Syntype (Natural History Museum, London), 2. Mass of eggs and hatched out egg shells, 3. early instar nymphs, 4. nymphs congregated for feeding, 5. adult

same data except date and host 13.xii.2012, *Ipomoea* sp.; 2♂, 1♀ Tirurangadi, N 11° 02' 14.3", E 75° 55' 27.8", 14.xii.2014, Prathapan & Shameem Coll., Ex. *Ipomoea carnea*; Karnataka: 1♂ Bangalore, GKVK, N 13°04'36.18" E77°34'41.79", SR Hiremath Coll.; Manipur:1♂, 1♀ Churachandpur, Ngaloi Falls, N 24° 19' 53.7", E 93° 38' 47.7" 1148 m, 18.viii.2014, Prathapan & Shameem Coll.; 1♀ Keibul Lamjao N.P., N 24° 28' 47.4", E 93° 48' 29.7" 774 m, 20.viii.2014, Prathapan & Shameem Coll.; 1♂ Pallel, Saivom, N 24° 23.506' , E 94° 05.200' 1387 m, 21.viii.2014, Prathapan & Shameem Coll.; Arunachal Pradesh: 1♀ Kebali, N 28° 11' 56.0", E 95° 48' 48.0", 783 m, 10.ix.2014 Prathapan KD Coll.; Andaman & Nicobar Islands: 1♂ Little Andaman, VK Pur, N 10° 41' 47.0", E 92° 33' 25.8" 56 m, 30.iv.2014, Prathapan KD Coll.

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AUTHOR CONTRIBUTION STATEMENT

KMS first observed the pest; collected specimens, made biological observations, preparation of the manuscript; SRH collected specimens, prepared plate, gathered biological data; writing up of the manuscript; KDP identified the insect, collected specimens, made observations; writing up of the manuscript.

CONFLICT OF INTEREST

Authors declare no conflict of interest.

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EFFICACY OF BOTANICAL FORMULATIONS AGAINST COCONUT RHINOCEROS BEETLE *ORYCTES RHINOCEROS*

M Alagar*, T Srinivasan[1], K Rajamanickam[2], A Josephrajkumar[3], A Yasmin[1], S Chinnadurai[1], V Sivakumar, S Praneetha and H P Maheswarappa[4]

Coconut Research Station, Aliyarnagar 642101,
Tamil Nadu Agricultural University (TNAU), Tamil Nadu, India
[1]Department of Agricultural Entomology; [2]Directorate of ODL, TNAU, Coimbatore 641003, Tamil Nadu, India
[3]ICAR-Central Plantation Crops Research Institute, Regional Station, Kayamkulam 690533, Kerala, India
[4]University of Horticultural Sciences, Bagalkot, Karnataka 587102, India
*Email: siaamalagar@gmail.com (corresponding author)

ABSTRACT

Field efficacy of botanical cakes and insecticides when evaluated in coconut against the rhinoceros beetle *Oryctes rhiniceros* L., revealed that leaf damage reduced to 9.5% with botanical cake and paste. Palms treated with chlorantraniliprole 0.4% GR (10.5%) and neem cake admixed with sand (11.5%) were also effective compared to control (40.0%) at 30 months after treatment (MAT). The leaf damage was significantly low (14.2%) in chlorantraniliprole 0.4%GR treated palms, and the next best was botanical cake and paste (15.2%). The palms treated with the botanical cake and paste revealed the least spear leaf damage of 15.0%, compared to that of chlorantraniliprole 0.4% GR (18.5%) and naphthalene balls (20.0%). The overall mean spear leaf damage was significantly lower in chlorantraniliprole 0.4% GR treated palms (40.4%) followed by palms treated with naphthalene balls (42.9%) and botanical cake and paste (44.4%) compared to control (78.9%).

Key words: *Oryctes rhinoceros*, coconut, botanical formulations, juvenile palms, leaf damage, spear leaf, chlorantraniliprole, botanical cake and paste, weed extracts

Coconut (*Cocos nucifera* L.) is one of the major plantation crops in India. Among the various insect pests causing damage to coconut, rhinoceros beetle (*Oryctes rhinoceros* L.) is a serious pest in South East Asia (Bedford, 1980). It causes serious damage in juvenile coconut palms in the age group of one to six years. The adults upon emergence go in search of crown region of juvenile palms during night for feeding, remaining in the breeding sites during day time. The adult beetle also causes injury to the juvenile palms by boring into the spear leaf, spathe and young petioles and eating away the growing spindle leads to the 40-45% failure in the seedling establishment (Josephrajkumar et al., 2015). Damaged spear leaf is prone to breakage and drying up and exhibit 'V' shaped cuts on the leaf lamina when unfurls. Repeated attacks results in stunted growth or mortality of the juvenile palms (Hinckley, 1966; Chandrika et al., 2018). Of late, the pest was found boring into the immature tender nuts causing yet another route of feeding when the spear leaf is protected (Josephrajkumar et al., 2019; Chandrika et al., 2018). In majority of the cases, rhinoceros beetle attack leads to infestation by red palm weevil, fungal infections, etc. (Sharadraj and Chandramohanan, 2013; Josephrajkumar et al., 2015) causing death of the juvenile coconut palms (Molet, 2013).

This pest could be kept under check by using varied options including cultural, mechanical, biological and chemical control measures. Recently, ICAR-Central Plantation Crops Research Institute (ICAR-CPCRI), Regional Station, Kayamkulam, Kerala developed a botanical cake and paste using hexane and methanolic extracts from weed plants (*Clerodendrum infortunatum* L. and *Chromolaena odorata* (L.) to safeguard juvenile palms from rhinoceros beetle attack (CPCRI, 2016). Earlier studies on management of rhinoceros beetle using biorationals revealed that application of oil cakes of neem (*Azadirachta indica* A Juss.) or marotti (*Hydnocarpus wightiana* Bl.) in powder form @ 250 g mixed with equal volume of sand, thrice a year during May, September and December to the base of three leaf axils surrounding spear leaf is an effective prophylactic method against rhinoceros beetle and red palm weevil (Chandrika et al., 2001). Placement of botanical cake

developed by ICAR-CPCRI @ 10 g was found effective during monsoon phase (Josephrajkumar et al., 2015). The botanical cake and paste formulated from botanicals is easy to handle and apply, ecofriendly and compatible with other IPM methods. With this background the present study was carried out to evalaute the field efficacy of CPCRI-botanical cake and paste against the rhinoceros beetle infesting juvenile coconut palms.

MATERIALS AND METHODS

The botanical cake and paste were developed at the ICAR-Central Plantation Crops Research Institute, Regional Station, Kayamkulam. The botanical cake was prepared using 10% hexane and methanolic extract of *C. infortunatum* L. and *C. odorata* (L.) and incorporated in the soap making process and moulded as a tablet. The paste was prepared using white grease and added with 10% cashew nut shell liquid and botanical extract of *C. infortunatum* and *C. odorata* made in a paste form. To evaluate the field efficacy of botanical cake and paste in juvenile coconut palms a trial was laid out in a farmer's field located in Angalakurichi village (10°29'26.5"N 76°59'01.8"E) of Anaimalai block, Coimbatore district, Tamil Nadu during 2016 to 2019 . The experimental field comprised Dwarf x Tall (GBDG x WCT) coconut hybrid that are six years old juvenile palms and have started bearing. The treatment details are: T_1: Botanical cake @ 10 g applied three times once in four months (February, June & October) + botanical paste @ 15 g/ palm applied three times once in four months (April, August & December), T_2: Neem cake + sand @ 150 g/ palm to be filled in the inner most leaf axils - once in four months (February, June & October), T_3: Placement of naphthalene balls in the inner most leaf axils @ 12 g/ palm - once in two months (February, April, June, August, October & December), T_4: Placement of chlorantraniliprole 0.4% GR @ 6 g per palm (in perforated sachets) in the inner most leaf axils - once in 4 months (February, June & October) and T_5: Control. The experiment was laid out in RBD design, with four replications and 20 palms/ treatment. The observations on rhinoceros beetle incidence in terms of leaf damage (No. of infested leaf x100/ total number of leaf) and spear leaf damage (Infested spear leaf x100/ total number of spear leaf) were recorded one day before the treatment. The post-treatment observations were recorded during March, June, September and December, every year. The experiment was conducted for two and half years. The data were analyzed using AGRES statistical package and mean data were compared using Least Significant Difference (LSD).

RESULTS AND DISCUSSION

There were no significant differences among the treatments at three months after treatment (MAT). The palms treated with chlorantraniliprole 0.4% GR registered the least leaf damage of 16.6%, followed by botanical cake and paste (17.1%) when compared to control palms (27.3%) at six MAT. The palms treated with botanical cake and paste recorded significantly lowest leaf damage of 9.50%, followed by chlorantraniliprole 0.4% GR (10.5%) and neem cake and sand-treated palms (11.5%) as compared to control palms (40.0%) at 30 MAT.

With regard to spear leaf damage, there was no significant difference among the treatments at three to twelve MAT. However, palms treated with chlorantraniliprole 0.4% GR and naphthalene balls registered least spear leaf damage of 50.0% and 55.0% respectively, as compared to 75.0% spear leaf damage in control palms at six MAT. At 30 MAT, a gradual and significant damage reduction was observed in all the treatments. The palms treated with botanical cake and paste recorded least damage of 15.0%, followed by chlorantraniliprole 0.4% GR (18.5%) and naphthalene balls-treated palms (20.0%) at 30 MAT. The overall means indicated that leaf damage and spear leaf damage was significantly lowest in palms treated with chlorantraniliprole 0.4% GR followed by botanical cake and paste treated palms compared to control palms (Table 1).

In a similar study, application of naphthalene balls @ 12 g/ palm in the leaf axil at the base of spear leaf safeguarded the juvenile coconut palms against rhinoceros beetle in Malaysia (Singh, 1987) and India (Sadakathulla and Ramachandran, 1990). Chandrika et al. (2001) reported that the application of neem cake in powder form @ 250 g admixed with equal volume of sand, thrice a year on the top most three leaf axils of coconut palm is an effective prophylactic method. Srinivasan and Shoba (2017), Josephrajkumar et al. (2012) and Wankhede at al. (2020) also reported that palms treated with chlorantraniliprole 0.4% GR, ICAR-CPCRI botanical cake @ 10g/ palm + paste @ 15 gram/ palm followed by naphthalene balls @12g/ palm are effective in different coconut growing belts. Thus, the present results agree with those of previous studies. Among the biorationals, palms-treated with ICAR-CPCRI botanical cake @ 10g/ palm + paste 15 g/ palm followed by naphthalene balls @12g/ palm are found effective. Thus, it is an ecofriendly alternative for

Table 1. Efficacy of botanical cake and paste for the management of rhinoceros beetle in coconut

Treatments	Leaf damage (%)											Mean
	Oct. 2016 (PTC)	Dec 2016 (3 MAT)	March 2017 (6 MAT)	June 2017 (9 MAT)	Sept. 2017 (12 MAT)	Dec. 2017 (15 MAT)	March 2018 (18 MAT)	June 2018 (21 MAT)	Sept. 2018 (24 MAT)	Dec. 2018 (27 MAT)	March 2019 (30 MAT)	
T_1 - Botanical cake @ 10g + paste @ 15g / palm	21.5 (27.6)	19.5 (26.2)	17.1 (24.1)	15.2 (22.9)	17.3 (24.6)	16.8 (24.2)	14.9 (27.6)	13.7 (21.7)	11.5 (19.8)	10.5 (18.9)	9.5 (18.0)	15.2 (23.0)
T_2- Neem cake+ sand @150 g / palm	20.3 (26.8)	19.6 (26.3)	18.7 (25.6)	17.3 (24.6)	18.5 (25.5)	17.9 (25.0)	16.7 (26.8)	15.5 (23.1)	13.4 (21.4)	13.1 (21.2)	11.5 (19.8)	16.6 (24.0)
T_3 -Naphthalene balls @12 g/palm	23.60 (29.1)	20.6 (27.0)	18.5 (25.5)	15.9 (23.5)	15.8 (23.4)	14.50 (22.4)	16.2 (29.1)	16.0 (23.6)	15.3 (23.0)	13.8 (21.8)	12.00 (20.3)	16.6 (24.0)
T_4 -Chlorantraniliprole 0.4% GR @ 6g/ palm	25.4 (30.3)	20.5 (26.9)	16.6 (24.0)	12.2 (20.4)	15.6 (23.3)	12.4 (20.6)	11.1 (30.3)	11.0 (19.4)	10.5 (18.9)	10.5 (18.9)	10.5 (18.9)	14.2 (22.1)
T_5 - Control	24.9 (30.0)	26.7 (31.1)	27.3 (31.5)	30.9 (33.8)	30.2 (33.3)	29.6 (33.6)	30.4 (30.0)	32.1 (34.5)	35.8 (36.8)	38.5 (38.4)	40.0 (39.3)	31.5 (34.1)
CD (p=0.05)	NS	NS	4.7	6.13	4.26	5.91	4.34	1.6	1.8	1.4	1.3	2.0
S.Ed.	0.7	0.9	1.2	2.1	1.7	1.9	2.1	0.7	0.8	0.6	0.6	4.4
Treatments	Spear leaf damage (%)											Mean
T_1 - Botanical cake @ 10g + paste @ 15g/ palm	85.0 (67.2)	75.0 (60.0)	70.0 (56.8)	70.0 (56.8)	45.0 (42.1)	30.0 (33.2)	25.0 (30.0)	25.7 (30.5)	20.5 (26.9)	20.2 (26.7)	15.0 (22.8)	44.4 (41.4)
T_2 - Neem cake+ sand @150 g/ palm	85.0 (67.2)	75.0 (60.0)	75.0 (60.0)	75.0 (60.0)	40.0 (39.2)	40.0 (39.2)	35.0 (36.3)	35.0 (36.2)	33.5 (35.3)	30.5 (33.5)	25.5 (30.3)	49.1 (45.0)
T_3 -Naphthalene balls @12 g/ palm	70.0 (56.8)	60.0 (50.8)	55.0 (47.9)	55.0 (47.9)	40.0 (39.20	45.0 (42.1)	30.0 (33.20)	30.0 (33.2)	28.7 (32.1)	20.7 (27.1)	20.0 (26.6)	42.9 (40.0)
T_4 -Chlorantraniliprole 0.4% GR @ 6g/ palm	75.0 (60.0)	60.0 (50.8)	50.0 (45.0)	50.0 (45.0)	35.0 (36.3)	40.0 (39.20)	30.0 (33.2)	25.0 (29.9)	23.5 (28.9)	20.2 (26.7)	18.5 (25.6)	40.4 (38.5)
T_5 - Control	70.0 (56.80)	75.0 (60.0)	75.0 (60.0)	75.0 (60.0)	70.0 (56.8)	75.0 (60.0)	80.0 (63.4)	80.0 (63.5)	82.6 (65.4)	85.5 (67.7)	90.0 (71.6)	78.9 (62.1)
CD (p=0.05)	NS	NS	4.7	NS	NS	21.8	21.2	2.7	1.6	1.7	1.5	2.6
S.Ed.	2.1	2.3	3.3	3.3	3.9	4.8	6.4	1.2	3.5	3.7	3.1	1.2

Figures in parentheses arcsine transformed values; MAT: Month After Treatment

the prophylactic management of the rhinoceros beetle in juvenile coconut palms.

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EFFICACY OF COLOURED STICKY TRAPS AGAINST THRIPS IN COTTON

M Amutha

ICAR-Central Institute for Cotton Research (CICR),
Regional Station, Coimbatore 641003, Tamil Nadu, India
Email: amuento@yahoo.co.in

ABSTRACT

Colour sticky traps are used in several crops for monitoring and mass trapping. This study evaluated coloured sticky traps for mass trapping of thrips *Scirtothrips dorsalis* (Hood), *Thrips tabaci* (Lindeman) and *Thrips palmi* (Karny) in cotton. The attractiveness of six colours viz., blue, yellow, orange, green, red and white in traps was evaluated during 2018 to 2020. Number of thrips captured in differed coloured traps was significantly different, with the blue-coloured sticky trap attracting more thrips followed by yellow. These observations reveal that blue and yellow- coloured traps can be used for monitoring and mass trapping of thrips as a component of IPM programme in cotton.

Key words: *Scirtothrips dorsalis* (Hood), *Thrips tabaci*, *Thrips palmi*, management, sticky traps, yellow, blue, white, attraction, monitoring, IPM

Bt cotton hybrids have become highly susceptible to sucking pests viz., thrips, leafhoppers and whiteflies which result in increased crop damage (Nagrare et al., 2014). Due to climate change thrips *Scirtothrips dorsalis* (Hood), *Thrips tabaci* (Lindeman) and *Thrips palmi* (Karny) (Thysanoptera) have become major sucking pests, due to direct feeding and transmitting viral diseases. Among the viral disease Tobacco Streak Virus (TSV) transmitted by thrips causes more significant damage to cotton (Vinodkumar et al., 2017). The polyphagous nature, high reproductive capacity, short generation time, cryptic living habit, parthenogenetic reproduction and its insecticide resistance mechanisms altogether have made thrips serious in cotton (Diaz Montano et al., 2011). For managing these thrips farmers use many insecticides, which results in many hazards, making non-chemical pest management as the need of the hour. Monitoring and assessment of pest population are important for decision making in any IPM strategy. Coloured sticky traps provide effective tools for monitoring and mass trapping of sucking pests and for reducing pesticide load on cotton. Although many studies have explored colour preference by thrips, still there is ambiguity in precise colour preference by thrips. The present study evaluates this by different colour sticky traps under field conditions.

MATERIALS AND METHODS

The field experiment was conducted in the cotton fields at ICAR-CICR, Regional Station, Coimbatore, Tamil Nadu during kharif 2018-19, Summer 2019 and kharif 2019-20, with cv.Suraj. The crop was planted with the spacing of 60x45cm. Six coloured sticky traps viz., yellow, blue, red, orange, green and white of uniform size were used. Traps were prepared with the respective coloured polythene sheets of size 45x 25 cm, and erected across the wind direction with bamboo stacks, with their height adjusted each time @ one foot above the plant canopy. Transparent white grease was applied (at 15 days interval) uniformly as a thin layer on both sides of the colour surfaces. No insecticides were sprayed and randomized block design was followed with three replications. Six colour traps with replication of three, totally eighteen coloured traps were installed. Mean number of thrips stuck on traps were counted using zoom lens from 30 days onwards at 15 days interval up to 105 days after sowing (DAS). Thrips species were got taxonomically confirmed by Dr Rachana, ICAR-NBAIR, Bengaluru, Karnataka, India. Data were subjected to ANOVA and treatment means differentiated by LSD (p=0.05) in Agres software.

RESULTS AND DISCUSSION

The observations revealed that dominant thrips species prevalent are *Scirtothrips dorsalis* (Hood), *Thrips tabaci* (Lindeman) and *Thrips palmi* (Karny), Observations on number of thrips during 2018-19 revealed that, the blue colour sticky traps attracted more thrips followed by yellow sticky traps; blue colour traps attracted 48.33, 63.00 and 76.33/ trap on 30, 45 and 60 DAS, respectively. Thus, blue colour sticky traps

Table 1. Attraction of thrips to sticky traps in cotton

Seasons	Treatments	Mean number of thrips/ trap*						Mean
		Vegetative phase			Flowering and boll developmental phase			
		30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	
Kharif 2018-19	Yellow sticky trap	34.67	52.67	63.67	81.33	136.33	104.67	78.89
	Blue sticky trap	48.33	63.00	76.33	85.33	163.67	125.33	93.67
	Red sticky trap	13.00	13.00	17.67	25.33	43.67	33.67	24.39
	Orange sticky trap	11.67	11.67	17.00	24.33	43.67	32.33	23.44
	Green sticky trap	27.00	34.33	36.33	43.67	82.33	65.67	48.22
	White sticky trap	21.33	21.33	31.67	38.33	75.67	52.33	40.11
	S.Ed	0.509	0.495	0.519	0.441	0.506	0.493	0.272
	CD (0.5%)	1.149	1.117	1.171	0.995	1.142	1.114	0.615
Summer 2019	Yellow sticky trap	45.67	63.33	75.67	90.67	146.00	117.33	89.78
	Blue sticky trap	58.00	73.67	76.67	98.00	174.00	136.67	102.83
	Red sticky trap	25.67	25.67	28.33	37.00	57.00	46.67	36.72
	Orange sticky trap	25.00	24.67	31.00	38.00	57.00	45.67	36.89
	Green sticky trap	38.33	44.67	46.67	55.00	95.67	77.67	59.67
	White sticky trap	43.67	47.33	55.33	61.33	100.33	78.67	64.44
	S.Ed	0.270	0.481	0.444	0.402	0.458	0.416	0.220
	CD (0.5%)	0.610	1.085	1.001	0.907	1.034	0.939	0.497
Kharif 2019-20	Yellow sticky trap	16.33	35.00	48.33	65.00	121.33	92.00	63.00
	Blue sticky trap	32.33	47.00	61.67	71.33	142.00	114.00	78.06
	Red sticky trap	9.00	10.00	14.67	18.67	34.33	22.00	18.11
	Orange sticky trap	11.00	9.33	16.00	17.67	31.00	25.33	18.39
	Green sticky trap	14.33	21.67	23.33	33.33	65.00	51.67	34.89
	White sticky trap	15.33	28.00	38.33	49.00	95.00	74.00	49.94
	S.Ed	0.474	0.395	0.397	0.424	0.445	0.390	0.147
	CD (0.5%)	1.069	0.891	0.896	0.957	1.005	0.880	0.332

*Mean of three replications; DAS- Days after sowing

attracted maximum (93.67/ trap) followed by yellow sticky traps (78.89/ trap) and green sticky trap (48.22/ trap). Blue sticky traps were the most significantly attractive for onion thrips *T. tabaci* in onion (Liu and Chu, 2004). Similar was the case with *Frankliniella occidentalis* (Chen et al., 2004a). Blue traps were the most attractive to *Thrips fuscipennis* and *T. tabaci*, followed by yellow and white trap (Maria et al., 2020). Similarly, the other findings (Chen et al., 2004b; Ren et al., 2020; Sandra et al., 2018) confirm that blue colour traps are the most attractive for *F. occidentalis*. During summer, more thrips got attracted compared to kharif season, and again similar to that of previous season blue colour attracted 58 thrips/ trap at 30 DAS, 73.67 at 45 DAS, 76.67 at 60 DAS, 174 at 90 DAS and 136.67 at 105 DAS. The results show that after 90 DAS the number of thrips trapped got reduced. The overall means indicate that blue sticky traps attracted more thrips (102.53/ trap) followed by yellow sticky trap (89.78/ trap) and white (64.44/ trap). Similar trend was observed during kharif 2019, with blue colour attracting more thrips (78.06/ trap) followed by yellow (63.00/ trap) and white ones (49.94/ trap) (Table 1). The performance of colour traps was in the order of blue > yellow > white > green > red > orange. Minimum thrips catches were recorded during the cotyledon stage (30 DAS), which gradually increased during the vegetative and flowering stage (45 to 90 DAS). High chlorophyll content during the vegetative stage attracted more thrips towards cotton (Atakan and Ozgur, 2000). Thus, blue sticky traps were the most effective for monitoring thrips in cotton.

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EVALUATION OF INSECTICIDES AND SUITABLE TRAP CONTAINERS FOR EFFECTIVE FRUIT FLY CATCHES

Singh H S, Gundappa Baradevanal* and Dharm Beer

ICAR-Central Institute for Subtropical Horticulture, Lucknow 226101, Uttar Pradesh, India
*Email: Gundappa@icar.gov.in (corresponding author)

ABSTRACT

Fruit flies are quarantine pests and major impediments in horticultural production, domestic market, and export of fresh fruits and vegetables. Trapping with a lure is the best known method to monitor/ manage the fruit fly *Bactrocera dorsalis* populations. The fruit fly attraction and its mortality depend on the lure, type of killing agent, and design of the trap container. To make the trapping technology more robust, a study was conducted to find out the suitable killing agent amongst ten insecticides and the best trap design among the available six trap designs. The results revealed that emamectin benzoate 1.9EC was superior as killing agent with the maximum trap catches (648.75 to 1304.75 fruit flies/ trap) up to 12 weeks, followed by abamectin 1.9EC and profenophos 50EC. Among the trap designs, the CISH trap container was found to be superior (306.25 to 940.00 fruit flies/ trap/ week).

Key words: Fruit flies, mango, *Bactrocera dorsalis*, insecticides, trap designs, methyl eugenol, emamectin benzoate, abamectin, profenophos, CISH trap

Post-harvest losses in fresh fruits and vegetables are caused by tephritid fruit flies. Furthermore, they are significant impediments to the trade of fresh fruits and vegetables. Mango and guava are two of the most important fruit crops that are being affected by fruit fly all over the world. Despite decades of research, fruit flies continue to be a significant threat to India's fruit and vegetable production. Fruit flies (*Bactrocera* spp.) cause significant damage and economic impact to all stakeholders. Smallholder farmers may suffer greater losses as a result of fruit fly infestation. These quarantine pests may also endanger the export potential of fresh fruits and vegetables. In general, fruit flies monitoring is being done in India using parapheromones like methyl eugenol (in the case of fruit crops like; mango, guava, banana, peach, orange, fig, sweet lime, etc) and cue lure (in the case of cucurbits). Male tephritid fruit flies show strong behavioural responses to these parapheromones. Methyl eugenol is widely recognized as the most powerful male lure currently in use for detection, control, and eradication of any tephritid species (Verghese et al., 2012; Singh et al., 2008). These lures, when used together with an insecticide-impregnated into a suitable wood substrate, forms the basis of the male annihilation technique (MAT) and result in the reduction of the male population of fruit flies to such a level that eradication and suppression are achieved (Stonehouse et al., 2005). This technique has been successfully used for the eradication and control of several *Bactrocera* species (Cunningham, 1989). A concerted effort has been made on fruit fly trapping technology in India and abroad however there has always been a scope of improvement in this technology, hence the present study was designed to evaluate the different pesticides as killing agents in methyl eugenol-based traps and the different trap designs for their trap catch efficiency.

MATERIALS AND METHODS

The present study comprised of two sets of experiments first was for the evaluation of insecticides for their efficacy in killing blocks and the second was on the evaluation of trap containers. These experiments were conducted in mango orchards of ICAR-CISH, Rehmankhera experimental farm Lucknow (Uttar Pradesh) during the mango season. Ply woodblocks of 4.5x4.5x1.2 cm were soaked in ethyl alcohol 99.9%AR, methyl eugenol, and different insecticides (T_1: bifenthrin 10EC, T2: carbosulfan 25EC, T3: profenophos 50 EC; T4:imidacloprid 17.8 SL; T5:indoxacarb 14.5 EC, T6:spiromecifin, T7:emamectin benzoate 1.9 E, T8:abamectin 1.9 EC, T9:lamda cyhalothrin, T10:malathion 50 EC in the ratio of 5:4:1. These impregnated ply woodblocks were suspended in a uniform type of trap container in mango orchards and catches were counted at weekly intervals. Different designs of fruit flies trap containers are commercially available in the market. They are

available as a package of trap containers and killing blocks of different sizes. Based on their container design and killing block size, their attraction potential and persistence may vary. Individually they are being promoted by their promoters but their relative efficacy in catching fruit flies has not been tested so far. Many of them are rain sick and killing block get wetted in rains.

The CISH new trap container was designed by using a specific dye that gave rainproof provision and a mechanism of easy handling for installation and flies count. This trap container was compared with the other five different types of traps to work out its relative efficiency. T1 comprised trap of private company had a volume of 550 ml with two round holes of 1.6 cm in opposite directions. It used a plywood block of 4x1.5x1.2 cm having a volume of 7.2 cm^3 which soaked 2.64 ml of soakate mixture but lacked a water drainage system in its base. T2 is ICAR - CISH old model trap had almost similar specifications as T1 trap excepting its volume of 500 ml. T3 popular company trap with 600 ml volume had 3 rectangular holes of 1.6x2.5 cm in opposite directions but without water drainage system in its base. Its plywood block of 5x3.5x1.2 cm having a volume of 21 cm^3 soaked the soakate mixture to the tune of 9.31 ml. T4 and T5 traps of IIHR -CHES, and IMFFI -Water bottle trap, respectively had common features such as volume of 950-1000 ml with 4 round holes of 2 cm diameter in opposite directions with a water drainage system in their bases. The plywood blocks of these two traps had woodblock dimension of 5x5x1.2 cm with a volume of 30 cm^3 and soaked around 13.31 ml soakate mixture. T6 is ICAR- CISH new model trap with a volume of 1150 ml had 4 round holes of 2.5 cm diameter in opposite directions with the rainwater drainage system in its bottom. Its plywood block of 4.5x4.5x1.2 cm with a volume of 24.30 cm^3 absorbed 10.48 ml of soakate mixture. Trap container-specific plywood blocks were soaked in ethyl alcohol 99.9% AR, methyl eugenol, and Malathion 50 EC (6:4:1). These soaked killing blocks were loaded in respective traps and installed in the mango orchard and catches were counted at weekly intervals. In the mango orchards, ten traps/ ha were placed at a uniform distance to cover the entire orchard. The traps were replicated four times. The traps with lures were placed at 1.5 to 2 m in height. Observations were taken every week during the fruiting period from May to August. During each observation, the flies were counted after the opening of the trap container lid, and traps were emptied to get the exact number of attracted flies in the next week. Fruit fly trap catch data were subject to ANOVA and means were compared by Tukey's honesty test of significance (p=0.05, 0.01).

RESULTS AND DISCUSSION

The data on fruit flies in mango trapped with the methyl eugenol mixed with insecticides as killing agents presented in Table 1 reveal that trap catches differed significantly ($F_{9, 360}$=204.34; p<0.00), over the different weeks ($F_{11, 360}$=37.62; p<0.00) and in their interactions ($F_{99, 360}$= 1.80;p<0.001). Malathion 50EC, emamectin benzoate 1.9EC, abamectin 1.9EC, and prophenophos 50EC resulted in maximum catches over all the weeks. Emamectin benzoate 1.9EC was found superior with the highest catches ranging from 648.75 to 1304.75 fruit flies/ trap/ week over all the weeks of monitoring. The killing efficiency varied over the period as observed by Stonehouse et al. *(*2005) that insecticides' persistence and their killing efficiency differ in killing blocks. In the present study, malathion was very effective up to 12 weeks; however, its equally effective alternatives were found as emamectin benzoate 1.9EC, abamectin 1.9EC, and prophenophos 50EC. Study on the trap container and respective wooden blocks indicates the persistence of soakate mixture and thereby catch was highly dependent on the size of killing blocks and the amount of mixture soaked into it. The smaller blocks were less effective with low persistence capacity. The number of the fly catch was higher in the CISH trap container, which might be due to the bigger size killing block and design of the container. It was found that methyl eugenol traps were capable of effectively attracting fruit flies up to 12 weeks, though varying greatly in persistence and attraction. The duration of lure effectiveness was found to be in accordance with earlier results of others. Stonehouse et al. (2005) reported long-term eradication/ suppression campaigns were made by using a combination of cue lure and insecticides against *B. cucurbitae*. The higher number of fruit fly catch/ trap with plywood killing block had also been reported by Patel et al. (2005). Singh et al. (2005) observed that plywood blocks attracted and killed more flies than those of mango wood, hardwood, or soft board.

Trap catches were found to significantly vary in different type of traps ($F_{5, 213}$=301.17; p<0.00), among the different weeks ($F_{11, 213}$=70.15; p<0.00) and their interaction ($F_{55, 213}$= 1.89;p<0.001). Among traps, CISH trap container was found more efficient (catches of 306.25 to 940.00 fruit flies/ trap/ week (Table 1). This might be due to four holes of bigger size located in opposite direction facilitated lure dispensing effectively as compared to other trap containers. The size and

Table 1. Fruit fly catches in different insecticide treatments and in different traps over different weeks

	No. of fruit flies/ trap/ week											
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Efficacy of insecticides												
Bifenthrin 10EC	80.5^{c}	109.5^{b}	103.25^{b}	85^{c}	64.75^{d}	52^{d}	44^{d}	23.5^{b}	18^{f}	15.25^{d}	12^{d}	4^{d}
Carbosulfan 25EC	352.5^{abc}	805.5^{a}	922.5^{a}	888.75^{b}	796.5^{c}	670^{ab}	610^{b}	700^{a}	392.5^{cde}	292.5^{cd}	285^{bcd}	216.25^{bcd}
Profenophos 50 EC	308.5^{abc}	898^{a}	1131.25^{a}	1136.25^{ab}	971.75^{abc}	545^{bc}	651.5^{ab}	625^{a}	521.25^{abc}	446.25^{abc}	427.5^{abc}	363.75^{abcd}
Imidacloprid 17.8 SL	217.75^{bc}	375^{b}	392.75^{b}	395^{c}	324.75^{d}	231.25^{cd}	185.75^{cd}	190^{b}	133.5^{def}	107.5^{cd}	83.75^{cd}	68.75^{cd}
Indoxacarb 14.5 EC	177.25^{bc}	331.25^{b}	346.25^{b}	450^{c}	399^{d}	206.25^{cd}	165^{d}	106.25^{b}	81.25^{def}	73.75^{cd}	66.25^{cd}	58.75^{cd}
Spiromeciphan	65.5^{c}	101.75^{b}	181.25^{b}	168.75^{c}	163.75^{d}	98.25^{d}	67^{d}	63^{b}	46^{ef}	34^{d}	30^{d}	32.5^{cd}
Emamectin benzoate 1.9 EC	648.75^{a}	1037.5^{a}	1215.75^{a}	1266.25^{a}	1304.75^{a}	1033.25^{a}	989.75^{a}	928.25^{a}	851.5^{a}	775^{a}	725.25^{a}	682.5^{a}
Abamectin 1.9 EC	332.5^{abc}	760^{a}	952.5^{a}	906^{ab}	930^{bc}	812.5^{ab}	555^{bc}	566.25^{a}	455^{bcd}	336.25^{bcd}	358.75^{abcd}	391.25^{abc}
Lamda cyhalothrin	93.75^{c}	138.75^{b}	141.25^{b}	156.5^{c}	149.75^{d}	86.25^{d}	74.25^{d}	67.25^{b}	58.25^{ef}	43.25^{d}	19.25^{d}	12^{d}
Malathion 50 EC	504^{ab}	953.78^{a}	1191.25^{a}	1190^{ab}	1260^{ab}	977.5^{a}	922.5^{ab}	845^{a}	792.5^{ab}	706.25^{ab}	626.25^{ab}	525^{ab}
Efficacy of traps												
Private company trap	311.25^{de}	249.25^{d}	222.00^{c}	204.00^{d}	155.75^{c}	85.00^{c}	55.50c	42.25^{c}	32.25^{c}	25.75^{c}	13.25^{b}	5.25^{b}
ICAR - CISH old model trap	266.25^{e}	227.50^{d}	220.25^{c}	152.25^{d}	144.75^{c}	79.25^{c}	50.50c	33.75^{c}	27.25^{c}	17.50^{c}	4.75^{b}	3.50^{b}
Popular private company trap	331.25^{cd}	290.50^{c}	435.75^{b}	181.25^{c}	158.50^{b}	78.00^{c}	256.25^{b}	230.75^{b}	225.75^{b}	208.75^{b}	66.25^{b}	4.00^{b}
IIHR -CHES trap	656.25^{ab}	668.25^{ab}	830.50^{a}	703.25^{ab}	670.75^{a}	570.50^{ab}	415.00^{ab}	445.25^{a}	393.25^{a}	310.50^{ab}	282.50^{a}	267.75^{a}
IMFFI -Water bottle trap	532.50^{bc}	512.50^{bc}	600.25^{b}	599.75^{bc}	589.00^{a}	480.00^{b}	393.00^{ab}	380.75^{ab}	358.75^{ab}	289.00^{ab}	258.50^{a}	268.00^{a}
ICAR- CISH new model trap	792.50^{a}	768.75^{a}	940.00^{a}	857.50^{a}	750.00^{a}	657.50^{a}	535.25^{a}	515.00^{a}	457.50^{a}	395.00^{a}	338.00^{a}	306.25^{a}

Means with same letter not significantly different in Tukey's honesty test (p=0.01)

direction of the hole on the trap body influence the fly catch- Ravikumar and Viraktamath, (2006) found bottle traps with 4 holes of 20 mm dia were significantly superior in attracting *B. dorsalis, B. correcta, and B. zonata* than those with l, 2, 3, 5, or 6 holes/ trap. In the present study also traps with 4 holes opposite to each other (CISH trap) were found superior. Shanker et al. (2010) also observed that traps with 4 holes had the highest fruit fly catch. Thus, it is evident that insecticide type and trap container design affect the catch potential of the fruit fly traps. The present results are more relevant in the light of the ensuing ban on the most used insecticide in the MAT technique is malathion and, in that case, emamectin benzoate, abamectin, or profenophos may be used as an efficient killing agent in fruit flies traps. Although, a lot of work has been done on the development of various types of trap containers, however, so far, no universal, effective trap has been developed, nevertheless the CISH trap container with the rainproof provision and has been found superior among the existing commercial traps.

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SEASONAL INCIDENCE OF WHITEFLY *BEMISIA TABACI* (GENN.) ON MUNGBEAN

Nadeya Khaliq*, Uma Shankar and Bashir Ahmad Rather

Division of Entomology, FoA SKUAST-J Chatha, Jammu 180009, UT of J&K, India
*Email: nadeya786@gmail.com (corresponding author)

ABSTRACT

This study on the seasonal incidence of whitefly *Bemisia tabaci* (Gennadius) on mungbean was done during kharif, 2014. Weekly observations on incidence were made on five randomly selected tagged plants. The results revealed that the first incidence was observed during 22nd standard meteorological week (SMW)- 66.67 whitefly/ plant. This reached at its peak (89.67 whitefly/ plant) during the 34th SMW. Correlation coefficients between incidence and weather factors revealed that maximum temperature had a positive relationship (r = 0.51) while the minimum temperature and relative humidity- RH (morning) revealed a negative one (r = -0.03 and r = -0.52); and RH (evening) and rainfall showed a highly significant but negative correlation.

Key words: *Bemisia tabaci*, mungbean, seasonal incidence, correlation coefficients, weather factors, maximum temperature, relative humidity, population dynamics

Legumes occupy an important place in human nutrition as these are a good source of protein (Kutos et al., 2002). Amongst the kharif pulses, mungbean *Vigna radiata* (L.) R. Wilczek is a major pulse crop and India is the leading producer (Singh Ahlawat, 2005). The losses due to insects and non-insect pests to pulses are of the major factors responsible for low yields (Lal et al.,1980). In Jammu subtropics, 38 insect pests occur on this crop out of which 22 are regular (Tikoo, 1996). The loss due to insect pests in mungbean was estimated to be 34.7% (Asthana et al.,1997). The economically important pests include whitefly *Bemisia tabaci* (Gennadius), aphid *Aphis craccivora* Koch, pod borer, *Maruca testulalis* Geyer, Bihar hairy caterpillar, and *Spilosoma obliqua* Walker. Among these *B. tabaci* is important as it causes damage directly through feeding and indirectly through the transmission of plant pathogenic viruses (Oliveira et al.,2001). The weather factors play a key role in determining the incidence and dominance of a pest or a pest complex (Butani, 1976). Hence, it is necessary to study the population dynamics in relation to weather factors, and this study evaluates the seasonal incidence of *B. tabaci* in mungbean.

MATERIALS AND METHODS

A field experiment was conducted at the Research field, Division of Entomology, Main Campus, Chatha, Jammu during kharif 2014. The seeds were sown in plots of size of 3x 2 m with row to row and plant to plant spacing of 30 and 10 cm, respectively, without manures and fertilizer. The experiment was laid out in randomized block design (RBD) with three replications, and observations made weekly on randomly tagged 5 plant; these were made during morning hours from 2 upper, 2 middle and 2 lower leaves and mean incidence was calculated. These observations were correlated with weather factors- with weekly data on mean temperature (maximum/ minimum °C), mean relative humidity- RH (morning and evening %), and rainfall (mm) obtained from the Agrometeorological Section, Division of Agronomy, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. These data were subjected to correlation analysis.

RESULTS AND DISCUSSION

The mean seasonal incidence of *B. tabaci* observed on the mungbean is depicted in Fig. 1. These data reveal that first incidence was during the 22nd standard meteorological week (SMW) (66.67 whitefly/ plant); this increased to 76.67 whitefly/ plant during the 23rd SMW, and then declined to 30.33 whitefly/ plant) during the 33rd SMW; then increased again and reached to the maximum of 89.67 whitefly/ plant during 34th SMW at harvest. These results agreement with those of earlier workers (Chaman et al., 2021; Patel et al., 2021). Dar et al. (2002) reported peak incidence during the 25th and 26th SMW on urd bean and mungbean, respectively. Kumar et al. (2004) also reported such changes. Correlation coefficients between weather factors and incidence revealed that maximum temperature had a positive relationship (r= 0.511) while as minimum temperature and mean RH (morning) showed a negative

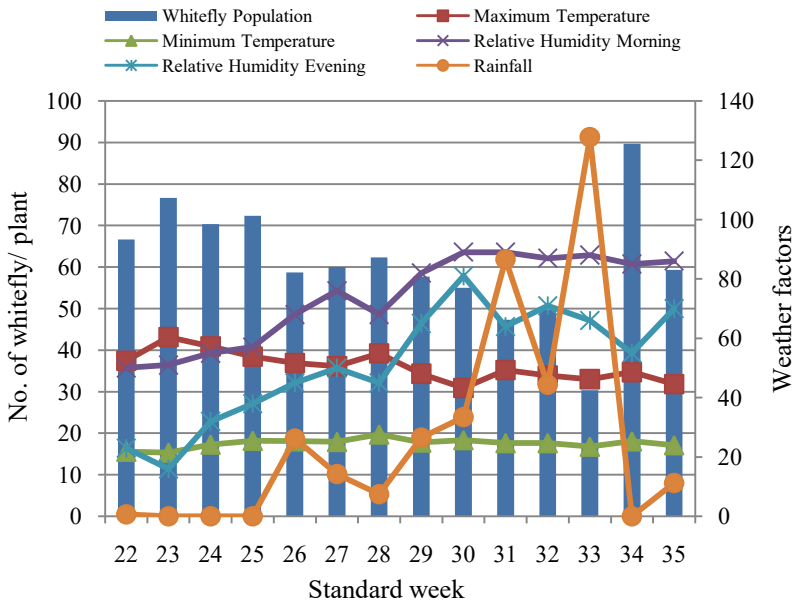

Fig. 1. Seasonal incidence of *B. tabaci* whitefly on mungbean

one (r= -0.039 and -0.524, respectively); similarly RH (evening) also showed a significantly negative relationship (r= -0.568), while rainfall showed a highly significant negative relationship) (r= -0.865). Chaman et al. (2021) observed that temperature exhibited a significantly positive correlation while RH and rainfall did not show any significant correlations Patel et al. (2021) also recorded a significantly positive correlation with maximum temperature and sunshine hours. The regression equation ($Y= 35.522 - 0.098X_1 + 0.219X_2 + 1.054X_3 - 0.864X_4 - 0.347X_5$, where, Y= mean whitefly/ plant, X_1= maximum temperature, X_2= minimum temperature, X_3= RH % morning, X_4=RH% evening and X_5= rainfall) revealed a significant effect (86.30%) of weather factors on incidence of *B. tabaci*. These results corroborate with the findings of Yadav and Singh (2013) on a positive correlation with temperature and sunshine hours, and a negative one with RH. Bashir et al. (2001) observed that rainfall was negatively correlated; Bairwa and Singh (2017) also reported a negatively non-significant correlation between rainfall. Singh and Kumar (2011) reported that minimum temperature and RH had non-significant positive correlation, whereas maximum temperature and rainfall had a non-significant negative one in black gram.

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STUDY ON VARIETAL PREFERENCE OF TEA MOSQUITO BUG *HELOPELTIS ANTONII* SIGNORET IN GUAVA

K Aravinthraju*, K Suresh, S Manisegaran and C Rajamanickam[1]

Department of Agricultural Entomology; [1]Department of Horticulture,
Agricultural College and Research Institute, TNAU, Madurai, 625104, Tamil Nadu, India
*Email: aravinth4697@gmail.com (corresponding author)

ABSTRACT

Different guava varieties in farmer's field at Kovilur village, Madurai district, Tamil Nadu, were screened for tea mosquito bug (TMB) *Helopeltis antonii* incidence. Five varieties were subjected to one month of observation for the incidence during the peak period viz., November- December, 2020. The varietal preference of the evaluated cultivars was- Arka Rashmi, Red Flush, Arka Kiran, Taiwan Red and Lucknow-49, with resistance ranging from 0.95 to 7.75 TMB/ 15 flush.

Key words: *Helopeltis antonii*, guava, varieties, Arka Rashmi, Red Flush, Arka Kiran, Taiwan Red and Lucknow-49, preference, non-preference

The tea mosquito bug (TMB) *Helopeltis antonii* Signoret (Miridae: Hemiptera) is emerging as a major pest in horticultural crops. The first record of TMB was in Java during 1847 on tea crop (Rao, 1970) and in India it was in Cachar District in Assam during 1968 (Aravinthraju, 2021). It is a major pest of tea, and also a major threat to cashew, moringa, neem, *Acacia*, cocoa, camphor, pepper and cardamom etc, Now, it is emerging as a pest on guava in many areas, besides having few alternate weed hosts to complete their lifecycle during off-season. The nymphs and adults insert their proboscis into the young leaves, buds, tender shoots, inflorescence and fruits to suck the plant sap. The toxin injected through saliva causes the tissues around the punctured shoot to dry and die. The affected portion becomes brown and later black, with leaves having many such black spots shriveling and eventually falling off (Gundappa et al., 2018). The infested shoots and flowers also show such spots which may extend over young shoots. Damage to flowers leads to dropping (Haseeb, 2007). Fruits show symptoms like corky growth and pustules on its surface, which in severe cases will show cracks on its surface followed by drying and falling off. Hence, it is necessary to evaluate TMB incidence in guava varieties to incorporate these in IPM, and the present study evaluates the varietal preference.

Table 1. Preference to *H. antonii* in varieties of guava

S. No.	Varieties	TMB incidence (No./ 15 flush)*				Mean
		1st week	2nd week	3rd week	4th week	
1	Red Flush	2.00	2.80	1.20	3.40	2.35
		(1.41)^{ab}	(1.67)^{a}	(1.10)^{a}	(1.84)^{ab}	(1.53)^{ab}
2	Taiwan Red	6.40	6.60	4.60	5.20	5.70
		(2.53)^{c}	(2.57)^{bc}	(2.14)^{ab}	(2.28)^{bc}	(2.39)^{c}
3	Lucknow- 49	9.60	7.20	6.40	7.80	7.75
		(3.10)^{c}	(2.76)^{c}	(2.53)^{b}	(2.79)^{c}	(2.78)^{c}
4	Arka Kiran	3.20	3.60	2.40	3.60	3.20
		(1.79)^{b}	(1.90)^{ab}	(1.55)^{ab}	(1.90)^{b}	(1.79)^{b}
5	Arka Rashmi	0.60	1.40	0.60	1.20	0.95
		(0.77)^{a}	(1.18)^{a}	(0.77)^{a}	(1.10)^{a}	(0.97)^{a}
	SEd	0.28	0.47	0.41	0.40	0.21
	CD (p=0.05)	0.58	0.61	0.86	0.58	0.44

*Each value mean of five replications; Figures in parentheses square root transformed values $\sqrt{(x + 0.5)}$; Mean followed by same alphabets in a column not significantly different by LSD ($p<0.05$)

MATERIALS AND METHODS

The field experiment was carried out in a farmer's field at Kovilur village, Madurai district during November- December (2020). Five varieties viz., Red flush, Taiwan Red, Lucknow-49, Arka Kiran and Arka Rashmi were observed for TMB incidence. The experiment was laid in randomized block design with five replications, each comprising of three trees, and maintained unsprayed. In these, five twigs were selected at random and observations on TMB were made at weekly intervals, and means of these were analyzed after square root transformation with AGRES statistical package, and means were compared (LSD, p=0.05).

RESULTS AND DISCUSSION

The results given in Table 1 reveal that there are significant differences in the feeding preference of TMB among the varieties. Arka Rashmi has recorded the least incidence (0.95 bugs/ 15 flush) indicating the non-preference nature, whereas the maximum incidence was in Lucknow- 49 (7.75 bugs/ 15 flush). The ascending order of varietal preference was Arka Rashmi, Red Flush, Arka Kiran, Taiwan Red and Lucknow- 49. Earlier studies by Gopalan and Perumal (1973) revealed that Lucknow-47, Saharanpur seedless and Smooth green were resistant. The genotypes Bapatla, AC-10, Bangalore Seedless and Round were found tolerant (Pasupathy, 2000).

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PERSISTENCE AND DEGRADATION BEHAVIOUR OF DIMETHOATE IN GRAPES

Banka Kanda Kishore Reddy, K Bhuvaneswari*, M Paramasivam, A Suganthi, P Geetha[1]

Department of Agricultural Entomology; [1]Centre for Post Harvest Technology,
Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India
*Email: bhuvaneswari.k@tnau.ac.in (corresponding author)

ABSTRACT

Through a field experiment, the dissipation pattern of dimethoate in grapes was evaluated during December 2020 - February 2021. Dimethoate 30%EC was sprayed twice at ten-days interval at recommended (X) dose (445 g a.i ha^{-1}) and double the recommended (2x) dose (890 g a.i ha^{-1}). The samples were collected from 0 (2hr), 1, 3, 5, 7, 10, 15 and 20 days or till degradation to below detectable level (BDL) and at harvest time. The residues were extracted by the modified QuEChERS method and analyzed by LCMS. The method performance was satisfactory in terms of SANTE guidelines and with good linearity (r^2>0.99). The mean total dimethoate residue including omethoate was 1.047 and 2.168 mg kg^{-1} at x and 2x doses, respectively with half-lives of 5.47 and 5.59 days. The calculated Risk Quotient (RQ) at both x and 2x dose with Good Agricultural Practices (GAP) indicated that for dimethoate these are not safe for human health due to the intake of residue.

Key words: Grapes, dimethoate, omethoate, method validation, QuChERS, dissipation, risk assessment, risk quotient, acceptable daily intake, maximum residue level

Organophosphorus (OP) pesticides account for 34% of global insecticide consumption and are the most extensively used broad spectrum insecticides. There are around 100 different OP pesticides that are used to control pests in horticultural crops (Jaipieam et al., 2009). Among the OP pesticides, dimethoate [O, O-dimethyl S-(2-(methylamino)-2-oxoethyl) phosphorodithioate] is a broad spectrum systemic insecticide largely used to manage pests in fruits and vegetables (Zheng and Sun, 2014). Dimethoate is transformed to omethoate in crops due to the oxidation process, which is more harmful than dimethoate itself (EFSA, 2013).

In India, dimethoate is registered for control of aphids, mealybugs, hoppers and stem borer in various fruit crops viz., mango, banana, citrus, apple, fig and apricot but not registered for use in grapes (CIBRC, 2021). However, a survey conducted in major grape growing districts of Tamil Nadu revealed that 93.33% of farmers are using dimethoate as a plant protection input to mitigate the pest problem in grapes (Jayabal et al., 2020). Dimethoate dissipation has been widely investigated in various fruit crops viz., mango (Bhattacherjee and Dikshit, 2016), pomegranate (Utture et al., 2012) and guava (Khan et al., 2009; Devi et al., 2016). It is one of the most widely used insecticides in Indian viticulture and globally for pest management (Moyer and Neal, 2014; Patil et al., 2017; Preetha and Stanley, 2020).

In a desperate bid to save the crop, farmers often take intensive sprays of dimethoate at the berry initiation stage which is likely to leave toxic residues in/ on berries and may be unsafe to the consumers. The consumption of insecticide treated product become risky due to the residual persistence of the insecticide. So, it is necessary that insecticide should be active against pests while leaving only tolerable residue on food commodity. OPs are common pollutants that pose significant toxicological risks to soil, aquatic ecosystems, and human health (Ji et al., 2019). Therefore, it is important to understand how pesticide residues dissipate at various stages in order to ensure the supply of safe and fresh produce to the end users.

To our knowledge, there are no published reports in India on the dissipation of dimethoate and its metabolite omethoate in grapes. Therefore, a field study was conducted to monitor the degradation pattern of dimethoate in response to the above issue. Using Indian dietary data, the preharvest interval (PHI) and dietary risk assessment were calculated.

MATERIALS AND METHODS

For the estimation of dimethoate and omethoate

residues, certified reference material (CRM) of dimethoate (99.5%), omethoate (96.8%), anhydrous sodium citrate dibasic sesquihydrate (≥ 99% purity) (Sigma Aldrich, Bangalore, India); HPLC grade of ethyl acetate (≥ 99.9%), n-hexane (≥ 99.9%) (Sisco Research Laboratories, Mumbai, India); LCMS grade methanol (> 99.9%) (Avantor Sciences, PA, USA); Anhydrous sodium chloride (≥ 99%), anhydrous tri-sodium citrate dihydrate (≥ 99%) (Merck, Mumbai, India); anhydrous magnesium sulphate (≥ 99%) (Himedia Laboratories, Mumbai, India); primary secondary amine (PSA, 40 µm) and graphitised carbon black (GCB) (Agilent Technologies, USA); and formic acid (≥ 99%) (Fisher Scientific Limited, Czech Republic) were obtained. The commercial formulation of dimethoate 30% EC was purchased locally from a pesticide dealer in Coimbatore, Tamil Nadu, India.

Individual stock solutions of 400 mg/l dimethoate and omethoate were made in LCMS grade methanol by independently weighing 10.05 and 10.33 mg of the analytical standards into a calibrated glass A volumetric flask (25 ml). Dimethoate and omethoate secondary stock solutions (40 mg/ l) were made separately from the stock solution in a 25 ml container by transferring 2.5 ml of each. A working standard mixture of 10 mg/ l was prepared using secondary stock solution. The linearity and spiking standard solutions were obtained by serial dilution from the mixed standard solution in the range of 0.005 - 0.1 mg/ l. All standard solutions were maintained at -20°C in the deep freezer until use. Matrix matched standard solutions (0.01, 0.025, 0.05, 0.075, and 0.1 mg/ l) were prepared with immature and mature grape matrix.

Dissipation study was carried out in a farmer's field in Theni district of Tamil Nadu, India (9° N, 76° E and 375 masl) following good agricultural practices. The plot size was 50m^2 area that had no application of dimethoate before taking up the study, with three replicated plots. The commercial product of dimethoate 30% EC was applied (Muscat Hamburg variety) at the berry initiation stage (45 days after flowering) at the recommended dose (445 g a.i ha^{-1}) and double the recommended dose (890 g a.i ha^{-1}). A high-volume sprayer with 500 l ha^{-1} of spray fluid, was used and two foliar sprays were given at an interval of 10 days for dissipation study. During the field trial, maximum and minimum temperatures were recorded as 28.16 and 19.16° C, respectively and relative humidity was 78.16%. No rainfall was received.

The grape berries for residue analysis (0.5 kg) were randomly picked from vines from each replication at 0 (2hr), 1, 3, 5, 7, 10, 15, 20, 25, 30 and 35 days after second spraying and at the time of harvest. A high-volume blade homogeniser was used to homogenise samples using a Robot Coupe cutter mixer (Blixer 6 VVA, France) and stored at -20°C for residue analysis,

A modified QuEChERS (Quick, Easy, Cheap, Effective, Rugged, and Safe) technique was adapted, validated and used for residue extraction (Anastassiades et al., 2003). 10 g of grape sample was added in a 50 ml centrifuge tube and vortexed for one min after adding 20 ml of ethyl acetate. After that, 1 g NaCl and 4 g anhydrous MgSO4 were added, vortexed and centrifuged completely for 10 min at 6000 rpm. Following centrifugation, a 6 ml aliquot of the supernatant was transferred to a 15 ml centrifuge tube containing 100 mg PSA, 600 mg anhydrous MgSO4, and 10 mg GCB and vortexed for one min before centrifugation at 3000 rpm for ten min. In a low volume concentrator at 40°C, 2 ml of aliquot was evaporated to near dryness under a gentle stream of nitrogen gas. Finally, the residue was mixed in 1.0 ml methanol and filtered by using a 0.2 µm membrane syringe filter and transferred into 1.0 ml autosampler vials for analysis of residues by LC-MS.

The detection, estimation and confirmation of dimethoate and omethoate were done in Shimadzu 2020 series LCMS equipped with a reverse phase C18 (Eclipse plus- Agilent) column (250 mm length x 4.6 mm id, 5 µm particle size) at a column oven temperature of 40˚C. The mobile phase used for the separation of target compounds were methanol and ultra-pure water with 0.05 % formic acid in the ratio of 50:50. The LCMS pump was run in binary mode at a pressure of 48 kgf/ cm^2 to discharge the mobile phase at a constant isocratic flow rate of 0.5 ml/ min. The chromatograms were analysed using Shimadzu lab solutions software (5.6) and further calculations were based on obtained peak areas in the chromatograms. Samples were ionized using positive electron spray ionization (ESI+) mode and 0.1 µA° of interface current, 350° C of heat block temperature, 250°C as desolvation line (DL) temperature, nebulizer gas (N_2-99.99%) flow of 1.5 l/ min, drying gas of 12 l/min and scan speed of 15000 sec were employed.

The method used to determine the residues of dimethoate and omethoate in grape matrices was validated as per SANTE guidelines (SANTE, 2019) and evaluated with parameters viz., linearity, limit of detection (LOD), limit of quantification (LOQ),

recovery, precision, repeatability and matrix effect. The Horwitz ratio (HorRat) is a measurement tool that reflects the acceptability of analytical processes in terms of interlaboratory precision (reproducibility). It is the ratio of the observed relative standard deviation among laboratories (RSD), to the corresponding predicted relative standard deviation (PRSD), calculated using the Horwitz equation PRSD = $2C^{(-0.15)}$, where C is the concentration found or added, expressed as a mass fraction and PRSD was calculated for all the fortified concentrations of 0.01, 0.025, 0.05, 0.075 and 0.1ppm (Horwitz and Albert, 2006). The matrix effect (ME) was assessed using the formula mentioned by (Dong et al., 2018).

The amount of dimethoate residue (log value) over time (days after application) was subjected to weighted linear regression to calculate half-life and safe waiting period values of dimethoate (Hoskins, 1961; Handa et al., 1999). Half-life of dimethoate was determined as $T_{1/2}$ = 0.693/k. The maximum residue limit (MRL) for dimethoate in grapes was 0.01 mg/kg as per the European pesticide (EU) database, 2020. The safe waiting period of dimethoate was calculated using the formula mentioned as PHI = [log (A)-log (MRL)]/K

EDI was divided by the acceptable daily intake (ADI) to arrive the risk quotient (RQ), which was used to quantify the long-term risk of intakes in comparison to pesticide toxicological data (Dong et al., 2018). ADI value of dimethoate is 0.002 mg/ kg/ bw/ day (EFSA, 2013). The average body weight of an Indian (male- 65kg and female- 55kg) adult (NIN, 2020) and recommended total fruit consumption is 150 g/ day (NIN, 2020). If the RQ is <1, the risk of long-term human dietary consumption of dimethoate is acceptable; if the RQ is >1, the risk is unacceptable.

RESULTS AND DISCUSSION

Instrument conditions were optimised using single quadrupole LC-MS to identify, confirm, and quantify dimethoate and its metabolite omethoate in grapes. By setting standard chromatographic conditions, dimethoate and omethoate were separated and eluted at retention times of 8.47 and 5.31 min, respectively (Fig. 1). Quantification of dimethoate and omethoate was carried out using selected ion monitoring (SIM) mode and sensitivity was increased by using positive (+) SIM mode with target m/z at 230 and 214 for dimethoate and omethoate, respectively.

The recovery %, RSD, and linearity of the analytical

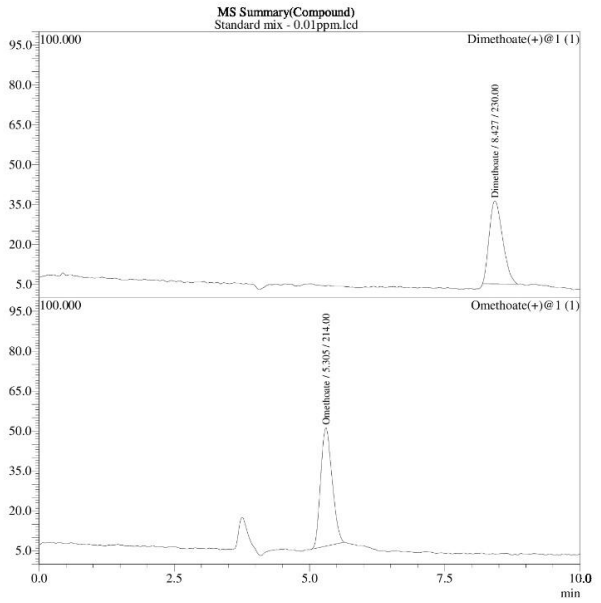

Fig. 1. Standard chromatogram of dimethoate + omethoate (0.01ppm)

method used to estimate the residues of dimethoate and omethoate were calculated and validated. In both immature and mature grape matrices, the method's linearity was determined to be between 0.005 to 0.1 mg/l. For both solvent and matrix-matched calibration standards, the correlation coefficient of dimethoate and omethoate was >0.99 (Table 1). The LOD (at a signal-to-noise ratio greater than 3) and LOQ (at a signal-to-noise ratio greater than 10) were determined as 0.005 and 0.01 mg/kg, respectively. The proposed LOQ (0.01 mg/ kg) of the method was in agreement with the MRL (0.01 mg/ kg) value fixed by EU pesticide database. Dimethoate and omethoate recovery in grapes was between 70 and 120% confirming to SANTE (2019) guidelines. RSD (<20%), matrix effect (<20%), horwitz ratio (0.5-2.0) were in acceptable range validating the analytical method (Table 1).

Residues of dimethoate reached BDL on 30 and 35 days after spraying at recommended (X) and double the recommended dose (2X), respectively (Table 2). Omethoate residues reached BDL 7 days after spraying. At harvest time samples, neither dimethoate nor omethoate was detected (45 days after spraying). Total residue (dimethoate + omethoate) was used to determine the half-life values and confirmed as 5.47 and 5.59 days at x and 2x doses, respectively. Reports on the dissipation of dimethoate in fruit crops like mango, guava, citrus, pomegranate are documented and available but could not get for grapes. Pappas et al. (2003) reported dissipation as 16.7 and 30.1 days

Table 1. Recovery, linearity parameters and matrix effect of dimethoate and omethoate in grape matrices

Pesticides	Calibration (matrix)	Calibration range (mg/ l)	Regression equation	Correlation coefficient (R^2)	Matrix effect (%)
Dimethoate	Solvent	0.005-0.1	y = 2E+07x + 39129	0.999	-
	Immature grapes	0.005-0.1	y = 2E+07x + 15789	0.9981	4.09
	Mature grapes	0.005-0.1	y = 2E+07x - 42273	0.9962	1.68
Omethoate	Solvent	0.005-0.1	y = 2E+07x + 36193	0.9993	-
	Immature grapes	0.005-0.1	y = 3E+07x + 13261	0.9972	3.56
	Mature grapes	0.005-0.1	y = 2E+07x - 4107.6	0.9985	6.79

Recovery of dimethoate and omethoate in grape matrix at different spiking levels (n=7)

Matrix	Spiked concentration (mg/ kg)	Dimethoate			Omethoate		
		Recovery (%)± SD	RSD (%)	HorRat	Recovery (%) ± SD	RSD (%)	HorRat
Immature grape berries	0.010	98.79± 2.49	2.52	0.08	96.59± 2.28	2.36	0.07
	0.025	93.55± 1.92	2.06	0.07	92.16± 2.71	2.94	0.11
	0.050	102.31± 1.64	1.60	0.06	103.05± 2.34	2.27	0.09
	0.075	97.92± 2.01	2.05	0.09	95.06± 1.80	1.89	0.08
	0.100	95.44± 2.90	3.04	0.14	95.61± 2.20	2.30	0.10
Mature grape berries	0.010	95.68± 1.72	1.80	0.06	85.28± 3.09	3.62	0.11
	0.025	90.10± 1.50	1.66	0.06	98.58± 1.48	1.51	0.05
	0.050	85.04± 1.68	1.98	0.08	93.54± 1.96	1.02	0.04
	0.075	92.08± 2.61	2.83	0.12	97.82± 2.88	2.94	0.13
	0.100	95.28± 3.17	3.33	0.15	94.19± 1.91	2.02	0.09

SD- standard deviation; RSD- relative standard deviation, HorRat- Horwitz ratio

Table 2. Residues, dissipation and dietary risk assessment of dimethoate in immature grape berries at 445 g a.i ha^{-1} (X) and 890 g a.i ha^{-1} (2X)

	x dose						2x dose				
Days after treatment	Dime-thoate residues* (mg/ kg)	Ome-thoate residues* (mg/ kg)	Total residues (mg/ kg)	Dietary risk assessment Risk quotient (RQ) Adult male (65 kg)	Adult female (55 kg)	Days after treat-ment	Dime-thoate residues* (mg/ kg)	Ome-thoater residues* (mg/ kg)	Total residues (mg/ kg)	Dietary risk assessment Risk quotient (RQ) Adult male (65 kg)	Adult female (55 kg)
0 (2hrs)	1.012	0.035	1.047	1.20	1.43	0 (2hrs)	2.107	0.061	2.168	2.50	2.96
1	0.607	0.026	0.633	0.73	0.86	1	1.098	0.051	1.149	1.32	1.56
3	0.527	0.022	0.549	0.63	0.75	3	0.802	0.035	0.837	0.96	1.14
5	0.385	0.011	0.396	0.46	0.54	5	0.632	0.028	0.660	0.76	0.90
7	0.272	BDL	0.272	0.31	0.37	7	0.567	0.014	0.581	0.67	0.80
10	0.162	BDL	0.162	0.19	0.22	10	0.337	BDL	0.337	0.39	0.46
15	0.099	BDL	0.099	0.11	0.13	15	0.295	BDL	0.295	0.34	0.40
20	0.078	BDL	0.078	0.09	0.11	20	0.205	BDL	0.205	0.24	0.28
25	0.044	BDL	0.044	0.05	0.06	25	0.091	BDL	0.091	0.10	0.12
30	0.014	BDL	0.014	0.01	0.01	30	0.051	BDL	0.051	0.06	0.07
35	BDL	BDL	BDL	-	-	35	0.010	BDL	0.010	0.01	0.01
Kinetic equation	y = 0.055x + 2.8862					y = 0.0538x + 3.1818					
R^2 value	0.974					0.947					
Half-life	5.47 days					5.59 days					
PHI	36.72 days					43.42 days					

BDL-Below Detectable Level (<0.01 mg/ kg); *Mean of three replicates, RQ- Risk Quotient

in lemons and mandarins, respectively, 5.75 - 7 days in pomegranate (Utture et al., 2012), two days in mango (Bhattacharya and Diskhit, 2016) and 2.8 - 8.15 days in guava (Khan et al., 2009; Devi et al., 2016). The variation in the degradation pattern of dimethoate in different crops is due to the association of pesticide chemistry, plant architecture and environmental conditions in that particular crop ecosystem.

Risk assessment is the process of identifying potential threats and related hazards to life and health due to long term human exposure to chemicals found in food. The implication of total dimethoate residues including omethoate in grapes was evaluated by calculating risk quotient. The RQ value was >1 at both doses on the day of application and first day after spraying which indicated that grapes harvested on particular sampling days were not safe according to the calculated risk quotient value (RQ>1) under Tamil Nadu agroclimatic conditions.

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A PRELIMINARY SURVEY OF ECTOPARASITES IN NEORA VALLEY NATIONAL PARK, WEST BENGAL

Amita Hajra, Shuvra Kanti Sinha[1]* and Santanu Mahato[2]

Department of Zoology, Government General Degree College,
Kharagpur II 721149, West Bengal, India
[1]Calyptrate Research Laboratory, Department of Zoology,
Sreegopal Banerjee College, Hooghly 712148, West Bengal, India
[2]Biopsychology Laboratory and Institution of Excellence, University of Mysore,
Mysuru 570006, Karnataka, India
*Email: suvrosinha@gmail.com (corresponding author)

ABSTRACT

A preliminary faunistic study was conducted explored the ectoparasites of animals in the Neora Valley National Park (NVNP), West Bengal, India. Many ectoparasites were observed on the bodies of domestic animals that graze on a regular basis in the national park. Major ones found include-*Bovicola bovis* (Linnaeus, 1758), *Ixodes granulatus* Supino 1897, and *Dermacentor auratus* Supino 1897, with *B. bovis* perhaps being reported for the first time in NVNP and India. The study also found that domestic animals and humans in NVNP are exposed to different ectoparasite species of medical and veterinary importance.

Key words: Ectoparasites, mite, lice, domestic animals, wildlife, zoonotic disease, *Bovicola bovis*, *Dermacentor auratus*, *Ixodes granulates*, Neora Valley National Park

Ectoparasites are hematophagous arthropods that are diverse and well-adapted groups of parasites. Some ectoparasite species are host-specific, while others can infest a wide variety of hosts (Nelson et al., 1975). Ectoparasites that infest domestic animals include fleas, lice, ticks, and mites (Angyiereyiri et al., 2015), which are linked to the transmission of veterinary and public health-related diseases and have a major impact on the ecosystem (Ehlers et al., 2019). Several diseases, including bubonic plague, murine typhus, and tularemia, can be transmitted by them (Pourhossein et al., 2015; Shakya et al., 2019; Farid et al., 2021). Domestic animals that dwell in areas near protected forests and their infestation by ectoparasites are the subject of limited research in India. Due to a lack of information about ectoparasites and disease transmission routes among wild and domestic animals in India, the focus of this study was to document the ectoparasitic arthropods of domestic animals found in and around Neora Valley National Park, West Bengal, in order to provide a preliminary interpretation in the context of possible zoonotic disease risk based on the hosts and vectors present.

MATERIALS AND METHODS

The study was undertaken as part of the Biodiversity Assessment Programme in Neora Valley National Park (NVNP hereafter), organised by the Department of Forest (North Division), Government of West Bengal from 2018 to 2021. NVNP is unique and ecologically important as it includes a relatively inaccessible patch of late successional forests with rich diversity, part of a larger and very important Eastern Himalayan landscape. NVNP comprises deciduous and coniferous forests, usually with an understory of bamboo. Cattle biting louse and hard ticks were collected from the bodies of goats and cows grazing regularly inside the national park by hand plucking. One sample of tick was found to stick on the upper arm of a forest guard. Just after collection, the ectoparasites were photographed and they were preserved in 70% alcohol. The description was made following Mathison and Pritt (2014).

RESULTS AND DISCUSSION

Field survey for ectoparasites in NVNP revealed the following louses and ticks as follows:

1. *Bovicola bovis* (Linnaeus 1758)

It is the common cattle biting louse, or Cosmopolitan Cattle biting louse of class Insecta, order Phthiraptera, and family Trichodectidae, distributed in temperate regions worldwide. Ajith et al. (2019) conducted an

Bovicola bovis (Linnaeus, 1758) *Ixodes granulates* Supino, 1897 *Dermacentor auratus* Supiono, 1897

Fig. 1. Ectoparasites observed in the Neora Valley National Park

experiment in which they used Ivermectin to control chewing lice, *Bovicola* (*Damalinia*) *caprae*, in Bengal black goats in Tamil Nadu, India. In NVNP, this louse was found in a huge number on the body hairs of domestic goats (Fig. 1). Report of *Bovicola bovis* (Linnaeus, 1758) is possibly for the first time in NVNP and also in India.

Diagnostics: 1.5-2 mm in length; yellowish-white body colour; abdomen with deep brown transverse bands; tersal claw on each leg; clubbed, filiform and three segmented antennae.

Material examined: 12 ♀♀, Mouchuki to Bhotaykharka, NVNP, 19.x.2019; 14 ♀♀, Thamkharka, NVNP, 18.iii.2020.

Host: Assam Hill Goat (Female)

Site of collection: On the way to Bhotaykharka from Mouchuki and near Koblong Village in Thamkharka, NVNP (27°05'51.9'' N, 88°41'26.5" E).

2. *Ixodes granulatus* Supino 1897

Known colloquially as "hard tick". It is the most common tick on rodents. It is very common in Malaysia and its distribution extends from South East Asia to eastern India. It is a vector of public health importance and also a vector of the Langat Virus, and is involved in the cycle of Tick Typhus and Q fever in the Climax forest of Peninsular Malaysia (Madinah et al., 2011).

In NVNP, this louse was found in a moderate number on the body hairs of domestic cows. The available literature does not show any reports of tick species, including the present from NVNP, West Bengal.

Diagnostics: Body length 5-7 mm.; prominent head; light brown body colour, small oval shield chocolate brown and inornate; visible lateral spiracles.

Material examined: 2 ♀, Mouchuki, NVNP, 18.x.2019.

Host: Siri cow (Female)

Site of collection: On the body of a cow during grazing in the forest near Mouchuki, NVNP (27°01'36'' N, 88°47'10.5" E).

3. *Dermacentor auratus* Supino 1897

Ticks of the genus *Dermacentor* are all potential vectors of diseases, although little work has been done on this. At least four possible human diseases are transmitted by *D. auratus*, none of which has been fully investigated (Petney, 1953). Ajithkumar et al. (2012) reported *D. auratus* from Wayanad, Kerala, India. *D. auratus* carries many recketsiae and viruses, including the Kyasanur Forest Disease (KFD) virus, which causes a fatal zoonotic viral disease reported from Karnataka, India (Ajithkumar et al., 2012). It is also found on the bodies of captive elephants (Islam et al., 2019).

Diagnostics: Body shape is flat and pear-shaped; body length is 4 mm; colour is creamy white with deep brown thick dorsal marking anteriorly and posteriorly; legs have 4 pairs of small claws; scutum is highly ornate; eyes are prominent.

Material examined: 1♀, Thamkharka, NVNP, 17.iii.2020.

Host: Collected on human body (One tick was found on the upper arm of a forest guard during a field survey).

Site of collection: Forest in Thamkharka, NVNP (27°05'51.9'' N, 88°41'26.5" E).

Three ectoparasites *Bovicola bovis*, *Ixodes granulates*, and *Dermacentor auratus* were documented in NVNP. Both the louse *B. bovis* and the tick *I. granulatus* were collected on the bodies of domesticated herbivores that regularly enter the national park for grazing, have medical and veterinary importance (Fig. 1). Survey conducted in four wildlife reserves in Peninsular Malaysia capturing small mammals revealed 14 ectoparasites from five host species, including three species of ticks (Ixodidae). Ticks pose a threat to humans and animals alike, and are arthropods of medical and veterinary importance next to mosquitoes (CheLah et al., 2016). Sanyal and De (2001) indicated the occurrence of both Ixodes granulatus Supino on the black rat Epimys rufescens and Dermacentor auratus Supino on the bodies of deer and humans in West Bengal. Debbarma et al. (2017) observed that ticks like *Rhipicephalus* (*Boophilus*) sp., *Hyalomma* sp., and *Haemaphysalis* sp., are prevalent in West Bengal. Though *I. granulatus* harbours some pathogens, a little work has been done on its medical significance (Petney, 1953). The present study revealed that domestic animals and humans in NVNP are exposed to different ectoparasite species, and that number may be higher. Therefore, future studies are needed to examine the occurrence of ectoparasites among domestic animals as well as wildlife in NVNP of the Eastern Himalaya.

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SCREENING OF BOTTLE GOURD GENOTYPES AGAINST FRUIT FLIES *BACTROCERA CUCURBITAE* (COQUILLETT)

D S Meena*, V S Acharya, K Mehra, V S Rajput and A K Yadav[1]

Department of Entomology, College of Agriculture,
Swami Keshwanand Rajasthan Agriculture University, Bikaner 334006, Rajasthan, India
[1]Department of Entomology, College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur 313001 Rajasthan, India
*Email: dmdaya0007@gmail.com (corresponding author)

ABSTRACT

The present study with bottle gourd in the zaid season in open field, assessed the infestation of fruit fly *Bactrocera cucurbitae* (Coquillet). The infestation was observed from third week of May, with the peak being in the first week of June. Five varieties and three genotypes were screened and none exhibiting resistance. The incidence assessed by fruit number and weight basis revealed that variety PSPL (28.07and 23.34) and Narendra rashmi (30.32 and 25.14) were least susceptible; Pusa Naveen (34.80 and 30.48), Pant louki -3 (35.85 and 32.03), Thar smridhi (33.66 and 27.68), DBG -5(36.74 and 33.53) and DBG-6 (37.87 and 34.90) were moderately susceptible; while, DBG -10 (39.06 and 36.18) was susceptible.

Key words: Bottle gourd, genotypes, *Bactrocera cucurbitae*, resistance, susceptible, least susceptible, moderately susceptible, germplasm, PSPL, screening

Bottle gourd *Lagenaria siceraria* (Mol.) belongs to the family Cucurbitaceae. Pests like melon fruit fly *Bactrocera cucurbitae* (Coquillett), red pumpkin beetle, *Raphidopalpa foveicollis* (Lucas), hadda beetle *Epilachna dermurili (*Mulsant), jassid *Amrasca biguttula biguttula* (Ishida) and whitefly *Bemisia tabaci (*Gennadius) etc. are its important pests. Of these, *B. cucurbitae* causes serious damage to bottle gourd and losses are serious (Vayssieres and Carel, 1999; Dhillon et al., 2005). Of the 207 species of fruit flies found in India, nine are major and economically important (Sardana et al., 2005). *Bactrocera cucurbitae* and *Bactrocera tau* (Walker), commonly called as melon fruit flies are the two major species. Pesticide use against these leads to residues in fruits, and use of fumigants etc., cause serious problems. It is necessary to find out ecofriendly alternatives in IPM, and host plant resistance can be considered. Screening of genotypes for resistance to fruit fly species, and success in developing high yielding and fruit fly-resistant varieties has been limited (Am et al., 2017). The present study evaluates the incidence of *B. curcurbitae* in bottle gourd during the zaid season (March- June) and explores the resistance, if any in varieties suitable for growing in zaid season.

MATERIALS AND METHODS

The experiment was conducted in simple randomized block design in which five varieties and three genotypes were replicated thrice, with seeds sown on 8th March, 2017 and 13th March, 2018, keeping row to row and plant to plant distance of 2.5 m and 0.75 m, respectively. The extent of damage of fruit fly was estimated on the basis of % fruit infestation, observed on weight and number basis, with picking of fruits done at three days interval. Infested and healthy fruits were weighed and counted separately, and % damage worked out by the following formula (Preetha and Nadarajan, 2006).The evaluated varieties/ genotypes were categorized using standard formula (Panda, 1979).

RESULTS AND DISCUSSION

The incidence of *B. cucurbitae* in five varieties and three genotypes of bottle gourd viz., PSPL (Pusa Summer Prolific Long), Pant lauki-3, Pusa Naveen, Narendra rashmi, Thar Samridhi and genotypes DBG-5 (Durgapura bottle gourd), DBG-6, DBG-10 was evaluated during summer 2017 and 2018. The maximum infestation was observed on DBG-10 (23.05 % on number and 22.72 % on weight basis) followed by DBG-6 (22.38 % on number and 21.15 % on weight basis). The minimum fruit damage (14.23 % on number and 14.77 % on weight basis) was recorded on variety PSPL. The incidence reached its peak on 4thJune, with least being with PSPL (46.10% on number and 29.17% on weight basis) followed by Narendra Rashmi (47.96% on number and 31.72% on weight basis), both differing

Table 1. Infestation of fruit fly, *B. cucurbitae* on different varieties/genotypes of bottle gourd, (Pooled) (number basis)

S. No.	Varieties/ genotype	% infestation of fruits at different picking (three days interval)															
		Number of picking															
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13tn	14tn	15tn	Mean
1.	PSPL	14.80	17.72	22.12	27.60	33.63	40.39	46.10	38.65	35.33	30.35	29.12	25.42	22.17	20.03	17.67	28.07
		(22.63)	(24.90)	(28.06)	(31.70)	(35.44)	(39.46)	(42.76)	(38.44)	(36.47)	(33.43)	(32.66)	(30.28)	(28.09)	(26.59)	(24.86)	(31.71)
2.	Pant Lauki-3	21.12	25.52	28.09	34.67	42.00	47.19	51.70	47.54	41.98	39.37	36.95	34.35	32.11	29.58	25.68	35.85
		(27.36)	(30.35)	(32.01)	(36.08)	(40.40)	(43.39)	(45.97)	(43.59)	(40.39)	(38.87)	(37.44)	(35.88)	(34.52)	(32.95)	(30.45)	(36.64)
3.	Pusa Naveen	19.97	23.57	26.82	33.74	41.15	46.06	50.42	46.66	41.10	38.49	36.29	33.16	31.11	28.44	25.07	34.80
		(26.54)	(29.05)	(31.19)	(35.51)	(39.90)	(42.27)	(45.24)	(43.09)	(39.88)	(38.35)	(37.04)	(35.16)	(33.90)	(32.23)	(30.05)	(35.96)
4.	DBG-5	21.40	26.64	29.81	36.44	42.42	48.27	52.54	48.74	43.09	40.26	36.52	35.08	32.78	30.28	26.97	36.74
		(27.56)	(31.08)	(33.09)	(37.14)	(40.64)	(44.01)	(46.46)	(44.28)	(41.03)	(39.38)	(37.18)	(36.32)	(34.93)	(33.39)	(31.29)	(37.18)
5.	Narendra Rashmi	15.99	19.11	24.10	30.34	36.85	41.49	46.97	41.27	37.75	33.64	29.70	28.34	26.66	23.47	19.21	30.32
		(23.53)	(25.93)	(29.40)	(33.43)	(37.38)	(40.10)	(43.26)	(39.98)	(37.91)	(35.45)	(33.02)	(32.16)	(31.09)	(28.98)	(26.00)	(33.17)
6.	DBG-10	23.37	27.90	31.65	38.35	44.03	51.35	55.61	51.48	45.45	42.37	39.77	37.32	34.85	33.41	29.06	39.06
		(28.91)	(31.89)	(34.24)	(38.26)	(41.57)	(45.78)	(48.22)	(45.85)	(42.39)	(40.61)	(39.10)	(37.65)	(36.18)	(25.31)	(32.62)	(37.90)
7.	DBG-6	23.00	27.06	30.57	37.54	43.44	49.34	54.55	49.71	44.05	41.25	38.75	35.97	33.35	31.22	28.37	37.87
		(28.66)	(31.35)	(33.57)	(37.78)	(41.23)	(44.62)	(47.61)	(44.83)	(41.58)	(39.96)	(38.50)	(36.85)	(35.27)	(33.97)	(31.19)	(37.79)
8.	Thar Samridhi	20.04	22.41	26.54	32.49	40.14	44.45	47.79	43.67	40.50	37.74	35.37	32.29	29.96	27.28	24.31	33.66
		(26.60)	(28.25)	(31.01)	(34.75)	(39.31)	(41.82)	(43.73)	(41.37)	(39.53)	(37.91)	(36.50)	(34.63)	(33.19)	(31.49)	(29.54)	(35.30)
	S.Em±	0.30	0.79	0.59	0.44	0.55	0.53	0.52	0.40	0.34	0.58	0.59	0.40	0.40	0.50	0.60	0.50
	CD at (P=0.05)	0.91	2.39	1.79	1.33	1.69	1.61	1.59	1.22	1.05	1.75	1.79	1.22	1.23	1.51	1.83	1.52

S. No.	Varieties/ genotype	Per cent infestation of fruits at different picking (three days interval)															
		Number of picking															
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13tn	14tn	15tn	Mean
1.	PSPL	15.56	15.88	17.32	21.88	24.80	26.66	32.75	29.31	29.16	27.86	26.35	26.00	23.49	19.55	13.65	23.34
		(23.23)	(23.48)	(24.60)	(27.89)	(29.86)	(31.08)	(34.91)	(32.78)	(32.68)	(31.86)	(30.89)	(30.66)	(28.99)	(26.24)	(21.68)	(28.72)
2.	Pant Lauki-3	19.91	20.90	24.66	30.94	31.87	32.52	45.50	41.29	40.21	38.11	35.99	35.56	34.49	28.97	19.58	32.03
		(26.50)	(27.21)	(29.78)	(33.80)	(34.37)	(34.76)	(42.42)	(39.98)	(39.35)	(38.12)	(36.87)	(36.61)	(35.96)	(32.57)	(26.27)	(34.30)
3.	Pusa Naveen	18.80	19.80	22.91	30.08	30.84	31.13	44.86	40.49	38.91	36.92	33.89	32.78	32.06	24.88	18.92	30.48
		(25.70)	(26.42)	(28.60)	(33.26)	(33.73)	(33.91)	(42.05)	(39.52)	(38.60)	(37.42)	(35.57)	(34.93)	(34.49)	(29.92)	(25.78)	(33.32)
4.	DBG-5	20.76	21.93	25.39	31.44	32.54	33.79	46.38	43.56	41.02	39.53	38.00	37.18	36.15	32.14	23.17	33.53
		(27.11)	(27.92)	(30.26)	(34.11)	(34.78)	(35.54)	(42.92)	(41.30)	(39.83)	(38.96)	(38.06)	(37.57)	(36.96)	(34.54)	(28.77)	(35.24)
5.	Narendra Rashmi	16.48	16.94	19.18	24.36	27.09	29.23	34.37	31.31	30.97	30.60	28.14	26.53	24.79	21.07	16.14	25.14
		(23.95)	(24.30)	(25.98)	(29.57)	(31.36)	(32.73)	(35.90)	(34.03)	(33.82)	(33.59)	(32.04)	(31.01)	(29.86)	(27.33)	(23.69)	(29.94)
6.	DBG-10	23.58	24.13	27.77	33.37	34.81	36.14	46.87	45.76	43.05	40.85	39.83	39.09	38.38	37.31	31.90	36.18
		(29.05)	(29.42)	(31.80)	(35.29)	(36.15)	(36.95)	(43.21)	(42.57)	(41.01)	(39.73)	(39.13)	(39.70)	(38.28)	(37.65)	(34.39)	(36.95)
7.	DBG-6	22.18	23.27	26.28	32.66	33.66	35.14	46.77	45.02	42.29	41.22	39.16	38.50	37.63	33.65	26.17	34.90
		(28.10)	(28.84)	(30.84)	(34.86)	(35.46)	(36.35)	(43.15)	(42.14)	(40.56)	(39.94)	(38.74)	(38.35)	(37.84)	(35.46)	(30.77)	(36.09)
8.	Thar Samridhi	18.06	18.43	23.57	28.12	30.13	31.49	35.98	35.42	35.35	34.16	31.93	29.43	25.52	20.96	16.65	27.68
		(25.15)	(25.43)	(29.04)	(32.03)	(33.29)	(34.13)	(36.86)	(36.52)	(36.48)	(35.77)	(34.41)	(32.82)	(30.35)	(27.25)	(24.08)	(31.57)
	S.Em±	0.35	0.47	0.53	0.50	0.66	0.56	0.69	0.53	0.57	0.65	0.73	0.66	0.60	0.73	0.49	0.58
	CD at (P=0.05)	1.07	1.43	1.60	1.52	1.99	1.69	2.10	1.62	1.75	1.97	2.22	1.99	1.81	2.21	1.50	1.76

significantly. The maximum infestation was recorded on genotype DBG-10 in 2017, with peak being on 2nd June, and the least being with PSPL, which was at par with Narendra Rashmi. Maximum incidence was on cultivar DBG-10, DBG-6 and DBG-5; maximum incidence was in DBG-10 in 2018. The pooled data revealed that no variety/ genotype has resistance for two consecutive seasons, with incidence being at peak in the seventh observation, least being on variety PSPL at par with Narendra Rashmi; and maximum in DBG-10 followed by DBG-6 (Table 1).

Dhillon et al. (2005) screened with 17 bitter gourd genotypes observed significantly least incidence in IC 256185 and IC 248256. Gogi et al. (2009) screened found that the genotypes COL-II and FSD-long can be categorized as resistant. Mallikarjunaro et al. (2020) with 23 genotype of bitter gourd found none as resistant. Nehra et al. (2019) with seven varieties of round gourd observed that varieties with hard rind of fruits were less susceptible. The varieties and genotypes with incidence on number and weight basis <30.80 and 26.01%, respectively can be categorized as less susceptible, between 30.80 to 38.30 and 26.01 to 35.79% as moderately susceptible; and >38.30 and 35.79% as as susceptible. The variety, PSPL and Narendra Rashmi can be considered as less susceptible. Such result were obtained by Dhillon et al. (2005), Gogi et al. (2009) and Mallikarjunoaro et al. (2020). Nehra et al. (2019) observed that the fruits having higher hair density and low softness were less susceptible.

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AUTHOR CONTRIBUTION STATEMENT

Vijay Shankar Acharya has designed the research, Daya Shankar Meena conducted the experiment. Keshav Mehra and Vimal Singh Rajput contributed in the analysis and wrote the manuscript whereas Ajay Kumar Yadav contributed in field and analytical tool.

CONFLICTS OF INTEREST

Authors declare no conflict of interest.

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A REVIEW ON VECTOR BORNE DISEASE TRANSMISSION: CURRENT STRATEGIES OF MOSQUITO VECTOR CONTROL

S Manikandan, A Mathivanan, Bhagyashree Bora, P Hemaladkshmi, V Abhisubesh and S Poopathi*

Unit of Microbiology and Immunology, Vector Control Research Centre,
Indian Council of Medical Research, Department of Health Research,
Ministry of Health and Family Welfare, Puducherry 605006, India
*Email: Subbiahpoopathi@rediffmail.com (corresponding author)

ABSTRACT

In this review, the mosquito vector borne diseases (VBD) majorly malaria, dengue, filariasis, chikungunya, Japanese encephalitis, Zika were presented to comprehend the global disease incidence as the control of these disease transmitting vectors are challengeable globally nowadays. It has been found that malaria affects nearly 500 million people and lymphatic filariasis about 100 million people worldwide every year. About 25 million people are infected by dengue, with approximately 25,000 deaths annually. For mosquito larval adult control measures, synthetic pesticides playing major role but owing to resistance development its application is impeded. Alternatively, bacterial biopesticides are very useful for larval control mainly due to environment friendliness and lack of resistance development. As of now, *Bacillus sphaericus* (*Bs*) and *B. thuringiensis israelensis* (*Bti*) are in use but *Bs* is nowadays not recommended for field application due to resistance. Significant results on resistance development are noticed in India, Brazil and France. Due to these situations, there is a growing interest in discovering novel biological agents from natural sources. In the present review, the current global scenario of VBDs were discussed.

Key words: Vector borne disease, mosquito vectors, socio-economic impact, integrated vector management, synthetic insecticides, bio-pesticides, vector control

In public health, the term "vectors" in broad spectrum refers to any organisms which can communicate infectious diseases to mankind and other living organisms. Major vectors belong to insects of the phylum *Arthropoda* in animal kingdom. Some important vectors are mosquitoes, sand flies, ticks, simulium, triatomine bug, etc., which transmit diseases by means of the infected bites. Among these insect vectors, mosquitoes play a vital role in transmitting many dreadful diseases like dengue, filariasis, Japanese encephalitis, chikungunya, malaria, West Nile fever, etc. These vectors are ectothermic and are vulnerable to climatic conditions. Weather affects the abundance, habitat suitability and distribution of the vector population (Dhanasekaran et al., 2014). Besides, it affects the reproduction rates, survival of the vectors, disease spreading capacity, feeding and biting rates. In addition, it also affects the multiplication and survival of the disease-causing pathogens which infests inside the vector. Globally, vectors are responsible for 17% of infections of mankind. More than 3.9 billion in 128 countries are prone to dengue infection with about 96 million dengue cases reported every year. As per latest report from World Health Organization (2022) nearly 0.5 million of severe dengue cases every year. Malaria is one of the major dreadful vector-borne diseases which can cause substantial economic and social disruption. Every year nearly 4,00,000 deaths were recorded due to malaria. Malaria affects mostly children below 5 years of age (WHO, 2018). In addition to the above, other illnesses like American trypanosomiasis, kala-azar and schistosomiasis affect the people worldwide. The burden of these vector borne diseases (VBDs) is highest in tropical and sub-tropical regions due to poor socioeconomic conditions. Most of these vectors are insects that suck blood from the host (animal or human). Vectors ingest the pathogen that causes disease while feeding on the blood of a diseased person and later transmit it to others. Due to the lack of effective vaccines or specific pharmacological drugs for most of these diseases particularly dengue fever and West Nile virus, vector management is the primary key element for the eradication of vector-borne diseases (El-Kersh et al., 20l6). There are four methods to control vectors which include environmental control, chemical control, biological control, and personal protection measures. Biological control is a powerful strategy to reduce public health problems related to vector-borne diseases without affecting the environment (Cuthbert et al., 2018). In other words, biological control is an

environment-friendly preventive technique to control pest organisms.

Vector control

During the 20th century, biological control of mosquitoes was very effectively carried out. However, the application of chemical insecticide was in top priority because of the easy availability and cost-effectiveness (Saleeza et al., 2014). However, due to the development of insecticide resistance in these vectors, in addition to their ill-effects on the ecosystem, chemical insecticides were less preferred, and biological control agents were prioritized. Biological control agents include larvivorous fishes (*Gambusia affinis, Poecilia reticulate* and *Clarialfuscus*) dragonflies, damselflies, a mosquito species (*Toxorhynchites*), cyclopoids and copepods. Besides, mosquitocidal bacteria like *Bti* (*Bacillus thuringiensis* var *israelensis*), and *Bs* (*Bacillus sphaericus*) are also used as biological control agents. It is therefore essential to explore further more natural resources and isolate more powerful bio-control agents other than *Bti* and *Bs* for the management of vector populations. Mosquitoes have occupied several natural niches including the greater altitudes, and are ubiquitous, found worldwide (Mondal et al., 2014). These extraordinarily adaptable insects continue to cohabit with humans and their domesticated animals. Even though there is public awareness and knowledge about the importance of these mosquito vectors and their part in causing and spreading disease for decades, VBDs are a significant threat to human society. Rapid urbanization, population dynamics, and industrialization are the main reasons for the increase in the mosquito population and thereby increase in mosquito borne diseases.

Vector surveillance

The study of vectors in relation to their habitats and feeding and resting habits is called vector ecology. Particularly mosquito vectors are more adaptable to climate changes than the other insect vectors. The dispersal, density, and survivability of mosquito vectors depend on biotic and abiotic factors such as competition, predators and humidity, temperature, pH, rainfall, salinity, light/darkness etc. (Chase and Knight, 2003). Furthermore, the ecological factors play a vital role in the occurrence of these diseases either directly or indirectly. More than 3000 species of mosquitoes under 34 genera are found worldwide. Out of these, only 300 mosquito species cause diseases. Mainly, the three mosquito genera of *Anopheles, Culex* and *Aedes* are responsible for spreading most of the dreadful VBDs (Das and Kalyanasundaram, 1989). Vector surveillance of mosquitoes is essential to understand the abiotic and biotic progression that rules abundance and distribution. Throughout their lifecycle, different mosquito species exhibit distinct resting and feeding habits. Most mosquito species rest during the day and are active from dusk to dawn. Most *Anopheles* and *Culex* species bite at night, while *Aedes* and *Armigeres* species feed during the day. The preference of hosts for mosquito blood-feeding differs between humans and other mammals and birds (Patil et al., 2002). Water is the primary breeding source for all mosquito species. Eggs are laid in water, and the developmental stages of larvae and pupae occur in water. Mosquito larvae prefer to live in water. The mosquito habitats are numerous and diverse, such as tree holes, ponds, and lakes. Some mosquito species breed in freshwater, while others are sewage water breeders. Nowadays, due to rapid urbanization and industrial development, mosquito breeding is enhanced to a greater extent. Human modification of the environment increases mosquito breeding sites (Norris, 2004). The primary cause of the rapid uncontrolled multiplication of vectors is the improper water management system (Joshi et al., 2005).

Disease incidence

According to the most recent malaria report, there is 241 million malaria cases in 2020 and there are 227 million cases in 2019. Malaria deaths are expected to reach 6,27,000 in 2020, a 69,000-death increase from the previous year. Disruptions caused by the COVID-19 pandemic may be responsible for approximately two-thirds of these deaths (47,000). The Democratic Republic of the Congo (13.2 percent), Nigeria (31.9 percent), the United Republic of Tanzania (4.1percent), and Mozambique (3.8 percent) accounted for roughly half of all malaria deaths worldwide (WHO, 2021). Seventeen countries and territories are mentioned to have eliminated filarial disease which is a serious health issues including Cook Islands, Cambodia, Egypt, Maldives, Kiribati, Malawi, Niue, Palau, Marshall Islands, Sri Lanka, Togo, Thailand, Tonga, Viet Nam, Vanuatu, Yemen, Wallis, and Futuna. Five more countries have successfully implemented the recommended strategy, stopped mass drug therapy, and are being monitored to ensure that elimination has been achieved. But still, 50 countries need preventive treatment and in ten of those countries, MDA has not been implemented till the end of 2019 (WHO, 2021).

There was an eight-fold increase in dengue cases in

the last two decades. Around 0.5 million cases in 2000, 2.40 million in 2010, and 5.20 million in 2019 were reported. The mortality rate from the year 2000 to 2015 varied from 960 to 4032. Children below five years of age were affected mostly. In 2020, dengue affected several countries like Brazil, Nepal, Mauritania, Bangladesh, Indonesia, Cook Islands, India, Ecuador, Maldives, Sri Lanka, Singapore, Mayotte (Fr), Sudan, Timor-Leste, Yemen, and Thailand. Dengue continues to affect Brazil, India, Vietnam, Philippines, prepare dinner Islands, Colombia, Fiji, Kenya, Paraguay, Peru and Reunion islands in 2021 (WHO, 2021).

Major mosquito borne diseases (VBD)

The major VBDs are malaria, dengue, filariasis, chagas disease, leishmaniasis, schistosomiasis, African trypanosomiasis, Japanese encephalitis, yellow fever, and onchocerciasis. These diseases are caused by viruses, bacteria, and parasites which are transmitted by vectors. Every year there are more than 7 lakh deaths reported due to VBDs. In 2014, major outbreaks of malaria, chikungunya, dengue, zika, and yellow fever were reported affecting the lives of many people and, posing a challenge to health systems in many nations. Other VBDs like chikungunya, leishmaniasis, and lymphatic filariasis result in persistent struggling, life-long morbidity, incapacity, and occasional stigmatization (WHO, 2020).

Malaria: Malaria is an acute febrile disease caused by *Plasmodium* species, an intracellular protozoan parasite that is transmitted by the bite of infected *Anopheles* mosquitoes. *Plasmodium falciparum, Plasmodium vivax, Plasmodium ovale* and *Plasmodium malariae* are the common parasite species that cause malaria. In India, *Plasmodium vivax* and *Plasmodium falciparum,* pose the most significant risk. *P. falciparum* is the most lethal malaria parasite and the most common in African continent. Infections with *P. vivax* are common in many countries.The first signs of malaria are headache, fever and chills, generally seen after ten to fifteen days after the infective mosquito bite. The symptoms may be moderate and also difficult to apprehend as malaria. If left untreated, *P. falciparum* malaria can progress to a severe infection known as malignant malaria and cause mortality within a day. In 2020, nearly half of the world's population were exposed to malaria. Some of them faced the problem of disease exposure and suffering severe disease, including pregnant women, newborns, children under the age of five, and HIV/AIDS patients, as well as people with low immunity who migrate to areas with high malaria transmissions, such as migrant workers, nomadic people and travelers (WHO, 2021). In India, totally 50 *Anopheles* species mosquitoes are found, but only ten species are the malarial vectors. The vector species of *Anopheles* are *culicifacies, fluviatilis, stephensi, varuna, sundaicus, Philippines, annularis, balabacensis, minimus,* and *jeyporiensis*. Among these, *An. culicifacies* in urban and *An. stephensi* in rural areas are prevalent in India (Das et al., 1990).

Filariasis: Lymphatic filariasis is a tropical and subtropical parasitic disease that affects people of low socio-economic status. Lymphatic filariasis (LF) is caused by three species of nematodes, namely *Brugia timori, B. malayi,* and *Wuchereria bancrofti* which affects the lymphatic system. The bite of infected mosquitoes transmits lymphatic filariasis. It has been one of the foremost public health issues in Africa, South Asia and also in India (WHO, 2013). Elephantiasis, scrotal swelling, and lymphoedema are the manifestations of the illness, which causes pain, disfigurement and lifelong disability. Patients are physically and mentally disabled, facing social and financial losses, contributing to social stigma and poor economic status. Preventive chemotherapy was required for 859 million people in 50 countries in 2019. As per the recent WHO report, there are more than 15 million people suffering from lymphoedema and 25 million men affected with hydrocele globally. These disease manifestations affect approximately 36 million people (WHO, 2021). It is a chronic disorder that results in social, physical, and economic problems. Globally, nearly 120 million people from 83 countries are affected by filariasis. In India 610 million people living in endemic areas in 20 states were affected by filariasis (Devi et al., 2018). Filariasis may manifest as chronic lymphoedema with swelling of limbs, genitals and scrotal sacs (hydrocele). In India alone, it contributes to 44.3 % of the global filariasis burden (7.44 million by lymphoedema, 12.88 million by hydrocele out of 31.26 million filaraemics) (WHO, 2012). Filariasis elimination strategy program released in 2004 through MDA (mass drug administration) with DEC (diethyl carbamazine) and albendazole was focused by 2015 (Shriram et al., 2014). WHO released the GPELF (Global Programme to Eliminate Lymphatic Filariasis) in 1997 based on the two fundamental ways to eradicate filariasis by using mass drug management and MMDP (WHO, 2013). Neglected Tropical Disease Control Programs (NTDCP) was established in 2012 in London to eliminate many NTDs, including LF by 2020 (London announcement to combat NTDs, 2013). Additionally, numerous NGOs

have funded to strengthen NTDs applications. Globally, filariasis has been eliminated in countries including Japan, Taiwan, South Korea, Solomon Islands, and China (Sabesan et al., 2000). Fifty-nine species of mosquito vectors transmit filariasis. Amongst them, the principal vector of parasites is *Culex quinquefasciatus*. It is widely distributed in tropical and sub-tropical countries and is responsible for ninety percent of the whole transmission. The vector species of *Culex* are *quinquefasciatus, pipiens, pallens, molestus, globocoxitus* and *australiens* (Devi and Jauhari, 2004), *Aedes* species include *polynesiensis, Samoans,* and *Poecilious,* and *Anopheles* species of *gambiae, flavirostris,* and *barbirostris. Manonioides* species of *annulifera, uniformis,* and *Indiana* also transmit filarial parasites. All of the above species are distributed in diverse areas and various sources. Increased number of microfilaraemics are found in Bihar, Andhra Pradesh, Tamil Nadu, the coastal region of Odisha, Kerala, and eastern Uttar Pradesh in India. In India, approximately 1.5 million people are exposed to the disease with 1.2 million people suffering from filariasis and 2 million microfilaria carriers (Patil et al., 2002).

Dengue: The causative virus for dengue is transmitted by infected *Aedes*, primarily the *Aedes aegypti,* besides other species (WHO, 2021). Dengue virus belongs to flavivirus group associated with other arboviruses like Japanese encephalitis and yellow fever. Dengue is caused by four types of virus (DENVI, DENV2, DENV3, and DENV 4). All four dengue virus serotypes have a unique host immune response to the infection. Currently, a new serotype of the dengue virus has been isolated in Malaysia in 2013 (Mustafa et al., 2015), which is genetically different from the previous three dengue serotypes (DENVI, DENV3, and DENV4) but slightly analogous with DENV2. After blood feeding of a dengue infected individual, the dengue virus enters and multiplies inside the mid gut of a mosquito. The virus then spreads to salivary glands and is transmitted to other hosts during subsequent blood meal. The extrinsic Incubation Period (EIP) is the time taken for a virus to spread from one host to another. When the ambient temperature is between 20 and 28 degrees, the EIP takes about 8-12 days. Differences in the EIP are influenced by ambient temperature, daily temperature variations, virus genotype, and initial viral concentration (Ye et al., 2015). The infected mosquito can spread the virus throughout its lifespan. Next to malaria, dengue fever is another most dangerous mosquito-borne disease in India. It is most common in cities, rural areas, and semi-urban areas. It can occasionally cause severe hemorrhagic manifestation, which can lead to death. (Viroj et al., 2006). Dengue vectors in India are *Aedes aegypti* and *Aedes albopictus,* and were initially found in Africa, and later spread to India. Dengue epidemics were first reported in Asia, Africa, and the United States in 1779-1780, indicating a remarkable tropical distribution of *Ae aegypti* over the previous 200 years. Due to its domestic breeding behavior and feeding preference on human blood, it is perfectly adapted to urban environments. *Aedes albopictus* is responsible for spreading dengue in rural and semi-urban areas. Each year, approximately 50 million dengue cases are reported in India and 2.5 million people face the threat of acquiring dengue. Dengue may become a more severe problem in the future if urbanization continues unabated unless strict environmental control measures are implemented. (Kwa et al., 2008). The *Aedes* species are the principal dengue vector in tropical and sub-tropical nations, particularly Africa and Asia. *Ae. aegypti* and *Ae. albopictus* pose danger of dengue transmission in Europe (Jensenius et al., 2013). The dengue hemorrhagic fever has been widely known since 1950 and is an emerging and re-emerging mosquito-borne disease. Apart from malaria and filariasis in Africa and Asia, dengue is one of the oldest mosquito-borne diseases. As per the latest WHO report, 390 million humans have been exposed to dengue virus, with 96 million new cases.

Japanese encephalitis (JE): Japanese encephalitis (JE) is a dangerous human disease commonly called Brain fever caused by JE-virus and transmitted through mosquito vectors of *Culex vishnui* and *Culex tritaeniorhynchus* in Asia. JE is caused by a flavivirus similar to that causing West Nile, yellow fever, and dengue. Japanese encephalitis was first recorded in Japan in 1871. During outbreaks, 1 to >10 clinical cases per 100,000 populations were reported from disease-endemic countries. As per the literature review, approximately 13,600 to 20,400 deaths and about 68,000 JE-clinical cases occur every year worldwide. Mostly children are affected by JE and adults have developed immunity due to childhood infection, but anyone of any age can be affected. In India, Japanese encephalitis (JE) is common. JEV is primarily an animal virus, with pigs serving as primary reservoirs. Pigs are infected with JEV transmitted by mosquitoes from birds, specifically egrets and pond herons. Humans are merely accidental hosts and are not intended to transmit the virus. JE cases have been reported on a large scale in Bihar, Uttar Pradesh, and Assam besides Andhra Pradesh and Karnataka. *Culex tritaeniorhynchus* and

Cx. vishnui are JE vectors found in India, accounting for 27 verified and suspected vectors. In India, vectors of JE include *An. subpictus, Cx. epidesmus anhyrcanus, Mansonia annulifera,* and *An. barbirostris* besides *Cx. bitaeniorhynchus, Cx. whitmorei* and *Cx. pseudovishnui, Cx. fuscocephala* and *Cx. gelidus*. JE is prevalent in the north eastern and southern part of India and a small part of Gujarat **(**WHO, 2021).

Chikungunya: Chikungunya is a VBD spread by the mosquito *Aedes albopictus* (Asian tiger mosquito). This mosquito is also known as the jungle mosquito, more common in semi-urban and rural areas. As a result, a more significant number of cases were reported from rural areas. In 2019, Asia and America were affected by chikungunya outbreaks. Pakistan faced a persistent outbreak and reported 8387 cases, while India suffered 62,000 cases. In America and in the Caribbean, 1,85,000 cases were reported; Brazil accounted for more than 90% of cases in America. Chikungunya outbreaks have also been reported in Yemen (2019), Sudan (2018), and more recently in Cambodia and Chad (2020). In 1952, the first case of chikungunya was reported in Africa and Tanzania. In India, the first outbreak occurred in Kolkata (Calcutta) in 1963. In general, chikungunya is not a fatal disease, but however, in 2005-2006, 200 people died due to a chikungunya outbreak in India, which began in Karnataka, Tamil Nadu, Andhra Pradesh, and Kerala. Many hundreds of cases have been detected in Bhilwara, Rajasthan, Chittorgarh, and Udaipur districts and adjoining areas of Madhya Pradesh and Gujarat following floods and heavy rains in August 2006. In addition, the neighboring country of Sri Lanka was affected. In Kerala, 125 people died due to this disease, with a maximum number of casualties occurring in Cherthala and Alapuzha (WHO, 2021).

Zika: Zika is also a vector-borne viral transmitting disease by *Aedes albopictus, Aed. aegypti, Aed. furcifer, Aed. apicoargenteus, Aed. luteocephalus, Aed. Vitattus* (Foy et al., 2011). The ZIKV is a flavivirus genetically related to the *Spondweni* virus (Hayes et al., 2009; Kuno and Chang, 2007). This disease is a challenge for the developing and developed nations and a significant problem in disease-prevalent countries owing to amplified globalization, urbanization, construction of dams, agricultural intensification, deforestation and global warming. Ignorance still prevails about such important mosquito vectors *(Aedes africanus, Aedes hansilli, Aedes luteocephalus, Aedes albopictus, Aedes aegypti,* etc.) and their role in spreading diseases. After Ebola, WHO has anticipated around 3-4 million infected cases in America by subsequent year across and CDCP (Center for Disease Control and Prevention) have advised to avoid the travel of pregnant women where the ZIKV is circulating as described by WHO (WHO, 2016). On 1st February 2016, the organization has publicized the epidemic of ZIKA as ‘’Public Health Emergency of International Concern” (WHO, 2016).

Socioeconomic impact

The socioeconomic condition of a country has an impact on disease prevalence. Knowledge of vector-borne diseases and health consciousness may aid in disease control. Malaria cases increase in poor households due to low resistance caused by malnutrition. Because of the ignorance of the general public, who are unaware of malaria-related symptoms, prompt therapy is not given to patients who develop severe complications. People are still ignorant about symptoms and treatment of malaria. The government plans and implements measures to control mosquito populations and disease spread. In addition, even though diseases are not under control, the government is running awareness campaigns through the social media. The geographic and ecological profile of a region, combined with the area’s socio economic status, allows the multiplication of mosquito population, which results in VBD episodes. Rapid urbanization, excessive deforestation, insecticide and pesticide use, the progress of new agro-ecosystems, and other factors have influenced the emergence of different vectors and VBDs over the last seven decades. Mosquito species that develop resistance require special and immediate attention (Jagdish, 2003). Chemical control measures directly affect mosquito vectors physiologically, and their continuous usage may alter the vector ecology. Mosquitos have plagued Rajkot for decades, and hundreds of people die each year due to VBDs. Dengue, malaria and recently, chikungunya are found in Rajkot, with malaria being the most common. Controlling the spread of vector-borne diseases has emerged as the most difficult challenge for the local government body. Local governments and private, non-governmental organizations are making enormous efforts to control disease and vectors.

Integrated vector management

Integrated vector management (IVM) is a tool that incorporates both chemical and non-chemical approaches and environmental management. It is part of a larger strategy that includes coordination with health division and other divisions, advocacy,

social mobilization, educational movements, solid evidence-based choice making, and capacity building. IVM can simultaneously control diseases spreading through various vectors in a specific area or can be a single tool controlling multiple VBDs transmitted by a vector (Grepin et al., 2008). The IVM agenda was utilized in 2004 to control all VBDs and is regarded as a sound method for vector control. Mosquito control must be based on a fundamental understanding of the target species ecology, bionomics, behavior and its relationship to its host and environment. Control measures can be directed at either the immature or adult stages or both stages simultaneously. In general, larval control measures are preferred when adulticidal steps are either expensive or unacceptable to society, and the larval breeding source is limited to a small area. In locations where outbreaks of VBDs are reported often, larval control measures are preferred, and in situations where house spraying alone or in combination with drug administration fails to interrupt disease transmission for technical or operational reasons.

Synthetic insecticides have been used successfully for decades for destroying vector insects in order to control VBDs. Larvicides are necessary weapons that humans have developed to combat larval and adult mosquitos. Many simple and complex synthetic insecticides have been developed due to the advancement of applied chemistry. Insecticides and larvicides are available in the form of dust, powder, or liquid and have different effects on insects. The discovery of DDT (Dichloro-diphenyl-trichloroethane) was a watershed moment in developing modern synthetic insecticides. DDT's contact action against insects was discovered by Muller in 1939. Following the failure of the chemical insecticide control, successive insecticide changes were made, resulting in sequential insecticide selection pressure. Finally, multiple insecticide resistance was developed by mosquito vectors. Mosquitoes that breed in pre-domestic breeding sites are becoming resistant to the various insecticides that protect the crop. Despite using chemical insecticides, these diseases still exist and spread to epidemic proportions. As a result, efforts have been made to find and develop alternative methods for controlling vector mosquitoes to reduce reliance on chemical insecticides. The development of resistance is expected to directly and profoundly impact the re-emergence of these diseases, and disease control may be jeopardized (Jones et al., 1998). Table 1 depicts the comparative analysis on the advantages and disadvantages of synthetic and biological pesticides.

Resistance to insecticides

Mosquitoes pose a severe threat to society by serving as a vector for various dangerous illnesses. Mosquito control programs rely heavily on the regular use of chemical insecticides, which leads to resistance among vectors and environmental hazards, bio-magnification, and adverse effect on public and animal welfare around the world. The global threat of vector-borne diseases and their negative impacts emphasizes the necessity for effective control of mosquitoes. As a result, there is an urgent need to develop new products that have the added benefits of being economic, biodegradable, environment-friendly, and safe to non-target organisms. The current knowledge regarding the plant-derived compounds with larvicidal properties is beneficial in controlling mosquitoes. The molecular mode of action of allele-chemical compounds synthesized from various kinds of plant species and also its secondary metabolites, extracts, and plant essential oils can be used for mosquito control (Senthilnathan, 2020). Since the use of chemical insecticide has become difficult because of bio-amplification of food materials, contamination of food chain, and negative impact on insects with beneficial properties, a surge in biological agents for mosquito control has developed in recent years. Biocontrol agents minimize environmental problems and are the best alternative for chemical pesticides.

Biological pest control

Presently, there is a surge in the use of biological pest control as a potential method for controlling vector mosquitoes. Many mosquitocidal bio-control strategies were evaluated, including their effectiveness, safety to non-targets, and the environment. Some types of protozoa, bacteria, nematodes, viruses, fungi, fish and invertebrate predators have been studied, in order to be used as potential vector control agents. Several bacteria are studied and are found to be effective biological control agents, including *Bacillus thuringiensis morrisoni, Bacillus thuringiensis. jegathesan, Bacillus thuringiensis niedellin, Bacillus thuringiensis canadensis, Bacillus thuringiensis malaysiensis, Asticcacaulis excentricus, Clostridium bifermentans malaysia* and *Synechococcus* (Poopathi et al., 2004).

Among various bio-control agents of *Bacillus* species, two strains of *Bacillus thuringiensis* subspecies *israelensis* and *Bacillus sphaericus* and have been extensively recommended because of their highly potent mosquitocidal activity. More *Bacillus* species like *Bacillus cereus* (Poopathi et al., 2013), *Bacillus alvei,*

Table 1. Control of mosquito vectors using the larvivorous fishes, synthetic and biological pesticides

Insecticides	Advantages	Disadvantages
Synthetic insecticides Malathion Chlorpyrifos Pyrethrins Cypermethrin Permethrin	Effectively used for insect control. Highly active. Effective in mode of action. Long residual activity.	Rapid development of resistance. Environmental pollution. Bio amplification. Harmful to non-target organisms.
Biological pesticides *Bacillus sphaericus* (*Bs*) *Bacillus thuringiensis* subsp. *israelensis* (*Bti*)	Environmental safety. Pollution free. Non-toxic to non-target organism. Recyclable. Effective in minimum dose.	 High level resistance to *Bacillus sphaericus*.
Larvivorous fishes *Gambusia affinis* *Poecilla reticulate* (guppy) *Aplocheilus panchax* *Cyanolebias bellotii* (argentine pearl fish) *Oreochromis mossambicus* *Cyprinus carpio*	 Self-perpetuating larval control method. Cost-effective. Effective method	It cannot be used in low density of water bodies. Time consuming method, no rapid results possible. It cannot work in water bodies with high vegetation and floating grarbages. Special care needed for transportation and stocking.

Bacillus brevis, *Brevibacillus leterosporous*, *Bacillus circulans, Bacillus subtilis*, *Clostridium bifermentans*, *Bacillus amyloliquefaciens*, *Pseudomonas fluorescens*, and *Pseudomonas aeruginosa* have also been used to control mosquito vectors (Lalithambika et al., 2016).

B. thuringiensis* subsp. *israelensis* (*Bti*) and *Bacillus sphaericus (Bs): *Bacillus thuringiensis (Bt)*-an entomo-pathogenic bacterium is a rod-shaped, gram-positive, spore-forming bacteria (Abo-Bakr et al., 2020), about 0.5-1.0 x 5µm in size, widely distributed in the natural environment like water, soil, plant leaves, stored grains, insect cadavers, and excreta of arid-birds etc (Poopathi et al., 2014). The mosquitocidal property of *Bacillus thuringiensis* is due to a toxic substance present in parasporal inclusion and crystals produced during sporulation. These toxins comprise of six major proteins aggregated into a solid crystal structure in the bacterial cell. The toxins responsible for the mosquitocidal activity are produced by Cry 4B (135 kDa), Cry4A (125 kDa), Cry11A (68kDa) and CytlAa (28kDa) present in the inclusions. Besides these bacterial toxins as mentioned above, other toxic proteins such as Cryl0A and Cyt2Ba also included. *Bacillus sphaericus* produces binary toxins, which are responsible for the toxic effects to the mosquitoes. The two components of the toxins are Bin B (51 kDa) and Bin A (42kDa), which binds to the specific midgut receptors on the epithelial cells and gastric caecum of the alimentary canal of the mosquito larvae. As like, the other potential strain of *Bacillus sphaericus*, is also gram-positive, rod-shaped, spore-forming bacteria isolated from natural soil. The first strain of *Bs* showing larval toxicity was reported in 1965. Following that, more than 300 strains from worldwide were isolated and identified. Since the late 1980s, *Bs* was used to control *Culex pipiens, Cx. quinquefasciatus* and *Cx. pipiens pipiens* larvae, besides *Anopheles* spp. The advantages of this mosquitocidal strain included high specificity, safe to the environment, potent efficacy, extended activity for a prolonged period of time. As on date, a few potential *B. sphaericus*-2362 based biopesticides are available in the market. The VectoLex and Spherimos are commercialized in the United States and Europe. *B. sphaericus*-1593 based biopesticide (Biocide-S) is also commercialized in India. Similarly, *B. sphaericus*-C3-41 is accessible in the People's Republic of China. All these commercially available bio-pesticides are effective due to specific toxins present in the spores, and these parasporal crystal proteins are directly involved in the mosquito-killing effect. It was reported that *B. sphaericus* has two significant polypeptides namely, Bin-A (42 kDa) and Bin-B (51 kDa), which are responsible for larval toxicity. The mode of action of the toxin complex is associated with the affinity of these toxins to a specialized receptor present in the mid-gut of the larvae of susceptible mosquitoes. The two crystal components work in

tandem; the Bin-B component is first binds in affinity with receptors, whereas the Bin-A comprising of 42kDa protein starts binding immediately after Bin-A (51kDa). More than 180 *Bs* strains were tested on a wide range of mosquito species, and the H5a5b serotype was found to be the most potent. Electron microscopy was used to observe the difference in the growth pattern of bacteria cultured from the liquid culture medium. During bacterial growth, vegetative cells started multiplication in the culture medium, and it steadily reached the sporulation stage after the lag phase of several hours. By about 72 hours, the crystal toxins became clear and conspicuous in the spores and the spores started rupturing as a result the crystal toxins were released into the culture medium (Charles et al., 1996). The authors further reported two types of bacterial toxins, namely, crystal and Mtx toxins, and both were entirely different in structural arrangement and synthesizing time. It is clear that the crystal toxins are responsible for the potent larvicidal effect of *Bs* strains and these toxins consists of 51 kDa and 42 kDa polypeptides (Bin-B and Bin-A found in the chromosome) and the components of these two polypeptides are quite different from that of other toxins, such as *Bti*. In spite of the valued nature of the above toxins from *B. sphaericus*, it is very unfortunate that the mosquito larvae developed resistance to the bacteria because of its continuous application over a period of time (Georghiou and Wirth 1997). This serious issue of resistance is mentioned in the succeeding section.

Mode of action of *Bacillus sphaericus:* Mosquito larvae present in the water habitats consume the crystal toxins of *Bs* strains. The crystal toxins are solubilized in the mid gut epithelium and activated by enzymes. Finally, the toxins get bind with epithelial cells, and takes at the stage of death. The whole mechanism on the mode of action of bacterial toxin is narrated as (i) bacterial binary toxins with spores engulfed into the alimentary canal, (ii) dissolving of binary toxin in the significant seat of digestion, *i.e.,* the mid gut, (iii) inactivated protoxin gets activated by the gut enzyme, namely proteases, thereby, the Bin-B and Bin-A (51 and 42 kDa) toxins are activated and cleaved into 43 and 39 kDa proteins (iv) the activated cleaved toxins starts binding to the seat of receptors present on the midgut epithelial cells containing the brush border membrane (MBBM). However, except for some reports on cyto pathological action caused by the toxins, the activity of binary toxin in cells has not been apparent. Significantly, molecular mode of action of binary toxins of *B. sphaericus* in the mid gut of *Cx. quinquefasciatus* was investigated using air-dried mosquito samples, which were easier to preserve and transport from the field to the laboratory (Poopathi et al., 2002).

Resistance to *B. sphaericus:* Previously, it was thought that using a microbial larvicide derived from *B. sphaericus* would not result in mosquito resistance. Nonetheless, previous three-decade studies have shown that the binary toxins from *B. sphaericus* are also complicated in this problem of resistance. The larvae developed resistance to the binary toxin of *B. sphaericus* under continuous application of selection pressure in the laboratory. It has been proved that both in the laboratory and the field experiments, the larvae of *Culex quinquefasciatus* developed resistance to Bin toxin (*B. sphaericus*) as described by (Poopathi et al., 1999). Cross-resistance is also inevitable to some bacterial strains. For example, the laboratory-reared *Culex* larvae already developed resistance to *B. sphaericus.* Resistance inherited to the most potential strain of *B. sphaericus* proved cross-resistance comparatively to other bacterial strains of the similar species of toxin synthesizing organisms, according to laboratory strains. (Nielsen-LeRoux, et al., 2001). As a result, resistance to *B. sphaericus* Bin toxin affects the continuation of already planned vector control programs using this *Bs* strain. Studies on resistance to *Bacillus sphaericus* binary toxins have been undertaken by researchers. It involves modification of receptor, which results in toxin binding affinity changes (Nielsen-LeRoux et al., 1995). As a result, a thorough understanding of the various genetic factors leading to insect resistance to *Bacillus sphaericus* will be helpful in planning strategies for management of resistance. The recent reports confirm an increase in mosquito resistance to these biocontrol agents. Hence, it is essential and indispensable to find newer alternatives to the existing, target-specific ones with high efficacy.

Genetic diversity

It has been noted that only little effort has been put into isolating genetically diverse bacteria, which show a high level of toxicity against insect vectors to be used for mosquito control (Poopathi et al., 2013). There is always a demand for more promising and potential bacterial strains in the production of biological pesticides. In the development of a formulation for medical and agricultural applications, genetically heterogeneous groups of strains can be utilized. The lack of attention paid to the genetically diverse microbes for biological control approach has been considered in recent years.

It is essential to know the spatiotemporal distribution and population dynamics of *Aedes* vectors for the prevention of dengue, especially while planning for dengue control programs. For long-term vector surveillance, an ovitrap surveillance system is an alternative tool. Ovitrap is a user-friendly and effective tool for monitoring dengue vectors and is applied in various countries like Singapore, Australia, Indonesia (Sasmita et al., 2021). A lethal oviposition trap was used to attract gravid female mosquitoes, subsequently laying eggs. Eventually, mosquitoes twig on the substratum. Many such ovitraps have been reported earlier, such as autocidal gravid ovitrap (AGO), sticky trap (ST), double sticky trap (DST) and gravid *Aedes* trap (GAT), Attractive baited lethal ovitrap (ALOT) (Facchinelli et al., 2007; Chadee et al., 2010; Mackay et al., 2013; Eiras et al., 2014; Paz-Soldan et al., 2016).

CONCLUSIONS

Mosquito control is the most important public health objective as mosquitoes transmit many human diseases meticulously, viz., filariasis, malaria, dengue, yellow fever, West Nile, Japanese encephalitis, and Chikungunya. These diseases pose a major problem in disease-prevalent countries and are presently on the rise owing to amplified globalization, urbanization, and global warming. On the whole, the successful method of reducing the occurrence of these human infections is through the control of disease transmitting vector mosquitoes, principally by the application of bio-pesticides to their breeding sites. *Bacillus sphaericus (Bs)*, *Bacillus thuringiensis* var. *israelensis* (*Bti*) are known mosquitocidal bacteria which produce endotoxins for mosquitocidal activity. Regrettably, the development of high and low level of resistance to *Bs* and *Bti*, respectively in several countries has impeded the progress of its application in mosquito control. Under these circumstances, new bacterial isolates have been successfully achieved recently and recommended the future researchers to identify further more suitable methods in vector control program.

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MUSCIDAE (DIPTERA)- A HISTORICAL PERSPECTIVE

Pravas Hazari, Shuvra Kanti Sinha*, Nandan Jana, Amita Hajra[1] and Santanu Mahato[2]

Calyptrate Research Laboratory, Department of Zoology, Sree Gopal Banerjee College, Hooghly 712148, West Bengal, India
[1]Department of Zoology, Government General Degree College, Kharagpur II 721149, West Bengal, India
[2]Biopsychology Laboratory and Institution of Excellence, University of Mysore, Mysuru 570006, Karnataka, India
*Email: suvrosinha@gmail.com (corresponding author)

ABSTRACT

In India, the history of biological research on muscid flies has never been thoroughly reviewed. There is no useful documentation of their recent and past taxonomic, medical, veterinary, and forensic research trends, as well as natural history and ecology studies. In the 75 years since independence, efforts have mostly focused on faunistic surveys. However, new study avenues have emerged in agricultural, medical, and forensic fields, as well as other areas such as molecular, ecological, and microbial research. In order to develop a state-wise perspective, we reviewed all the available old and recent studies on family Muscidae (Diptera) throughout the country and suggested areas for future research.

Key words: Muscidae, Diptera, faunistic survey, agricultural importance, medical importance, forensic importance, molecular taxonomy, ecological study, microbial study, India

At various points throughout history, different taxonomists around the world have proposed various classificatory schemes for the Muscidae family. Linnaeus (1758) described 11 species of Musca and Conops. Those 11 specimens are now placed in the families Fannidae, Anthomyiidae, and Muscidae (Pont, 1981). Brunetti (1917) described many Muscinae and Anthomyinae as new records from India, when Anthomyiinae were treated as one of the subfamilies of the family Muscidae. Townsend (1917) synonymized the family Calliphoridae with the family Muscidae. He divided the family Muscidae into two subfamilies, viz., Muscidae and Rhiniinae. Zimin (1951) classified the family Muscidae into two tribes, namely Muscini and Stomoxydini. In the early phases of the nineteenth century, Anthomyiinae were regarded as one of the subfamilies of Muscidae. Hennig (1955), on the basis of anal vein reaching the wing margin and the presence of fine cilia on the ventral surface of the scutellum, separated Subfamily Anthomyiinae as a different family, as Anthomyiidae from the family Muscidae. He also proposed a classification describing the family Muscidae into five subfamilies: Eginiinae, Fanniinae, Mydaeinae, Phaoniinae, and Muscinae. Emden (1965) divided the family Muscidae into seven subfamilies, viz., Muscinae, stomoxydinae, Phaoninae, Coenosiinae, Lispinae, Faniinae, and Anthomyiinae. Fonseca (1968) excluded Anthomyiinae from the earlier described classification and presented six subfamilies. Shinonaga and Kano (1971) divided the family Muscidae into seven subfamilies: Muscinae, Stomoxydinae, Phaoniinae, Coenosiinae, Lispinae, Faniinae, and Egniinae. In continuation of the previous classification, Pont (1980) divided the family Muscidae into six subfamilies, viz., Atherigoninae, Muscinae, Azeliinae, Phaoninae, Mydaeinae, and Coenosiinae. Later, Shinonaga and Singh (1994) divided the family Muscidae of Nepal into five subfamilies: Stomoxyinae, Phaoninae, Muscinae, Coenosiinae, and Mydaeinae. They included Atherigona as a genus in subfamily Phaoninae, also mentioned Stomoxyinae as a subfamily, and included Azellia as a genus under subfamily Muscinae. The two classificatory schemes given by Pont and Shinonaga and Singh were mostly followed by Indian taxonomists. The Muscidae family contains over 5000 described species spread across 170 genera (Kutty et al., 2008). Presently, there are 263 species in 35 genera of the family Muscidae in India (Bharti, 2008). Research on Muscidae is quite scanty in India except for a comprehensive work by Emden.

Muscidae research in India

A few faunistic surveys were carried out by various researchers in India. Only a few regions of the country were covered by the above-mentioned researchers, and most parts of India are still uncovered by muscid fly

researchers. There is still no taxonomic work regarding the family Muscidae in a few states of India. Therefore, the muscid fauna of the states of India has not been properly presented yet. Muscid flies are very important in agriculture as only a few species act as pests to many crops and vegetables. *Atherigona soccata* is one of the main pests on sorghum, tomato, rice, wheat, etc. There are many studies regarding the management of *A. soccata* as it is known to cause dead heart in a number of tropical grass species (Deeming, 1971; Pont, 1972). Sorghum shoot fly causes an average loss of 50% in India (Jotwani, 1983). *Atherigona* (*Acritochaeta*) *orientalis* Schiner often plays a role as a primary pest of a few agricultural crops (Hibbard et al., 2012). In India, *A. orientalis* infests maize (Panwar and Sarup, 1985), wheat (Singh, 1975), sorghum (Ramachandra, 1923), melon (Chughati et al., 1985) and soyabean (Singh and Chibber, 1972). In India, there are several works on the subject of shoot flies. Research on the medical importance of muscid flies was carried out by a few scientists in India. Dogra et al. (2009) worked on oral myiasis caused by *Musca domestica* larvae in a child. Bhagat (2016) worked on the biodiversity of dipterous flies (Insecta) of Myiasis regarding its importance to animals and humans in Jammu & Kashmir and the Ladakh Himalayas. A few studies were also carried out on the forensic importance of muscid flies, and a few molecular studies were also carried out by some workers.

Research on the family Muscidae was started years before independence in India. Fabricius (1794) mentioned eleven calyptrate species under the genus Musca, collected from India. Brunetti (1907) described Limnophora and Anthomyia in India for the first time. Sixteen species belonging to the group Stomoxinae were reported and described by him (1910–1922) from India for the first time. Also, Brunetti (1913) identified many calyptrate specimens of the families Tachininae, Muscinae, and Anthomyinae from the collection of the Indian Museum in 1911–1912. Townsend (1917) synonymized the family Calliphoridae with the family Muscidae. He divided the family Muscidae into two subfamilies, viz., Muscidae and Rhiniinae. Distributional records of Indian Calyptrate Muscoids, comprising 16 species under five genera in Muscinae, were published by Senior-White in 1930. Meanwhile, the first journal of the Entomological Society of India, 'The Indian Journal of Entomology', was published in 1939 under the chief editorship of Hem Singh Pruthi. A comprehensivestudy was started in independent India by workers like Von Emden, Satoshi Shinonaga, J.C. Reddy, K.V. Reddy, B.C. Nandi, and a few others who worked on the family Muscidae in the last century. Emden (1965) worked on Muscidae in India. A book, "Diptera Vol7: Muscidae Part I" by Von Emden, was published by the Zoological Survey of India, Kolkata, regarding the fauna of the family Muscidae in India. In his work, the author described the family Muscidae divided into seven subfamilies, namely Muscinae, Stomoxydinae, Phaoninae, Coenosiinae, Lispinae, Faniinae, and Anthomyiinae, providing keys to identify Diptera, Calyptera, and the subfamilies mentioned above. This particular publication dealt with three subfamilies, including Muscinae, Stomoxydinae, and Phaoninae. The author describes the external morphology of the species and also provides a comparative account of early stages such as larva, pupa, and egg. A key to each genus of subfamilies and the species under each genus is given in this publication. A total of 63 species of subfamily Muscinae, 12 species of subfamily Stomoxidinae, and 219 species of subfamily Phaoninae are dealt with in this volume. This was the first major work on the family Muscidae in independent India. Shinonaga (1970) worked on muscid flies of India and recorded *Orthelia fletcheri* from India. Recently, following taxonomists like B.C. Nandi, Bulganin Mitra, Devinder Shing, G.P. Gupta, K. Chandra, K.C. Verma, M. Mendki, Meenakshi Bharti, P. Parui, R. Achint, R.R. Tewari, S. Halder, S. Roy, S. Prakash, S.C. Majumder, S.K. Sinha, and V. Veer have been working on the family of Muscidae in India.

State-wise progress

In Andhra Pradesh, researchers concentrated mostly on shoot flies. Reddy and Davies (1981) recorded fly species of *Atherigona* from graminaceous species, including Sorghum. Three new species of *Atherigona* have been found. Singh et al. (2002) investigated the natural enemies of the sorghum shoot fly (*Atherigona soccata* Rondani). The parasitoids, predators, and pathogens attacking different stages of *Atherigona soccata* Rondani are reported. Dhillon et al. (2006) worked on host plant resistance as an effective component for the management of *Atherigona soccata* Rondani, developing a sorghum hybrid to increase the productivity of the crop. Resistance to *Atherigona soccata* Rondani is influenced by a factor associated with cytoplasmic male sterility and the interaction between nuclear and cytoplasmic genes. Aruna et al. (2009) evaluated the genetic potential of shoot fly resistance sources in sorghum (*Sorghum bicolor* (L.) Moench). Using a completely randomised block design with three replications, 36 hybrids and 15 parental genotypes were raised. Utilization of the resistant lines belonging to different clusters in improving shoot

fly resistance in sorghum is discussed. Thakur et al. (2019) reported field screening of sorghum genotypes for resistance to shoot fly, *Atherigona soccata,* and stem borer*, Chilo partellus*. Different genotypes were screened but in the cases of SPH-1564 and SPH-1571, there were no infestations of dead hearts but there was strong resistance to shoot flies.

From Arunachal Pradesh faunistic surveys were conducted by many taxonomists, Joseph and Parui, Dutta and Chakraborti, Mitra in this state. The muscid diversity of Arunachal Pradesh is quite significant. Joseph and Parui (1977) surveyed Diptera of the Tirap division. Six species of flies belonging to three genera were recorded by them, with four species under the genus *Musca* and one each of *Orthellia* and *Stomoxys*. Dutta and Chakraborti (1985) investigated faunal composition in Arunachal Pradesh. Four species under three genera, viz., *Musca* (*Viviparomusca*) *bezzii* Patton and Cragg*, Musca* (*Viviparomusea*) *convexifrons* Thomson, *Orthellia coerulea* (Wiedemann), and *Atherigona sp.,* were recorded. Mitra (2006) reported 32 species belonging to 11 genera under four subfamilies. Six species from this state of India were recorded for the first time. A short survey was carried out in Assam. Borah et al. (2015) investigated the diversity of dipteran insects in the Jorhat district of Assam. *Musca domestica* L. was reported, as well as other dipteran families.

There are only a few studies on Muscid flies in Bihar. Vishwakarma et al. (2017) worked on the foraging activity of insect pollinators and their impact on the yield of rapeseed mustard. One species of the family Muscidae (*Musca domestica* L.) was reported as a visitor to Rapeseed-Mustard in the flowering season. From Chhattisgarh, Halder et al. (2015) worked on Muscid fauna diversity, zoogeography, and bio-geographical analysis in this state. Their study provided 34 housefly species, of which subfamily Muscinae shares 17 species, Coenosiinae shares five species, Atherigoninae shares five, Phaoninae shares four, and Mydainae shares three. Halder et al. (2019) conducted a faunistic survey in Achanakmar Wildlife Sanctuary in this state. They reported nine species under six genera in three subfamilies. From Gujarat, Lahiri and Mitra (2004) worked on Diptera diversity, mentioning two species, viz., *Musca domestica* L. and *Atherigona* (*Atherigona*), *approximate* under two genera, were reported. *Atherigona* was placed in the subfamily Phaoninae by the authors. A key to species, genera, and subfamily levels was provided.

A faunistic survey was carried out in Himachal Pradesh by Mitra et al. (2015) and Sengupta et al. (2019). Mitra et al. (2015) worked on diversity and endemism. 43 Muscid fly species were reported from there, of which three species, namely *Limnophora perkensis* Malloch 1929, *Phaonia curviseta* Emden 1965, and *Phaonia simulans* Malloch 1931, were endemic to Himachal Pradesh. Sengupta et al. (2019) worked on a taxonomic account of dipteran flies from the Renuka Wetland and adjacent sanctuary. Four Muscidae species [*Musca* (*Musca*) *domestica* L.,1758; *Neomyia timorensis* Robineau-Desvoidy, 1830; *Stomoxys calcitrans* (L., 1758); *Gymnodia tonitrui* (Wiedemann, 1824)] from two subfamilies were reported. Besides the faunistic survey, Dogra and Mahajan (2009) worked on oral myiasis caused by *Musca domestica* larva in a child. Two cases of oral myiasis due to *Musca domestica* larva were reported in their study.

No survey was done in Jharkhand until Sinha (2014) focused on calyptrate flies of Jharkhand. Seven species of Family Muscidae including (*Musca* (*Byomya*) *ventrosa* Wiedemann, 1830, *Musca* (*Byomya*) *conducens* Walker, 1859*, Musca (Eusca) hervei* Villeneuve, 1922, *Orthellia timorensis* (Robineau-Desvoidy, 1830)*, Ophyra leucostoma* (Wiedemann, 1817), *Gymnodia tonitrui* (Wiedemann, 1824), *Stomoxys calcitrans* (L., 1758) under five genera and three subfamilies were reported for the first time from Jharkhand. Key to the subfamily, Genus and Species was provided. Joseph and Parui (1977) worked on Diptera diversity of Chota Nagpur. Eleven species under four Genera were reported. *Musca* (*Byomyia*) *lucens* (Villeneuve) was reported for the first time from India. No faunistic survey has been carried out in Jammu & Kashmir. Bhagat (2016) worked on the biodiversity of dipterous flies of Myiasis, causing importance to animals and humans in Jammu & Kashmir, and the Ladakh Himalayas. *Musca domestica* L., *Musca* (*Musca*) *domestica nebula* (F.), *Musca* (*Musca*) *vicinia* Macquart, *Muscina stabulans* (Fallen), and *Stomoxys calcitrans* (L.) were known to cause myiasis in Jammu & Kashmir and the Ladakh Himalayan region.

There are no faunistic surveys of muscid flies in Karnataka. Belamkar and Jadesh (2014) carried out a preliminary study on the abundance and diversity of insect fauna in Gulbarga District, Karnataka, India. One species of the family Muscidae was ported. Diversity indices for insect orders are also presented. Hosamani et al. (2016) worked on pollinator diversity, abundance, and their stay times in the onion, *Allium cepa* L. *Musca domestica was* reported as one of the

pollinators. Bawer et al. (2014) worked on biocontrol of *Haematobia irritans* with entomopathogenic fungi (*Beauveria bassiana* and *Metarhizium anisopliae*). A high concentration of (1X108 conidia/ml) *B. bassiana* and *M. anisopliae* showed mortality at different levels against eggs, larva, pupa, and adults of *Haematobia irritans*. Some molecular work on muscid flies has been carried out in Karnataka. Archana et al. (2016) presented DNA barcoding of flies commonly prevalent in poultry farms in Bengaluru district. Cytochrome oxidase I (COI) barcoding sequences were used to discover cryptic, closely related, and morphologically similar species. The barcoding of the COI gene of *Musca domestica, Chrysomya megacephala, Hydrotaea capensis, Hermetia illucens, and Sarcophaga ruficornis was* mentioned in their work. Using DNA barcoding based on the COX1 gene, Ojha et al. (2016) attempted to identify flies from the Salt Lake of the Great Rann of Kutch. Three species were identified as a result of this study (*Musca autumnalis, Atherigona varia, and Lispe orientalis*).

Very little work has been done in Kerala except by Joseph and Parui (1986), who worked on Diptera from the Silent Valley in Kerala. In their study, three species, viz., *Musca* (*Viviparomusca*) *bezzi* Patton and Cragg, *Orthellia claripennis* Malloch, and *Orthellia timorensis* (Robineau-Desvoidy) were reported. Some faunistic surveys on muscid flies were carried out in Maharashtra. Bharamal (2016) conducted a survey on the order Diptera in the Sindhugarg district of Maharastra and reported *Musca domestica* and *M. nebulo* of the family Muscidae from there. Sathe et al. (2013) worked on the diversity of dipterous forensic insects from western Maharashtra. Three flies of the family Muscidae (*M. domestica*, *M. nebulo*, and *Fannia scalaris*) were reported as forensically important throughout the year. Kale et al. (2007) worked on flowering phenology and pollination in *Cajanus cajan* L. and *M. domestica* (House fly) and reported it as one of the flower visitors. Their observations indicated that house flies spent two to four seconds during their visit to the flower. A microbial study on muscid flies was also carried out in this state. Gupta et al. (2012) worked on bacteria associated with the gut of house flies. A total of 22 genera of bacteria were found. The majority of genera reported from house fly guts included *Klebsiella*, *Aeromonas*, *Shigella*, *Morganella*, and *Staphylococcus*.

There was no study regarding muscid flies from Manipur except by Mitra (2004), who studied the diversity of the family Muscidae. Ten species belonging to five genera under four subfamilies were reported from Manipur for the first time. The author provided a key to the species, genus, and subfamily level for identification of the species. A diversity of muscid flies in Mizoram was presented in 2007. Mitra (2007) worked throughout the state. Eight species belonging to seven genera were reported. That was the first ever diversity study from Mizoram. All the species were reported for the first time from Mizoram. Mitra (2006) carried out a faunistic survey on muscid flies in Nagaland and studied the diversity of the family Muscidae. For the first time, six species belonging to three genera were reported from Nagaland. Parui and Dutta (1987) worked on the family Muscidae in Odisha. *Orthelia coerolea* (Wiedemann) and *Atherigona* (*Atherigona*) *pulla* (Wiedemann) were discovered in Timadehi, Sundargarh district, Sambalpur district, and Mayurbhanj district.

From Pondicherry, Srinivasan et al. (2003) studied the effectiveness of insect parasitoids and insect growth regulators against the house fly (*Musca domestica*). Their study concluded that the combined use of parasitoid and IGR was effective in reducing puparia and fly density. The diversity of muscid flies in Punjab is still unknown. There was no study on the diversity of muscid flies in Punjab except a survey by Parui et al. (2006) who worked on the diptera fauna of Punjab and the Himachal Shiwalik Hills. Two species under two genera and two subfamilies [*Orthellia timorensis* (Robineau-Desvoidy), *Stomoxys calcitrans* (L.)] were reported. A key to the subfamily, genus, and species is also provided by them. Molecular work on muscid flies was carried out by Malviya et al. (2011, 2012, and 2015), and Singh and Achint (2017). Malviya et al. (2012) conducted a study on genetic relatedness among different muscid fly species. During their study, they used the RAPD-PCR technique to show the genetic relatedness among muscid fly species. Singh and Achint (2017) studied the molecular identification of muscid flies. On the basis of the mitochondrial COII gene, five flies of the family Muscidae were identified. The identified flies were *Musca domestica*, *M. sorbens*, *M. crassirostris*, *Haematobia irritans*, and *Stomoxys calcitrans*. Besides this, the work on the forensic importance of muscid flies was also carried out in Punjab. Bharti and Singh (2003) focused on insect faunal succession on decaying rabbit carcasses. Ten species of family Muscidae: *Musca domestica nebulo* (F. 1784); *M. ventrosa* (Wiedemann 1830); *M. sorbens* (Wiedemann 1830); *M. pattoni* (Austen 1910); *Hydrotaea capensis* (Wiedemann 1818); *H. chalogaster* (Wiedemann 1818); *H. occulta* (Meigen 1825); *Atherigona orientalis* (Malloch 1928);

Atherigona sp. nr. orientalis (Malloch 1928); *A. savia* (Pont and Magpayo 1996) were reported. All the species were reported from the decaying rabbit carcasses. Bharti (2009) also investigated the life cycles of forensically important flies. The life cycle of *M. domestica nebula* F., 1784 at different temperatures was studied. Kaur et al. (2018) studied insect faunal succession on pork carrion in Punjab. Three species of the family Muscidae (*M. domestica, M. autumnalis, and M. sorbens*) were recorded in all stages (fresh stage, bloated stage, advanced decay stage, and decay stage).

Taxonomic research on the family Muscidae is very scanty in Rajasthan. Mitra et al. (2005) conducted a study on the diversity of muscid flies in the Thar Desert. Nine species (under three genera and three subfamilies) were collected from the Thar Desert. Prakash et al. (2005) worked on the diversity of Diptera from the Thar Desert and reported two flies (*Stomoxys calcitrans* L., *Musca crassirostris* Stein.) of the family Muscidae. Besides this, some work on the agricultural importance of muscid flies was carried out in Rajasthan. Joshi et al. (2016) worked on the management of the sorghum shoot fly, *Atherigona soccata* Rondani (Diptera: Muscidae) through botanicals. An effect of different botanicals (neem oil, karanj oil, and Nirgundi oil) on *Atherigona soccata* (Rondani) was reported. Srivastava and Bhardwaj (2012) conducted a study on insect visitors to certain cucurbit vegetable crops in an agroecosystem near Bikaner, Rajasthan. *Musca domestica* were found in large numbers on Lagenaria flowers in October. Research on muscid flies is very scanty in Sikkim. Mitra (2003) worked on the diversity of the family Muscidae in Sikkim, India. In the state fauna series, Fauna of Sikkim, part III, the author reports 22 species belonging to 11 genera under six subfamilies, with two species from Sikkim for the first time. Till 2000, there were no species of the family Muscidae reported from Tripura. In 1991 and 1992, ZSI undertook a few surveys in Tripura. Mitra (2000) reported six species under three genera in two subfamilies from Tripura in 2000. The distribution of each species in India and around the world has also been added.

From Uttar Pradesh, except for Tewari et al. (2012), who worked on temporal variation among the population of house fly (*Musca domestica*), no detailed faunistic survey has taken place. Mitra (2011) published a report on muscid flies from Uttarakhand. There were 22 species of muscid fly belonging to 10 genera and three tribes under four subfamilies reported. Six species under two genera were recorded for the first time in Uttarakhand. More faunistic surveys, bionomics, and life cycles of muscid flies were studied by various taxonomists in West Bengal in comparison to other parts of India. Sundarbans Biosphere Reserve (hereinafter, SBR) of West Bengal is rich in diverse flora and fauna. A great diversity of muscid flies was observed here in the Sundarbans. Sinha (2009) investigated the systematics and bionomics of Sarcophagid, Calliphorid and Muscid flies of SBR. A total of 13 species under six genera and two subfamilies were reported. Nandi and Sinha (2004) worked on muscid flies of SBR. 16 species of muscid flies under seven genera were included from there. The bionomics and distributional records of that species are also presented from SBR. The impact of that species on human beings and other animals was also discussed. A new species of *Musca* (*Byomya*) *emdeni* was described and illustrated. Sinha and Mondal (2013) worked on the life history of *Musca* (*Byomya*) *emdeni* Sinha-Nandi, the dung-breeding flies from SBR in 2013. In that particular study, they described three larval instars of that fly in detail. Sinha and Nandi (2005) studied the life history of the dung-breeding muscoid fly, *Neomyia indica* (R-D) (Diptera, Muscidae) from SBR. Mitra et al. (2016) conducted a faunistic survey in SBR. They reported 13 orders of insects from the Sundarbans. The Muscidae family accounted for 17% of all Diptera species.

Dutta et al. (1997) worked on the diversity of order Diptera in West Bengal. In the state fauna series of West Bengal, six species from three genera were reported. Majumder and Parui (2001) recorded four species of *Musca,* one of *Lispe* and two *Stomoxys* from SBR, along with a key to the collected specimens. Mitra and Parui (2012) reported four species of the family Muscidae, namely *Musca* (*Musca*) *domestica* L., *Orthellia indica* (*Robineau-Desvoidy*), *Orthellia lauta* (Wiedemann), and *Stomoxys calcitrans* (L.) from the Bibhutibhusan Wildlife Sanctuary situated in the district of North 24-Parganas, West Bengal, India. Mitra et al. (2016) conducted a survey in 12 different fish markets in North, South, and Central Kolkata and reported six species of the family Muscidae along with a few Calliphoridae and Sarcophagidae. Three Musca species (*Musca* conducens Walker, 1859; *Musca sorbens* Wiedemann, 1830; *Musca domestica* L., 1758; *Neomyia* indica Robeneu-Desvoidy, 1830; *Neomyia lauta* Wiedemann, 1830) were reported. Mitra et al. (2016) worked on the insect faunal diversity of Salt Lake City, Kolkata, India. Six species of family Muscidae [*Atherigona* (*Atherigona*) *simplex* (Thomson, 1869), *Musca domestica* L., 1758, *Musca ventrosa* Wiedemann, 1830, *Neomyia lauta* (Wiedemann, 1830), *Neomyia*

timorensis (Robineau-Desvoidy, 1830), *Neomyia indica* (Robineau-Desvoidy, 1830)] were reported. Gayen et al. (2019) worked on true flies (Diptera: Insecta) diversity in the recently urbanised areas (Saltlake and Newtown) of West Bengal, India. Nine Species of family Muscidae [*Atherigona* (*Atherigona*) simplex (Thomson, 1869), *Musca domestica* L. 1758, *Musca ventrosa* Wiedemann 1830, Musca (Byomya) sorbens (Wiedemann), *Musca* (Byomya) *pattoni* (Austen) *Morellia hortensia* (Wiedemann), *Orthelia timorensis* (Robineau-Desvoidy), *Orthelia indica* (Robineau-Desvoidy), *Orthelia lauta* (Wiedemann)] were reported. Sinha et al. (2021) worked on the diversity of muscid flies in Neora Valley National Park. They reported 31 species of muscid flies under 13 genera in three subfamilies. They reported *Limnophora* (Heliographa) *ceylanica* (Emden, 1965) and *Neomyia pacifica* (Zimin, 1951) from West Bengal as well as from India for the first time.

Besides the faunistic survey, a little work on the medical importance, agricultural importance, and forensic importance of Muscid flies was carried out in West Bengal (Sinha et al., 2003; Mitra et al., 2005; Mitra, 2010; Das et al., 2015; Bhadra et al., 2015; Mitra et al., 2017; Parui et al., 2017). Sinha et al. (2003) worked on the presence of bacteria on the body surface of *Musca domestica vicina* Macquart. A total of six types of bacteria (*E. coli, Klebsiella* sp., *Salmonella* sp., *Pseudomonas* sp., *Shigella* sp., *Proteus* sp.) were reported. Mitra et al. (2005) worked on flower visitors and pollinators (Diptera, Insecta) of Kolkata. Three species of the family Muscidae (*Musca domestica, Musca ventrosa,* and *Orthellia timorensis*) were reported along with the plant visited. Mitra et al. (2010) worked on the diversity of flower-visiting flies (Insecta: Diptera) in India and their role in pollination. Altogether, 19 species of house flies are reported as flower visitors or pollinators from India. Das et al. (2015) worked on forensically important dipteran species from West Bengal. *Musca* (*Byomya*) *sorbens* Wiedemann was reported as one of the forensically important species of the family Muscidae. Bhadra et al. (2015) worked on insect pollinators and their role in crop yield and quality of sunflower (*Helianthus annuus*, PAC-361) from West Bengal. One species of the family Muscidae (*Musca indica*) *was* recorded as one of the pollinators. Mitra et al. (2017) worked on true flies (Insecta: Diptera) and their association with tea plants in the Dooars, West Bengal, India. *Musca domestica* L., 1758 and *Neomyia indica* (Robineau Desvoidy, 1830) have been found visiting the flower throughout the day. In 2017, Parui et al. (2017) showed variation in colonisation and succession patterns of Dipteran flies of forensic importance on Indian Mole Rat carcasses in the Sundarban. Six species of Family Muscidae [*Musca domestica* (L., 1758), *Musca sorbens* (Wiedemann, 1830), *Ophyra capensis* (Wiedemann, 1818), *Hydrotaea chalcogaster* (Wiedemann, 1824), *Synthesiomyia nudiseta* (Wulp, 1883), *Atherigona orientalis* (Schiner, 1868)] at different stages of decomposition.

CONCLUSIONS

In India, there were very few studies on the Muscidae family. Most of the researchers from independent India contributed to a faunistic survey in different states. In recent years, very little effort has been made in describing new species of muscidae. After a comprehensive work by Von Emden (1965), no precise taxonomic work has been done here in India. A precise taxonomic study on the family Muscidae is very much needed as well, because the amount of taxonomic work done here in India is not up to the mark. Until today, small-sized muscid flies were not described. Molecular taxonomy may reveal a new horizon in the identification of Muscidae because the identification of many small-sized mucid flies is very difficult on the basis of morphological characters. Unfortunately, the amount of molecular taxonomy in the family Muscidae is very low here in India. This is the huge field to be nourished here in India. Most of the studies related to the family Muscidae in terms of faunistic surveys, though these works did not cover most of the places in various states of India (Fig. 1). So the actual picture of the diversity of muscid flies in different states of

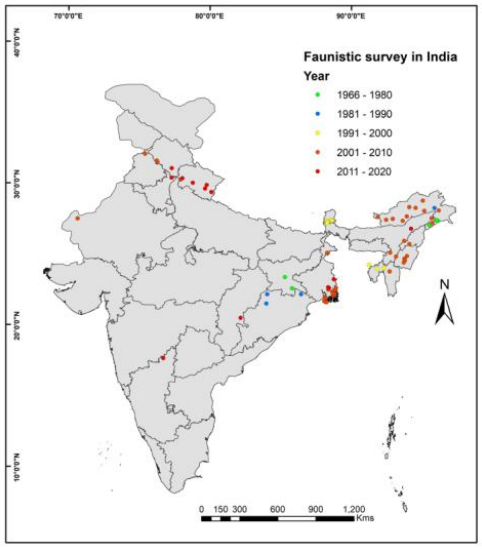

Fig. 1. Faunistic surveys (1966-2020)

India is not up to date. Besides the faunistic survey, only a few studies on agricultural importance, medical importance, forensic importance, molecular taxonomy, and ecological and microbial studies have been done on the family Muscidae. The life cycle of many species is still unknown, which needs more attention. Work on larval study and larval taxonomy is very much needed as this is very important in the cases of forensic, agriculture, medical, as well as ecological aspects. In Table 1, the number of species described from different states of India after 1965 is presented.

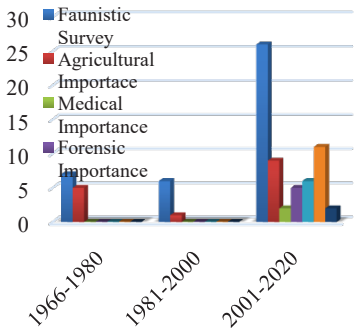

Fig. 2. Subject-wise work on Muscidae (1966-2020)

On the basis of the discussion, it can be concluded that there is an inadequate number of taxonomic works on the family Muscidae in different states of India. Scientists carried out mainly faunistic surveys in different states of India. Besides the faunistic survey, a few studies on agricultural importance, medical importance, forensic importance, molecular taxonomy, ecological studies, and microbial studies were conducted in Independent India (Fig. 2). From 1960-1980, the main focus of study on the family Muscidae was a faunistic survey and the agricultural importance of the family Muscidae. From 1980 to 2000, the same trend was followed in India. But in this century, many fields of study have emerged, especially in ecological, molecular, medical, and forensic studies (Fig. 2). Many projects on shooting flies have been completed in Andhra Pradesh, Arunachal Pradesh, and Rajasthan. Many states, like Bihar, Goa, Haryana, Karnataka, Meghalaya, Mizoram, and Telangana, have no comprehensive study on the family Muscidae. Having great importance in medical, veterinary, and agriculture, it is very important to know about the systematics and bionomics of Muscid fauna. As an agricultural pest, there should be more precise taxonomic work on shoot flies (*Atherigona sp*.), so new species of shoot flies having agricultural importance may be reported in the future. A few researchers also studied the myiasis and disease relationship of muscid flies. More studies should be done on stable flies as they have great veterinary importance. Muscidae as a potent pollinator is also very important. On the basis of the discussion, it can be concluded that only a few studies on muscid flies have been conducted. A lot of work on muscid flies regarding agricultural importance, medical importance, forensic studies, molecular taxonomy, ecological and microbial studies still has to be done in India. Therefore, more attention will be required in the coming years to this important but understudied field of study concerning the Muscidae.

Table 1. Muscidae- described species after 1965

No.	State	Period	Described species
1	Andhra Pradesh	1981, 2002, 2006, 2009, 2019	19
2	Arunachal Pradesh	1977, 1985, 2001	32
3	Assam	2015	1
4	Bihar	2017	1
5	Chhattisgarh	2015, 2019	37
6	Goa	No Survey	-
7	Gujarat	2004	2
8	Haryana	No Survey	-
9	Himachal Pradesh	2015, 2019	43
10	Jammu & Kashmir	2016	5
11	Jharkhand	1977, 2014	15
12	Karnataka	2007, 2014, 2016	4
13	Kerala	1986	3
14	Madhya Pradesh	No Survey	-
15	Maharashtra	2007, 2013, 2016	3
16	Manipur	2004	10
17	Meghalaya	No Survey	-
18	Mizoram	2007	8
19	Nagaland	2006	6
20	Odisha	1987	2
21	Punjab	2003, 2006, 2011, 2015, 2018	16
22	Rajasthan	2005, 2012, 2016	10
23	Sikkim	2003	22
24	Tamil Nadu	2006, 2009	3
25	Telangana	No Survey	-
26	Tripura	2000	6
27	Uttar Pradesh	2012	1
28	Uttarakhand	2011	22
29	West Bengal	1997, 2001, 2003, 2004, 2005, 2009, 2010, 2012, 2013, 2015, 2016, 2017, 2019, 2021	31* *Musca* (*Byomya*) *emdeni* Sinha and Nandi (2004)

*New species (1966- 2021)

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The Entomological Society of India

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