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Varroa destructor (Acari: Parasitiformes: Varroidae) a dangerous parasite of honey bees (Hymenoptera: Apidae)

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ABSTRACT: The honeybee is an essential element of environmental balance in the world, particularly for its role in the pollination of many plant species. It also has other interests such as the production of honey, propolis, royal jelly and wax. Among several diseases on honey bees, the most dangerous is varroosis and threaten different species of honeybee population. Varroosis is caused by an external parasitic mite, *Varroa destructor* which parasites both bees and brood. It causes enormous damage to the colony and is a gateway to other viral and bacterial diseases. Information on the influence of this disease on colonies, symptoms and pathogenic actions, reproduction, development cycle and treatment methods *viz* chemical, natural, biological and biotechnical against *Varroa* are discussed.

KEY WORDS: *Varroa destructor*, hematophagous mite, *Apis* spp., parasitosis, varroosis

INTRODUCTION

Honeybees, along with other wild pollinators, are essential to maintaining the diversity of plants and our food resources. However, for the past 20 years, the beekeeping sector has faced a general weakening of the colonies, leading to a sharp increase in bee mortality rates worldwide. The winter loss rate is 10%, which considered normal; it currently stands at 20% on average that adds losses during the seasons of around 10%. Among the causes of these mortalities, there is varroosis which is considered as the first risk factor, it is the main health hazard of honey bees (Adjlane *et al*., 2013, 2016; Van Der Zee *et al*., 2015; Thoms *et al*., 2016; Molineri *et al*., 2018; Adjlane and Haddad, 2017, 2018). According to Anderson and Trueman (2000) varroosis is a parasitosis of the adult bee and its brood, caused by an external parasitic hematophagous mite, *Varroa destructor* (Parasitiformes: Varroidae). *Varroa* has been responsible for an epidemic in *Apis mellifera* L. (Apidae) since it has been transferred from the Asian bee, *Apis cerana* (Colin, 1999). It is present in almost all countries around the world (Fig. 1).

The pathogenic role was ignored while the varrosis spread with extreme rapidity from 1964 all over the world, leaving no area unscathed to date and causing the death of colonies. The development of the transhumance of the colonies as well as the commercial exchanges allowed a contact between the two species of *A. cerana* and the European bee *A. mellifera* then the passage of the *Varroa*

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on the latter. This subsequently caused the spread of ectoparasitosis on all continents (Colin, 1999). Knowledge of the biology of the mite, population dynamics in a well-defined region and the race of bees are necessary for the programming of an integrated varroosis control strategy. This article elucidates on varroosis, its influence on the colony and the means of fighting the disease.

1. Systematics

The genus *Varroa* belongs to the subfamily Varroinae, family of Varroidae and the genus *Varroa* has four clearly identified species (De Guzman and Rinderer, 1999) (Fig. 2). The varroa mite was collected for the first time by entomologist Edward Jacobson from bees of the island of Java of the species *Apis cerana.* Oudemans, a Dutch acarologist first described it in 1904 and gave it the name of *Varroa jacobsoni* in homage to its discoverer. The existing host-parasite relationship between the bee *A. cerana* and the mite is currently in a state of equilibrium, so that *V. jacobsoni* does not presently constitute a threat for *A. cerana* (Donzé et al., 1998). The passage of *Varroa* from its original host *A. cerana* to its new host *A. mellifera* probably took place during the 1940s. The importation of colonies of *A. mellifera* bees into Asia where they were not present in the years 1930, gave the opportunity to pass on this freshly arrived host (Donzé and Guerin, 1994).

The first observation of *Varroa* in the brood of *A. mellifera* is thought to have occurred in Korea in the 1950s (Topolska, 2001). It was not until 1966 that the danger and potential damage to beekeeping caused by the spread of the parasite was officially reported. The distribution of *Varroa* in beehives has therefore become, according to international exchanges of bees (colonies, queens), gradually global. Anderson and Truemann (2000) separated the species mite originally known as *V. jacobsoni* into two distinct species. The name of the species which groups together the mites infesting the honeybee *Apis mellifera* is now *V. destructor*.

2. Adaptation of *Varroa* to *Apis mellifera*

Like all parasites, *Varroa destructor* has properties that allow it to adapt to its host. Morphologically, the flattened shape of the *Varroa* allows it to be applied to the body of the bee and to escape the movements of watering the latter. Its legs end in suction cups, its palms in claws allowing attachment.

- The varroa's life cycle follows to that of the bee (does not make sense), which allows it to reproduce and feed in the brood (Ritter, 1981), Compared to the original *A. cerana* host.

- The duration of the brooding of *A. mellifera* brood (12 days for workers and 15 days for males) is longer than that in *A.cerana* which gives more chance for immature (Donzé *et al*., 1998).

- The temperature regulation in *.A. mellifera* makes the brood more favorable than that of *.A. cerana.*

- The cleaning behavior in *A. mellifera* is not as frequent as in *A. cerana* (Naumann, 1991).

3. Biology of the mite

Varroa destructor has a remarkable sexual dimorphism (Martin, 2003). The male mite differs from the female by its small size, white color, globular body and legs stretched forward. It only exists in the alveoli at the time of reproduction, for this, its chelicerae are modified to inject spermatophores (Rosenkranz *et al.,* 2009).

The life cycle of *Varroa* is strictly linked to the bee. It has two phases: phoretic on the adult bee, and reproductive in the cells of the brooded brood of males and workers (Fries, 2005). The *Varroa*'s reproductive phase lasts from the seal to the emergence of the bee. The so-called founding varroa female enters a brood cell a few hours before sealing and immerses herself in the larval food (Ifantidis, 1988). After sealing, it perforates the integuments of the nymph creating a site of nourishment, stimulates its oogenesis and begins its laying. The first egg, haploid, will give a male; the other diploids will give females through the following stages: egg, larva, protonymph and deutonymph. Mating takes place in the socket, in the area of faecal accumulation. When the adult bee emerges, the founding female and the mature female exit

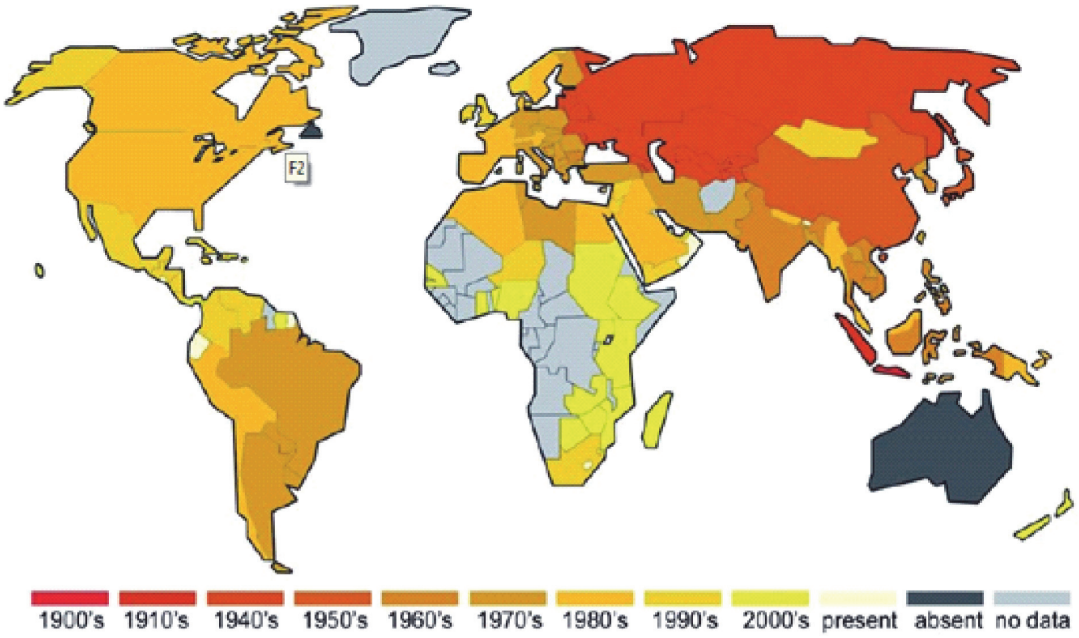

Fig. 1 Dispersal of *V. destructor* worldwide (Wilfert *et al*., 2016)

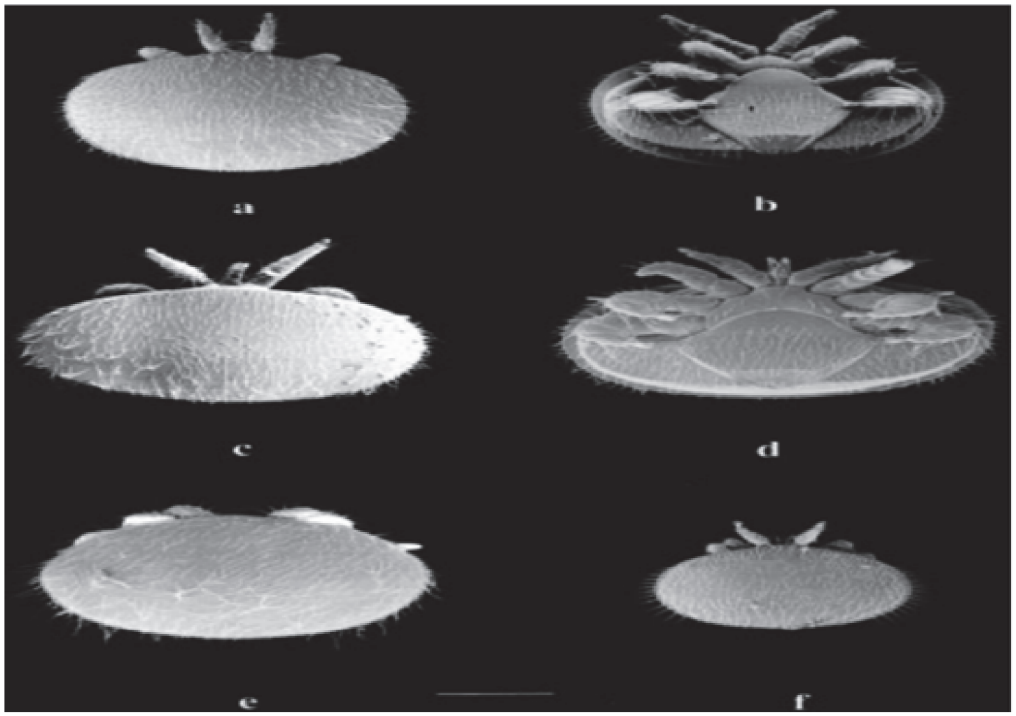

Fig. 2 Dorsal and ventral faces of adult females in electron microscopy of (a) and (b) *V. jacobsoni* (Java haplotype), (c) and (d) *V. destructor* (haplotype K), (e) *V. rindereri* and (f) *V. underwoodi.* The scale size is 500 ìm (Illustration from Anderson and Trueman, 2000)

Fig. 3 Parasitic mite *Varroa destructor* of the honey bee

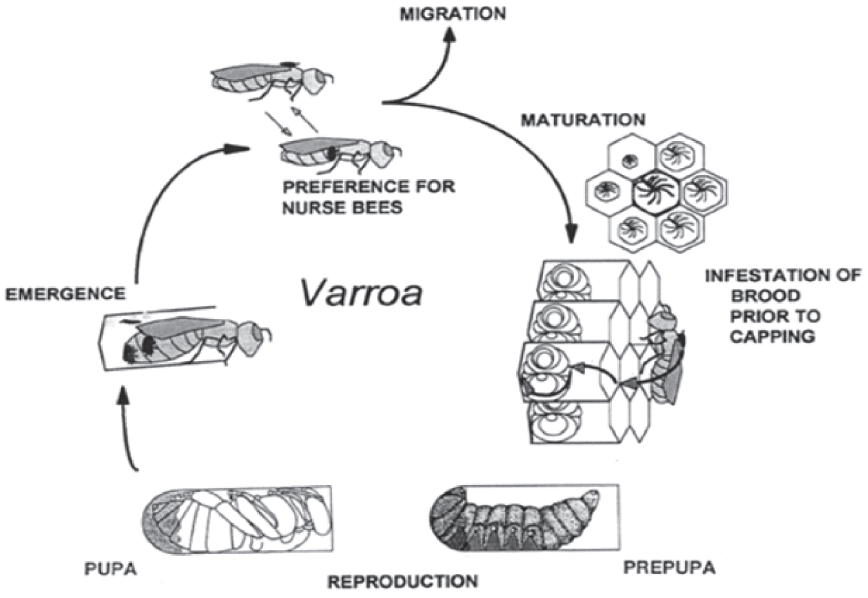

Fig. 4 *Varroa's* biological cycle (Donzé *et al*., 1996)

Fig. 5 Dead bees with deformed and atrophied wings

the socket while the male dies with the immature (Faucon, 2003). The phoresia phase corresponds to the period between the exit of the varroa from the cell and its entry into another cell (Martin, 2003). The duration of the life cycle is seven to eight days for females, and six to seven days for males. Females have four to five cycles in their life (De Vaublanc, 2004). The egg is white, ovoid and small in size (230 µm × 300 µm). Then the female varroa lays eggs approximately every 30 hours: between 26 and 32 hours at a temperature of 34-35° C. The female varroa generally lays five eggs, six rarely and seven exceptionally and has a laying potential of 18 to 30 eggs (Rosenkranz *et al*., 2009).The development time from egg to adult through the two larval stages (proto then deutonymphe) is between 5.8 and 6.6 days (Donzé and Guerin, 1994) (Fig. 4).

5 Factors influencing the entry of the female *Varroa* founder in the brood

Several authors have highlighted the influence of certain factors on the founder's entry into the brood.

Mechanical factors:

The size of the brood cells and the distance between the larva and the edge of the cell significantly influence the infestation (Calis *et al.,* 2006). As a result, the founder shows a clear preference for the brood of the male (Le Conte and Arnold, 1988).

Ethological factors:

In order to enter the brood, the founder must be only a few millimeters from the cell. To do this, the female prefers nurse bees, which are in contact with the brood (Krauss *et al*., 1986). On the other hand, the bumblebee brood cells are more attractive than those of workers (Calis *et al*., 2006).

Chemical factors:

Four fatty acid methyl esters (methyl palmitate, methyl oleate, methyl linoleate, and methyl linolenate) trigger the capping of the worker cells by the adult bees (Le Conte et al., 1989). These compounds are secreted by the worker larvae a few hours before the cell is closed and are present in great amounts on the larval surface during the capping period. They disappear during the following days (Trouiller *et al*., 1991)

Thermal factors:

The thermo-referendum of the varroa, which is between 31.3 and 34.2 °C, corresponds well to the temperature of the bee brood and to the temperature of the body of the workers (32.4 °C on the thorax and 31 °C on the abdomen). On the other hand, very high temperatures inhibit its reproduction (Le Conte *et al*., 1990).

6. Development of the *Varroa* population

The population-wide cycle of *Varroa* is dependent on that of the colony. During the summer period, the mite infestation increases in parallel with the bee brood. The number of parasites present in the colony at the start of the summer phase remains a determining parameter for the evolution of the infestation rate during the season. A study of 35 colonies suggests a 100-fold increase in the *Varroa* population over the course of summer (Garcia-Fernandez *et al*., 1995).

Martin (1997) proposed a mathematical model including multiple factors to describe the dynamics of *Varroa* population in bee colonies in a temperate region with a continental climate. These factors are: the total number of workers and brood (eggs, larvae and pupae) during the season, the total number of mites, the rate of *Varroa* invasion in brood cells, the proportion of *Varroa* having a viable reproduction, the density of the *Varroa* population and the mortality of *Varroa's*at emergence. This model predicts that approximately 65% of the mite population is found in the brood at all times (Martin, 1997).

7. Propagation factors

Varroasis has spread rapidly and inexorably from bee to bee, from beehive, and even from one apiary to another. This is due to several factors, either natural or beekeeping. Natural factors: varroasis can spread naturally by foraging drift, swarming and desertion, by looting and theft of males that change colonies. Beekeeping factors, in addition to

natural factors, the beekeeper's manipulations can contribute to the spread of the disease. These include transhumance, the concentration of colonies in the same region as well as commercial activities (trade in queens and swarms) (Faucon, 2003).

8. Pathological actions

The parasitism of *V. destructor* acts on adult bees and on the brood in three actions: spoiler, mechanical and vector.

Spoliatory action:

Varroa infestation is associated with a decrease in the total number of hemocytes in nurses, as well as for all life stages of drones (Salem *et al.*, 2006). At the gene expression level, infestation involves less expression of the gene encoding phenol oxidase and genes encoding antimicrobial peptides (Yang *et al*., 2005). Fat reduction has also been observed (Drescher and Schneider, 1987); all of these data suggest an overall decline in the immune competence of infested bees. Ramsey *et al*. (2019) have shown that *Varroa* does not consume hemolymph, as has been admitted, but damages the host bees by consuming the fatty substance, the drop in total protein fluctuates between 10 and 50% in parasitized nymphs (Dandeu *et al*., 1991).

Mechanical action:

The presence of the parasite in the adult bee alters its behavior to the detriment of its usual tasks (Faucon, 2003). The parasitism leads to malformations and weakness of the young worker. A heavy infestation causes the death of nymphs before the emergence and birth of mutilated bees (Boecking and Genersch, 2008). According to Schneider and Drescher (1987), the survival rate of adult bees beyond 25 days, under laboratory conditions, is around 50% if the bees are from healthy larvae, but it is reduced 25% if the larvae are contaminated with three varroa. In the internal organs, a reduction of 10% in the size of the acini of the hypopharyngeal glands is observed in born parasitized bees. De Jong *et al*. (1982) reported that 6% of the parasitized infant bees have a shortening of the abdomen and localized deformations, especially in the wings.

Vector action:

The role of the mite in the transmission and pathogenesis of certain viruses appears to be twofold. On the one hand, *Varroa*, through its role as a vector, injects the viruses which it carries directly into the hemolymph of the bee. On the other hand, an activating role through the bite of *Varroa* allows the activation of certain viruses, present in the latent state in the hemolymph of the bee (Tentcheva *et al*., 2004). The parasite is capable of transmitting a certain number of viruses: the acute paralysis virus (Acute Bee Paralysis Virus - ABPV), the Black Queen Cell Virus (BQCV), the wing virus Deformed Wings Virus (DWV), the Israel Acute Paralysis Virus (IAPV) or the Kashmeer Bee Virus (KBV) (De Miranda *et al*., 2013; Reyes-Quintana *et al*., 2019; Posada-Florez *et al*., 2019).

9. Symptoms

Varroasis clinical symptoms include brood and bee disorders (Charriere *et al*., 2011). One of the main signs of the disease is the presence of an irregular or lacunar brood with atrophied dead wings under the operculum. Symptoms in adult bees are mainly related to the presence of workers with deformed wings, trailing and dead bees (Fig. 5).

According to Faucon (2003), varroasis shows no sign of disease up to a critical level where the colony is difficult to recover. When the pressure of the parasite increases, the following symptoms appear at the level of adult bees: Trailing bees, walking in disorderly directions and dead bees, bees with deformed wings, sometimes black, spread apart, or asymmetrical and atrophied bees and nymphs. At the brood level, decrease in the laying of the queen, mosaic brood and nymphs alive but atrophied under the cover, or dead under the cover.

10. Screening

Varroa mite screening allows beekeepers to estimate the population of mites parasitizing a colony in order to apply the control strategy best suited to their situation. This is an essential step in pest control in beekeeping, which allows, in particular, to know the level of parasitism in a colony before

and after a treatment. Thus, precise monitoring and good knowledge of the levels of infestation in a beekeeping herd are the basis of an adequate integrated pest management strategy. Several methods are available and each one has a level of sensitivity (Dietemann *et al*., 2013; Calderone and Turcotie, 1998; Macedo *et al*., 2002).

Examination of the brood:

This method consists of removing mites, which are in the cells of the brooded brood (preferably those of the males). This method gives an idea of the brood parasitism rate or the brood infestation rate.

Bee examination:

This method allows us to assess the infestation rate of adult bees. It consists of taking sample of bees (about 200 bees), placing them in a jar containing 70% to 80 % alcohol or water with detergent added. After shaking well, we count the fallen mites, their percentage in relation to the bees collected tells us about the degree of infestation in the colony (De Jong *et al*., 1982).

The natural fall by placing swaddles:

The laying of greased swaddles covered with a grid on the floors of the hive for a few days, their reading and replacement allow estimating the daily mortality of the mite.

11. Management of varroosis

The fight against varroosis aims to keep the infestation below the harmful threshold.

Use of acaricide treatments:

Since the appearance of the varroa mite, several chemical molecules have been applied in several countries around the world. The most applied are based on Fluvalinate (Apistan®, Klartan®), Amitraz (Apivar®), Flumethrin (Bayvarol®) and Coumaphose (Perizin®). The single and repeated use of an active ingredient resulted in the development of resistance acquired by *V. destructor*. Thus, the effectiveness of most of the chemical acaricides used varies between 60 to 95% (Rosenkranz *et al*., 2010).

The phenomenon of resistance to several chemical molecules has been reported by several authors (Lodesani *et al*, 1995; Vandame *et al*, 1995; Londzin and Sledzinky, 1996; Elzen *et al*., 1988; Mozes *et al*., 2000; Milani and Della Vedova, 2002; Garcia-Salinas *et al*., 2006). This has forced beekeepers to move towards natural control based primarily on the use of oxalic acid, formic and thymol. In addition, it has been observed that certain acaricide residues and certain metabolites resulting from the degradation of these molecules accumulate in the wax (Bogdanov *et al*., 1988), and sometimes they even contaminate the products of the hive (Bogdanov, 2006).

Natural treatments:

These treatments are based on essential oils and organic acids, which can act on mites (Rosenkranz *et al*., 2009). Formic acid can be used in different forms, either at a concentration of 65% (w/w) for the fumigation of colonies ("MiteWipe" or "Flash" methods) or in the form of commercial MAQS strips ® 46.7% . This acidorganic kills mites by inhibiting their mitochondrial respiration (Johnson, 2015). In fact, formic acid is the only organic acaricide that has the ability to kill the mites inside brood cells (Fries *et al*, 1994). Lactic acid sprayin aqueous solution is very effective in the absence of brood. The presence of the latter causes the drop in efficiency from 80! to 40! (Rosenkranz *et al*., 2009). Oxalic acid has been used in the fight against varroasis for several years as an additional treatment as part of the integrated control plan (Barbançon and Monod, 2005). At first, it was used in the form of a spray, which involved removing each frame from the hive. Then, beekeepers used oxalic acid by dripping on bees in the back alleys of the frames. Applied by spraying, oxalic acid has proven itself for such a fall treatment. The efficacy is very high against mites and bees tolerate this treatment well (Toomemaa, 2019; Jack *et al*., 2020). Spraying application on the other hand has the disadvantage of being laborious (Chariere *et al*., 1998).

Essential oils:

Imdorf *et al* (1999) tested more than 150 essential oils by screening in the laboratory and in situ to assess their toxicity, repellency, attractiveness, as well as their effects on the reproduction of varroa mites. Among all the components tested, thymol had the best result in practical beekeeping. Thymol, camphor and other oils have shown effectiveness against varroasis with less risk on bees and on bee products (Rosenkranz *et al.*, 2009; De Jesús May-Itzá and Medina, 2019; Tlak Gajger *et al*., 2020). Thymol provides an efficiency comparable to that of formic acid. It is a volatile monoterpenoid naturally present in thyme, *Thymus vulgaris*. Thymol acts on the nervous system of varroamite by interacting with GABA receptors involved in neurotransmission in animals (Johnson, 2015).

Biological control:

Entomopathogenic fungi seem to present the most promising future. Several isolates from different species (*Verticillium lecanii, Hirsutella* spp., *Paecilomyces* spp., *Beauveria bassiana, Metarhizium anisopliae* and *Tolypocladium* spp.) have shown an interesting varroacid effect (Shaw *et al.*, 2002). Field tests with *M. anisopliae* (Metschnikoff, Hypocreales: Clavicipitaceae) indicated efficacy comparable to that of Apistan. The entomopathogenic fungi *Beauveria bassiana, M. anisopliae, Clonostachys rosea* and *Hirsutella thompsonii* have also demonstrated certain degrees of control against *V. destructor* in *in vivo* tests (Kanga *et al*., 2006). However, these fungi are also found to be pathogenic for bees and can interfere with the development of brood, among other things (Meikle *et al*., 2012).

Biomechanical control:

Removing the brood of males - technique consists in placing a frame of cells of false drones so that it is rebuilt by the workers in cells of false drones) at the edge of the brood chamber. The queen will lay male eggs (unfertilized) and, knowing that the mites prefer this type of brood, the latter will enter it. Once the cells are sealed, these frames are removed and destroyed, trapping a significant number of parasites (Wantuch and Tarpy, 2009).

Selection of bees tolerant or resistant to *Varroa destructor:*

Selection is based on the behaviors and genetic characteristics of bees contributing to resistance. The most studied are the attraction of brood for varroa mites, the duration of brooding time and the hygienic and de-husking behavior.

Varroosis is a very dangerous disease that attacks the honeybee. It causes enormous damage to bee colonies. Secondary infections caused by viruses are one of the causes of colony collapse. Knowledge of the biology of the mite, population dynamics in a well-defined region and the race of bees are necessary for the programming of an integrated varroasis control strategy.

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Impact of ecological attributes and feeding categorization of Ephemeroptera, Plecoptera and Trichoptera (EPT) insects in Kiliyur falls of Eastern Ghats, India

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ABSTRACT: Investigation on the diversity, ecology and trophic categorization of Ephemeroptera, Plecoptera and Trichoptera complex (EPT) was carried out in Kiliyur falls of the Eastern Ghats. An aggregate of 2,189 specimens belonging to 24 genera, 12 families and 3 orders were collected. Ephemeroptera was found to be high when compared to Plecoptera and Trichoptera. Baetidae was the most abundant taxa of all with presence of 5 genera and 6 species. Shannon-Weiner index and Simpson's index were calculated and it shows that Shannon-Weiner index was elevated in the August (2.882) and declines in January (2.744). Simpson's index was most noteworthy in December (0.9325) and it was least in January (0.9321). Canonical correlation analysis (CCA) shows that temperature, dissolved oxygen and rainfall turns into a major stressor in the EPT community of Kiliyur falls. Cluster analysis results prove that Baetidae and Caenidae shows comparative dispersion pattern as opposed to Teloganodidae and Perlidae. Functional feeding group (FFG) analysis shows that Kiliyur stream was overwhelmed by collectors followed by scrapers, predators and filter-feeders.

KEYWORDS: EPT complex insects, diversity, ecology, fresh water ecosystem

INTRODUCTION

Larval stages of Ephemeroptera, Plecoptera and Trichoptera are commonly known as EPT and they inhabit in freshwater streams (Allan, 1995) and they are viewed as satisfactory model organisms in addressing the ecological properties of the freshwater community (Beauchard *et al.*, 2003). The health of the freshwater ecosystem can be measure through collecting the freshwater macroinvertebrates because they normally imply the status of the particular habitat (Rosenberg and Resh, 1993; Wright and Burgin, 2009). Each taxa in the EPT complex reacts diversely to every pollutant present in the biological system and throughout time, they reacts to the contaminations contrastingly and fills in as bioindicator organisms (Bonada *et al.,* 2006; Odume and Muller, 2011). Earlier studies have shown promising results of EPT complex in biomonitoring studies by evaluating the connection between EPT taxa and ecological

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attributes (Hodkinson and Jackson, 2005; Silveira *et al.,* 2006; Milesi *et al.,* 2009).Various ecological factors include water flow, temperature, seasonality, altitude, pH and dissolved oxygen regulates the diversity and community structure of benthic macro invertebrates (Crisci-Bispo, 2007).

EPT insects develop uniquely in contrast to one environment to another biological system dependent on the habitat structure and food accessibility present in the specific habitat (Vannote *et al.,* 1980). Substrate present in the freshwater habitat becomes a major component in EPT complex because they form a source for feeding, deposition of eggs, shelter during physical disturbances (Stephanie *et al.,* 2000) and drought conditions (Fenoglio and Bosi, 2006). Functional feeding group (FFG) among benthic macro invertebrates can be studied based on the kind of food source utilized and the feeding mechanism involved (Cummins, 1973). These FFG encourages us to comprehend the different functions EPT insects perform inside freshwater environments and this helps in biomonitoring studies.

Most of the EPT organisms love pollution less environment and now a day due to anthropogenic impacts pollution becomes a significance issue in the freshwater habitat (Grzybowski and Gliñska-Lewczuk, 2019). This impacts downward dislodging in the development of local species and over the span of time, these are get supplanted by exotic and foreign species which will collapse the entire food chain of the freshwater ecosystem.

Normally, the studies on aquatic insects and its community structure is restricted only to the Western Ghats of Southern India, only limited studies were done in the Eastern Ghats (Srinivasan *et al.,* 2019). Kiliyur falls, which is one of the famous falls present in the Eastern Ghats of Southern India. It is part of the Salem district of Tamil Nadu; this part of region still remains unexplored in the light of ecology. So this work aims to study the diversity, distribution and functional feeding groups of EPT assemblages and how EPT insects responds to ecological factors in Kiliyur falls of the Eastern Ghats.

MATERIALS AND METHODS

Study area

Kiliyur Falls is situated in Shervaroyan slope of Salem district extends in the Eastern Ghats of Tamil Nadu, India. The waters flooding the Yercaud Lake fall into the Kiliyur Valley. It has the highest elevation of 4393 feet at a Latitude 11.7950° N and Longitude 78.2004° E. It receives an average annual rainfall of 1400 mm. EPT insects were collected from August 2017 to January 2018. Channel substrates of stream include bedrock, boulder, gravel, pebble and mostly covered with canopy cover. The sampling was done from August 2017 to January 2018; it is because the falls is usually dry during other seasons. Random sampling was made from three sites. Site I which is upstream, site II which is midstream and site III which is human inhabiting area where most people come and bath here. Each sampling site distinguishes at a distance of 1000 m. The EPT insects were collected by using 1m wide kick-net (Burton and Sivaramakrishnan, 1993) and surber sampling. The insects collected from the target habitats stored in 70% ethyl alcohol and labelled separately in the field for each sampling month.

Measuring water quality and habitat parameters

The physico-chemical parameters of stream water, habitat parameter, water flow, air temperature and water temperature were analysed for every month by using the guidelines of APHA (2005).

Specimen Identification

Using the stereomicroscope (Magnus MSZ-TR), the EPT insects were identified with the help of field guide by Sivaramakrishnan *et al.* (1998) and using other standard taxonomic literatures (Sivaramakrishnan *et al.,* 2009).

Data analysis

The biodiversity indices like Shannon- Weiner diversity and Simpson were calculated using the software PAST 4.2 (Hammer *et al.,* 2001). Canonical correspondence analysis (CCA) and

cluster analysis were also done using the PAST software to find the relation between EPT insects and environmental attributes (Ter Braak and Smilauer, 2002).

Functional feeding group (FFG) analysis

Based on the feeding behaviour and ingested substances studies by gut content analysis (Merritt and Cummins, 1984), EPT complex were grouped into four categories: collectors, shredders, scrapers, and predators.

RESULTS AND DISCUSSION

Diversity and distribution of EPT in Kiliyur falls

Examining of EPT immatures from Kiliyur falls brought about an aggregate of 2,189 specimens belonging to 24 genera, 12 families and 3 orders (Table 2). A total of 1,721 Ephemeroptera specimens were collected including fifteen genera and six families. For Plecoptera, 99 specimens were collected having one genera and one family and for Trichoptera 369 specimens were collected belonging to five genera and five families. The Ephemeroptera richness is higher when compared to other orders and during diversity investigation for richness was comparatively very low in Plecoptera due to high temperature because stoneflies normally prefer cool environment for their survival. Among all families, Baetidae was the most abundant taxa with presence of 5 genera and 6 species. Among alpha diversity indices, Shannon-Weiner index and Simpson's index were determined. Shannon index values normally lies between 0.0 – 5.0 and very rarely it exceeds 4.5 (Kocatas, 1992). The values above 3.0 normally indicate that ecosystem is healthy. In Kiliyur falls, Shannon-Weiner index (Fig. 1) is elevated in the month of August (2.882) and declines in January (2.744). The Shannon index values of all the six months were under 3.0 and this shows that the ecosystem is not healthy and it is slightly broken, in future it is of great concern. Simpson's index (Fig. 2) was highest in December (0.9325) and it was lowest in January (0.9231). This supports the results of Shannon index also and the results portrays that during the high rainfall months like December and August, the index values were high and it supports more diverse EPT taxa and in the less rainy months like January, the index values were low and it does not bolster the EPT community.

In the investigation of months, January had high air (26ºC) and water temperature (23ºC) and this also results in least number of individuals in the month of January (Table 1). Temperature plays an important role in diversity, distribution and functioning of EPT taxa (Ward and Stanford, 1982; Minshall *et al.,* 1985). Minshall and Robinson (1998), recorded temperature becomes a stressor than other physico-chemical variables in governing the aquatic insects community. Along these lines temperature might be a significant factor impacting taxa richness (Jacobsen *et al*., 1997). Despite the fact that, rainfall level (Table 1) is most noteworthy in the long stretch of December, it bolsters the

Table 1. Physico-chemical parameter of Kiliyur falls

Physico-Chemical Parameters	AUG	SEP	OCT	NOV	DEC	JAN
Water temperature (Cº)	21.5 ± 0.8	21 ± 0.6	20.5 ± 0.5	20 ± 1.1	19 ± 0.8	23 ± 0.6
Air temperature (Cº)	25 ± 0.7	24 ± 0.6	22.5 ± 0.7	21 ± 0.9	21 ± 0.6	26 ± 0.5
Dissolved oxygen (mg/l)	5.7	6.3	6.6	7.5	8.2	5.7
pH	7.5	7.2	7.4	7.1	7.2	7
Water flow (m/s)	0.48	0.50	0.56	0.52	0.60	0.45
Mean monthly rainfall (mm)	187	143	156	148	260	164

Table 2. List of taxa present in Kiliyur falls in different months

Order	Family	Genus/ Species	Number of individuals					
			AUG	SEP	OCT	NOV	DEC	JAN
Ephemeroptera	Baetidae	*Baetis acceptus* (Müller-Liebenau & Hubbard 1985)	15	23	18	17	20	12
		Baetis conservatus (Müller-Liebenau & Hubbard 1985)	5	4	8	6	5	3
		Tenuibaetis frequentus (Müller-Liebenau & Hubbard 1985)	23	14	25	25	34	11
		Centroptella similis (Waltz & McCafferty 1987)	10	12	4	12	24	14
		Acentrella vera (Müller-Liebenau 1982)	5	4	5	7	9	8
		Procloeon regularum (Müller-Liebenau & Hubbard 1985)	36	32	36	25	34	22
	Caenidae	*Caenis* sp	5	5	4	6	5	3
		Clypeocaenis bisetosa (Soldán 1978)	3	0	5	5	4	8
	Heptageniidae	*Afronurus kumbakka-raiensis* (Venkataraman & Sivaramakrishnan, 1989)	14	18	15	13	20	12
		Epeorus petersi (Sivaruban, Barathy, Arunchalam, Venkataraman & Sivaramakrishnan, 2013)	28	34	18	32	38	25
		Thalerosphyrus flowersi (Venkataraman & Sivaramakrishnan, 1987)	8	6	12	15	18	6
	Leptophlebiidae	*Choroterpes alagarensis* (Dinakaran, Balachandran & Anbalagan, 2009)	45	48	44	53	58	40
		Edmundsula lotica (Sivaramakrishnan, 1985)	12	12	12	12	3	0
		Indialis badia (Peters & Edmunds, 1970)	3	4	0	0	1	2
	Neoephemeridae	*Potamanthellus caenoides* (Ulmer 1939)	8	6	10	3	4	4
	Teloganodidae	*Teloganodes kodai* (Sartori, 2008)	35	36	38	40	42	37
		Teloganodes sartorii (Selvakumar, Sivaramakrishnan & Jacobus, 2014)	23	26	23	28	32	25

Order	Family	Genus/ Species	Number of individuals					
			AUG	SEP	OCT	NOV	DEC	JAN
Plecoptera	Perlidae	*Neoperla* sp	8	6	8	14	12	2
		Neoperla biseriata (Zwick & Anbalagan, 2007)	7	7	5	12	14	4
Trichoptera	Rhyacophilidae	*Rhycophila* sp	5	3	2	0	6	0
	Philopotamidae	*Wormaldia* sp	1	3	0	0	5	0
	Stenopsychidae	*Stenopsyche kodaikanalensis* (Swegman & Coffman, 1980)	15	8	12	15	18	24
	Polycentropodidae	*Polycentropus* sp	12	13	11	12	12	12
	Hydropsychidae	*Hydropsyche* sp	24	32	36	33	30	25

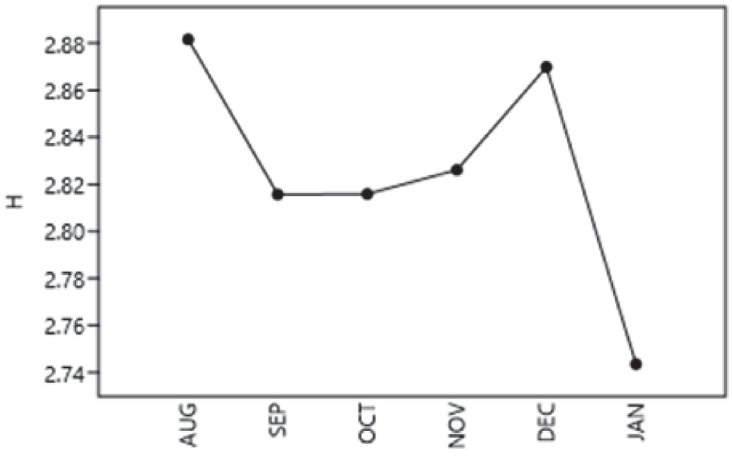

Fig. 1. Shannon_H index values of EPT insects in Kiliyur falls

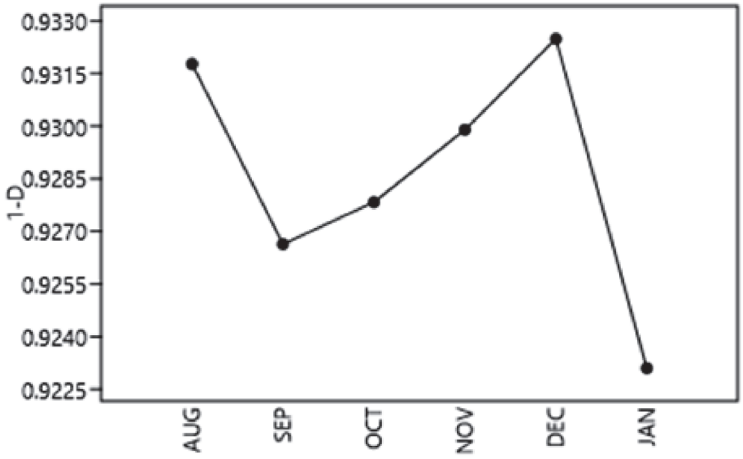

Fig. 2. Simpson_1-D index values of EPT insects in Kiliyur falls

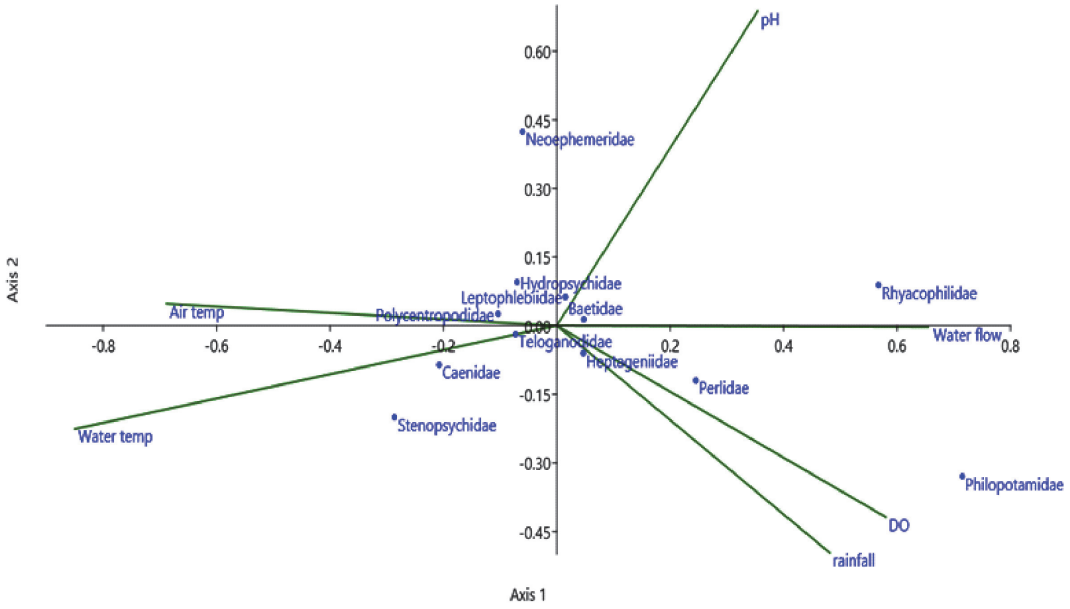

Fig. 3. Canonical Correlation Analysis (CCA) of EPT complex in correlation with ecological attributes

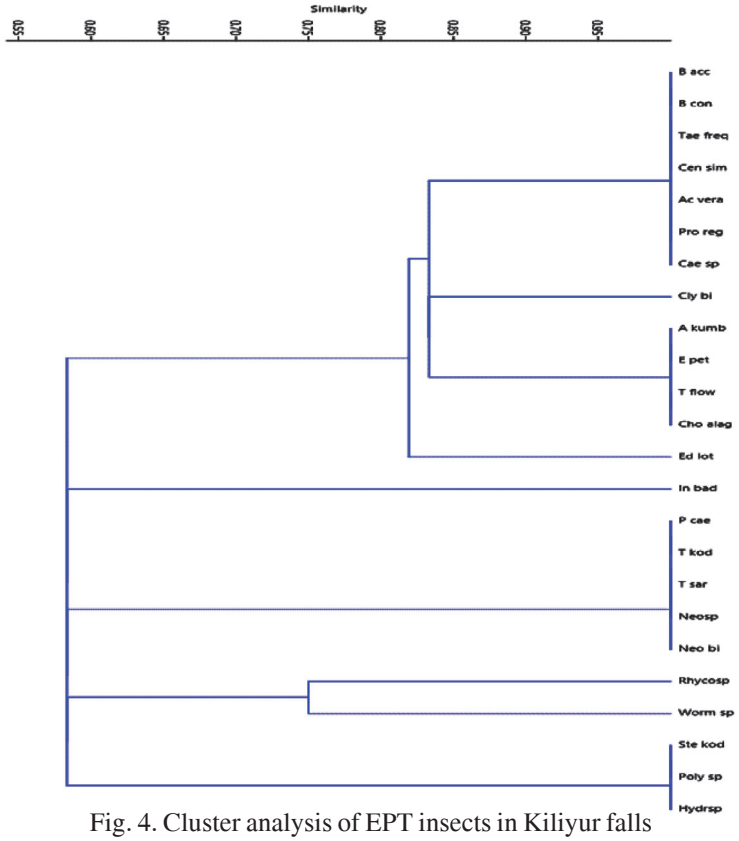

Fig. 4. Cluster analysis of EPT insects in Kiliyur falls

(B acc- *Baetis acceptus*, B con- *Baetis conservatus,* Te fre- *Tenuibaetis frequentus*, Ce sim- *Centroptella similis,* Ac ver- *Acentrella vera, Pro reg- Procloeon regularum,* A kum -*Afronurus kumbakkaraiensis* , Ep pet- *Epeorus petersi,* T flo- *Thalerosphyrus flowersi,* C ala- *Choroterpes alagarensis,* Ed lot- *Edmundsula lotica,* Ind bad- *Indialis badia*, P cae- *Potamanthellus caenoides*, T kod- *Teloganodes kodai,* T sar - *Teloganodes sartorii*, Cae sp- *Caenis* sp, Cly bi- *Clypeocaenis bisetosa*, Neo sp.- *Neoperla* sp, Neo bi- *Neoperla biseriata*, Rhyco sp- *Rhycophila* sp, Worm sp- *Wormaldia* sp, Ste kod- *Stenopsyche kodaikanalensis*, Poly sp- *Polycentropus* sp and Hydr- *Hydropsyche* sp)

development of EPT community. Normal dissolved oxygen (DO) level in the fresh water streams was found to be 4.6 – 8.6 mg/l (Srinivasan *et al.,* 2019) and here it falls in 5.7 – 8.2 and it is of acceptable range. Low DO in the January reduces the EPT richness whereas high DO in the December supports high richness of EPT taxa. Hence this proves, EPT community gets affected by low DO and high temperature and it also supports the results of Gage *et al.* (2004). The other physico-chemical parameters fall within normal permissible limit in Kiliyur falls.

FFG analysis

In Kiliyur falls, collectors were seen as the prevalent group than the other functional feeding groups (Table 3). Collectors were (48.3%) dominated followed by scraper (31.5%). Predators (8.2%) and filter-feeders (12%) were the least occupied group. FFG analysis shows that Kiliyur stream is dominated by collectors followed by scraper, predator and filter-feeder. The functional feeding group results concur with the River Continuum Concept (RCC) (Vannote *et al.,* 1980) as the number of collectors tends to increase in mid reaches streams.

CCA analysis

CCA analysis (Fig. 3) predicts that various physico chemical parameters have influenced the diversity and distribution of the EPT community. The CCA biplot reveals that the distribution of families Caenidae, Teloganodidae and Stenopsychidae were characterized by increasing water temperature. High pH influences the diversity and distribution of Baetidae, Rhyacophilidae and Leptophlebiidae. High DO, rainfall and water flow which supports the growth of Heptageniidae and Perlidae and they are exceptionally sensitive to increasing levels of water temperature. This proves that stoneflies and heptageniids prefer cool environment for their survival and they also need oxygen rich environment for their survival. Polycentropodidae, Hydropsychidae and Neoephemeridae which gets upheld in the high air temperature and they were negative in relation with rainfall.

Cluster analysis

Cluster analysis results shows that four conspicuous clusters were formed (Fig. 4) of which family Baetidae and Caenidae of Ephemeroptera shows similar diversity and distribution pattern, in the second cluster family Heptageniidae and *Choroterpes alagarensis* of Ephemeroptera shows similar distribution over a period of time whereas in the third cluster family Teloganodidae of Ephemeroptera and Perlidae of Plecoptera shows similar pattern. In the fourth cluster, *Stenopsyche kodaikanalensis*, *Polycentropus* sp and *Hydropsyche* sp shows similarity in distribution. Taxa include *Edmundsula lotica*, *Indialis badia*, *Rhycophila* sp and *Wormaldia* sp shows novel distribution pattern.

It is concluded that, the greater part of EPT taxa present in Kiliyur falls were adversely related with temperature, rainfall and DO and it shows temperature, rainfall and DO turns into a major stressor in the EPT community of Kiliyur falls. Collectors were found to be the predominant group than the other functional feeding groups. CCA results prove that stoneflies and heptageniids prefer cool environment for their survival. Cluster analysis shows family Baetidae and Caenidae of

Table 3. Percentage of Trophic categorization of EPT complex in Kiliyur falls

Functional feeding groups	No. of individuals	Percentage
Collectors	1098	48.3%
Scrapers	716	31.5%
Predator	187	8.2%
Filter feeders	272	12%

Ephemeroptera shows similar distribution pattern contrast to Teloganodidae and Perlidae. So this work provides essential information about the diversity, distribution and community structure of EPT insects in Kiliyur falls and gives more knowledge about the EPT insects in less explored Eastern Ghats.

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Natural parasitism of eggs of yellow stem borer, *Scirpophaga incertulas* Walker (Lepidoptera: Crambidae) in rice ecosystem at Tiruchirappalli, Tamil Nadu

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ABSTRACT: Three species of parasitoids viz., *Telenomus dignus* Gahan, *Trichogramma japonicum,* Ishii and *Tetrastichus schoenobii* Ferriere were recorded from the egg masses of rice yellow stem borer, *Scirpophaga* incertulas (Walker) in a field study. The extent of parasitism was high during *Rabi* (43.33 – 93.33 %) and low during *Kharif* (0 - 40.00 %). Parasitism by *T. dignus* was maximum in October (50.00 %), *T. japonicum,* in November (23.08 %) and *T. schoenobii* in February (55.55 %). *T. dignus* and *T. schoenobii* in combination parasitized maximum number of egg masses (41.82 %). Multiple parasitism by the three species was high in December (8.33 %) and January (7.14%). Parasitic potential was maximum, when *T. schoenobii* alone parasitised the egg masses followed by *T. dignus* and *T. schoenobii* in combination. Host density in the field influenced the extent of parasitism.

KEYWORDS: Rice yellow stem borer, *Scirpophaga incertulas,* egg parasitoids, seasonal incidence

INTRODUCTION

Rice (*Oryza sativa* L.) belonging to family Poaceae is an important grain crop in the world feeding more than 50 per cent of the human population (Agrawal *et al*., 2005). Globally, it is the second most cultivated cereal crop next to wheat. India ranks first in area (43.79 m. ha) and second in production (101.96 MT) Anonymous (2018). Tamil Nadu is one among the major rice producing states in India. The productivity of rice crop is influenced by several biotic and abiotic factors. The rice crop is subjected to considerable damage by nearly 300 species of insect pests, among which only 23 species are serious (Pasalu and Gururaj, 2006). Yield loss due to insect pests of rice has been estimated to be about 25 per cent (Dhaliwal *et al.,* 2010). In India, out of the total loss incurred by different insect pests of paddy, 25 to 30 per cent damage is done by stem borer alone (Dhivahar and Dhandapani,2003). The yellow stem borer (YSB), *Scirpophaga incertulas* (Walker) (Lepidoptera: Crambidae) is the most predominant species of stem borer in rice ecosystem in Tamil Nadu (Reuolin and

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Soundararajan, 2019). Each unit increase in white ear damage has a greater impact on rice yield (Jiang *et al.,* 2005).

Globally, rice stem borer accounts for 50 per cent of the insecticides used in rice fields (Huesing and English, 2004). Over reliance on synthetic pesticides causes ecological adversity and health related problems (Carvalho, 2017). It has also led to an exponential increase in the number of insect species developing resistance to insecticides (Sparks and Nauen, 2015) and destruction of population of beneficial insects (Jafar *et al.,* 2013). To combat this, the use of biocontrol agents has to be promoted as the best alternative to insecticides for pest management. A maximum of 95.00 per cent natural parasitism of yellow stem borer eggs by the parasitoids *Trichogramma sp., Telenomus sp.* and *Tetrastichus sp*. have been reported in rice ecosystem (Lakshmi *et al.,* 2010; Rahaman and Stout, 2019). Prasanthi *et al.* (2020) have reported the natural parasitism of YSB eggs by the parasitoid species such as *Telenomus dignus* Gahan, *Tetrastichus schoenobii* Ferriere and *Trichogramma japonicum* Ashmead. Management of yellow stem borer is easy and effective at the egg stage, as the larva is concealed inside the stem. Hence, the present study was conducted to examine the egg parasitoids of yellow stem borer and the extent of natural parasitism of eggs in the rice ecosystem at Tiruchirappalli, Tamil Nadu.

MATERIALS AND METHODS

Field study was conducted at the experimental farm of Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli District, in a Randomised Block Design during (*Kharif*) 2018 and (*Rabi*) 2019 with cv. TRY 3 and replicated thrice with a plot area of 30m^2 for each replication. The standard agronomic practices recommended by Tamil Nadu Agricultural University were adopted except the plant protection measures. Based on weather parameters obtained from the Agrometeorological Station at Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, an average maximum temperature of 34.79°C and 32.11°C, average minimum temperature of 25.20°C and 22.55°C and average relative humidity of 65.14 per cent and 71.17 per cent were observed during the study in *Kharif,* 2018 and *Rabi,* 2019 respectively.

1. Parasitism of *S. incertulas* in rice ecosystem

1.1. Natural parasitism of egg mass

The egg masses of yellow stem borer were collected thrice per month with 10 days interval (30 egg masses/replication) during *Kharif,* 2018 and *Rabi,* 2019 from the field plots and kept in petri plates with moist filter paper to avoid drying of leaves. Then the egg masses were observed for the emergence of the adult parasitoids. Once emergence was completed, the egg masses were dipped in 70 per cent alcohol to remove the hairs. The eggs were then separated with a fine camel hair brush and the number of unemerged adults, hatched and unhatched eggs, were counted under a stereo zoom microscope. The emerged adult parasitoids were also observed under the stereo-zoom microscope to identify the respective species and number. The extent of parasitism of egg masses of yellow stem borer was worked out (Vennila *et al.,* 2018).

$$\text{Parasitism (\%)} = \frac{\text{No. of parasitised egg mass}}{\text{No. of sampled egg mass}} \times 100$$

The data obtained from the experiment was statistically analysed by RBD one factor analysis using a computer based AGRES software after arcsine transformation.

1.2. Relative parasitism of egg masses by parasitoids in combination or alone

The parasitism by each species (egg parasitoids recorded based on emergence) of *Trichogramma japonicum* (Ashmead), *Telenomus dignus* (Gahan) and *Tetrastichus schoenobii* (Ferriere) was assessed by the formula given below,

$$\text{Adult emergence (\%)} = \frac{a}{b} \times 100$$

Where, a- no. of egg mass with adult emerged (each species of parasitoid), b- no. of parasitized egg mass.

1.3. Parasitic potential of parasitoids in combination or alone

The parasitic potential of different species of egg parasitoids was assessed based on the hatching of yellow stem borer larvae using the formula,

$$\text{Parasitic potential (\%)} = \frac{A}{E} \times 100$$

Where, A-Number of larva emerged and E- Total number of eggs in an egg mass, which is obtained by, E= A+B+C+D, where, B-Unemerged larva, C-Emerged parasitoids and D - Unemerged parasitoids.

The parasitisation of eggs in an egg mass by each species of parasitioid was assessed (Kim and Heinrichs, 1985)

$$T.\ schoenobii\ (\%) = \frac{3C + 3D}{(A + D) + (3C) + (3D)} \times 100$$

$$T.\ dignus\ (\%) = \frac{C + D}{A + B + C + D} \times 100$$

$$T.\ japonicum = \frac{\frac{C}{2} + D}{A + B + \frac{C}{2} + D} \times 100$$

Where, A- no. of hatched stem borer larvae, B- no. of unhatched stem borer larvae, C- no. of emerged parasitoid and D- no. of unemerged parasitoid

Three host eggs are needed to complete the larval period by *T. schoenobii* whereas *T. japonicum* is tiny, so that, one to four (average of two) parasitoids developed from one host egg. Thus, in calculating the parasitic potential of *T. schoenobii*, the number of emerged parasitoids was multiplied by three. For *T. japonicum,* the number of emerged parasitoids was divided by two.

2. Seasonal incidence of yellow stem borer by light trap catches

The seasonal incidence of stem borer species was monitored using light trap to arrive at the moth population during *Kharif,* 2018 and *Rabi,* 2019. The light trap unit made of galvanised iron sheet with a trapping device and collecting chamber was installed in the field and operated from 7.00 PM to 11.00 PM. The mercury vapour lamp of 160W was used as the light source. The collecting jar with insecticide was changed every day and insects collected were counted each day and the species was assessed and sexed to arrive at the monthly mean population.

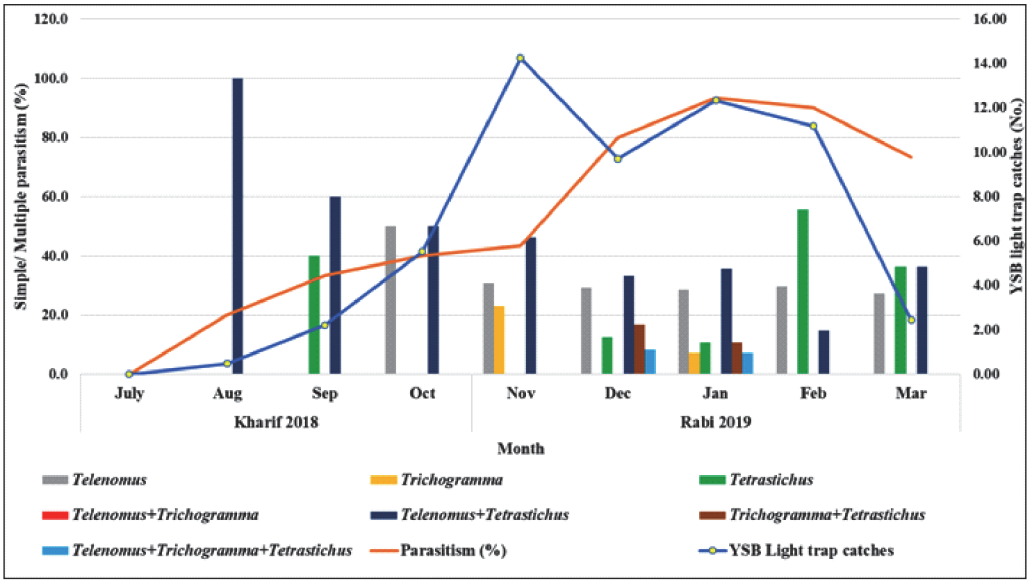

Fig. 1. Seasonal influence on yellow stem borer population and natural parasitism of egg mass

RESULTS AND DISCUSSION

Natural parasitism of egg mass of yellow stem borer

It was clearly evident from the present observations that, the parasitism of egg mass of was yellow stem borer minimum in August 2018 (16.67 %) which subsequently increased in September 2018 (33.33 %), October 2018 (40.00 %) in *Kharif,* and maximum parasitism was observed in January 2019 (93.33 %), which was on par with the parasitism in February 2019 (90.00 %) and in December 2018 (80.00 %) during *Rabi,* (Fig. 1), which varies from the early report that, peak parasitisation was observed during *Kharif,* 2018, particularly in October ranging from 75.29 to 97.56% (Varma *et al.,* 2013). Lakshmi *et al.* (2010) reported a maximum of 95.0 per cent parasitism of egg mass of yellow stem borer as against 93.33 per cent in the present study, which would be due to variations in weather parameters or repeated application of insecticides in rice ecosystem at Tiruchirappalli.

Relative parasitism of yellow stem borer egg mass by egg parasitoids, either alone or in combination

The activity of *T. dignus* was maximum in October 2018 (50.00 %) during *Kharif,* 2018 which is in agreement with the maximum parasitisation by *Telenomus* during October in *Kharif* (Varma *et al.,* 2013). The activity of *T. japonicum* was observed only during *Rabi,* 2019, in November with parasitism of 23.08 per cent of egg masses (Fig. 1). The relative parasitism of yellow stem borer egg mass by different species of egg parasitoids revealed 8.33 per cent and 7.14 per cent multiple parasitism by the three species (*T. dignus, T. schoenobii* and *T. japonicum*) during December and January of rabi respectively (Table 1). The species *T. japonicum* and *T. schoenobii* in combination parasitised egg masses (16.67 %) and *T. dignus* and *T. schoenobii* together parasitised egg masses (33.33 %) in December 2018. The maximum parasitism of egg masses was done by *T. dignus* and *T. schoenobii* in combination (41.82 %) and minimum (1.72 %) was done, when mulitiple parasitism occurred by the three species of egg parasitoids. The species *T. dignus* and *T. japonicum* did not parasitise any egg mass in combination.

The activity of *T. dignus* was maximum in October 2018 (50.00 %) followed by January 2019 (28.57 %). The parasitism by *T. japonicum* was maximum in November 2018 (23.08 %), followed by January 2019 (7.14 %). The activity of *T. schoenobii* was maximum in February 2019 (55.55 %) and March 2019 (36.36 %).

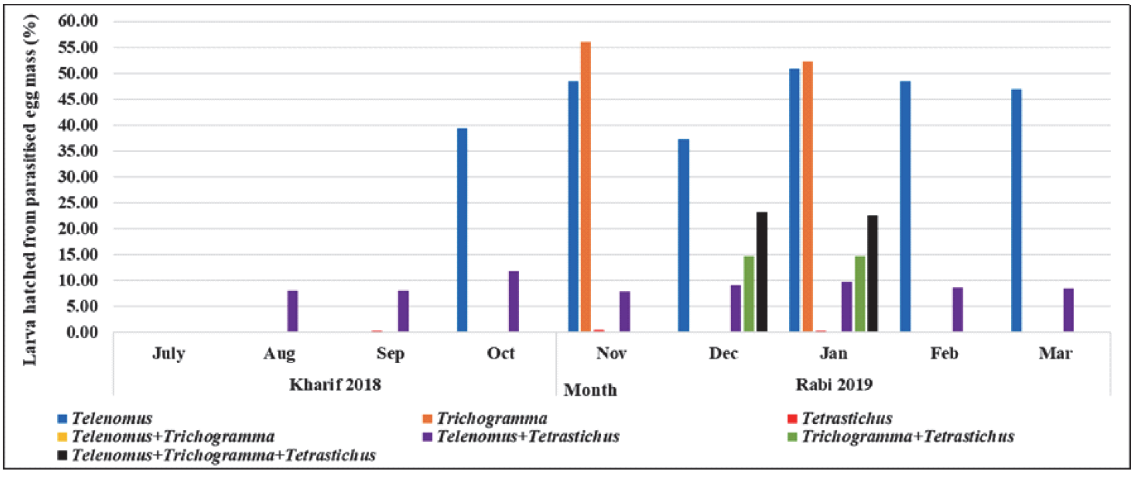

Fig. 2. Parasitic potential of different species of egg parasitoids

Table 1. Relative parasitism of yellow stem borer egg mass by egg parasitoids

Season	Month	Egg mass parasitised by species (%)*						
		Telenomus	*Tricho-gramma*	*Tetrastichus*	*Telenomus* + *Tricho-gramma*	*Telenomus*+ *Tetrastichus*	*Trichor-gramma*+ *Tetrastichus*	*Telenomus*+ *Tricho gramma*+ *Tetrastichus*
Kharif, 2018	July	0.00 (0.91)c	0.00 (0.91)c	0.00 (0.91)d	0.00 (0.91)	0.00 (0.91)e	0.00 (0.91)c	0.00 (0.91)b
	August	0.00 (0.91)c	0.00 (0.91)c	0.00 (0.91)d	0.00 (0.91)	100.00 (89.10)a	0.00 (0.91)c	0.00 (0.91)b
	September	0.00 (0.91)c	0.00 (0.91)c	40.00 (39.23)bc	0.00 (0.91)	60.00 (50.77)b	0.00 (0.91)c	0.00 (0.91)b
	October	50.00 (45.00)a	0.00 (0.91)c	0.00 (0.91)d	0.00 (0.91)	50.00 (45.00)bc	0.00 (0.91)c	0.00 (0.91)b
Rabi, 2019	November	30.77 (33.69)c	23.08 (28.71)a	0.00 (0.91)d	0.00 (0.91)	46.15 (42.79)bc	0.00 (0.91)c	0.00 (0.91)b
	December	29.17 (32.69)c	0.00 (0.91)c	12.50 (20.71)c	0.00 (0.91)	33.33 (35.26)cd	16.67 (24.09)a	8.33 (16.78)a
	January	28.57 (32.31)b	7.14 (15.50)b	10.71 (19.10)c	0.00 (0.91)	35.71 (36.70)cd	10.71 (19.10)b	7.14 (15.50)a
	February	29.63 (32.98)c	0.00 (0.91)c	55.55 (48.19)a	0.00 (0.91)	14.81 (22.63)d	0.00 (0.91)c	0.00 (0.91)b
	March	27.27 (31.48)c	0.00 (0.91)c	36.36 (37.08)ab	0.00 (0.91)	36.36 (37.08)cd	0.00 (0.91)c	0.00 (0.91)b
Mean	-	21.71	3.36	17.24	0.00	41.82	3.04	1.72
SEd	-	4.85	2.93	7.07	-	7.94	1.49	4.35
CD (p=0.05)	-	10.29	6.2	14.98	-	16.84	3.16	9.23

*Mean of three replications; Figures in parentheses are arcsine transformed values
In a column, means followed by similar letter(s) are not statistically different (p=0.05) by LSD

Parasitic potential of different species of egg parasitoids of yellow stem borer

The egg masses parasitised by *T. schoenobii* alone, had a minimum of 0.24 per cent YSB larval emergence, thus revealed that, maximum eggs in an egg mass were parasitised by *T. schoenobii* alone, followed by *T. dignus* and *T. schoenobii* in combination parasitising eggs/egg mass (8.95 % hatching) (Fig. 2). The species *T. dignus* and *T. schoenobii* together parasitised maximum number of egg masses (41.82 %), which is in contrast to the earlier report that, highest parasitisation (35.00 %) was by the combination of *T. rowani* and *T. japonicum* (Kim and Heinrichs, 1985). Maximum number of eggs in an egg mass was parasitised by *T. schoenobii,* since two to four (average of three) host eggs were needed to complete the larval period by *T.* schoenobii, which is in accordance to earlier finding that, *T. schoenobii* was the most abundant parasitoid, parasitising 95 per cent of the eggs.

Maximum number of larvae hatched from the egg mass parasitised by *T. japonicum,* since an average of two parasitoids developed from one host egg (Kim and Heinrichs, 1985). Further, maximum larval hatching was observed in the egg mass parasitised by *T. dignus* (45.21 %) and *T. japonicum* (54.16 %), since both the parasitoids parasitised only those eggs laid on the upper surface of the egg mass, allowing the remaining eggs to hatch. Such partial parasitism reduced their efficacy in controlling the stem borer. *T. schoenobii* destroyed all the eggs in an egg mass and appeared to be effective in controlling stem borer which henceforth is clear from the present study, that only 0.24 per cent larva hatched from the egg mass parasitised by *T. schoenobii* alone (Manjunath, 1990). The parasitism of eggs in an egg mass declined on the occurrence of multiple parasitism, as 22.88 per cent larvae hatched in an egg mass parasitised by the three species.

Seasonal incidence of yellow stem borer by light trap catches

The observations on the seasonal incidence of yellow stem borer adults based on light trap catches indicated that, the mean moth population of YSB reached its peak during November 2018, followed by December 2018 and January 2019 in *Rabi* (Fig. 1), which was in direct proportion with the maximum parasitism by the egg parasitoids in January 2019 (93.33 %), followed by February 2019 (90.00 %) and December 2018 (80.00 %) during *Rabi.* Justin and Preetha (2013) reported that, the infestation of *S. incertulas* was found during August to September and December to January. The relative parasitism by all the three species of egg parasitoids either alone or in combination was also observed during *Rabi,* 2019, when the pest population was more than *Kharif*, 2018. Thus, the present study indicated that, the extent of parasitism and the activity of parasitoids were influenced by the host density.

A maximum of 93.33 % of natural parasitism of the egg mass of yellow stem borer was observed, which managed the pest in the egg stage itself. Hence, in rice ecosystem, with the natural occurrence of egg parasitoids, measures must be taken to avoid insecticide spray or to spray with the insecticides safer to the parasitoids to conserve them. The parasitic potential was maximum in an egg mass parasitised by *T. schoenobii* alone, followed by *T. dignus* and *T. schoenobii* in combination. Hence augmentative measures must be taken to enhance it, for successful management of yellow stem borer with the biocontrol agents.

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A checklist of bees (Insecta: Hymenoptera: Apoidea) of Kerala

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ABSTRACT: A checklist of bee species from Kerala based on literature survey belonging to three families are listed. Accordingly 86 species of bees under 19 genera are enumerated.

KEYWORDS: Bee fauna, Apidae, Halictidae, Megachilidae

INTRODUCTION

Bees are the group of beneficial insects belong to the order Hymenoptera. They are the members of the superfamily Apoidea and are further classified into seven families namely, Apidae, Halictidae, Megachilidae, Andrenidae, Colletidae, Melittidae and Stenotritidae (Michener, 2007). Bees are known for their important role as pollinators in nature since they provide valuable pollination services to many crops and natural vegetations (Free, 1993; Delaplane and Mayer 2000; Michener, 2007; Thakur, 2012). There are 20,473 described species of bees in the world (Ascher and Pickering, 2020). Bees exhibit a wide range of lifestyles from solitary to social (Benton, 2017). Honey bees, bumblebees and stingless bees are social bees. They live in colonies in which the members follow the division of labour.

In India, important works on the taxonomy of the bees were done by Bingham (1897). Jobiraj (2002) conducted studies on the systematics of the bee family Apidae of Kerala. Gupta in 2003 published an annotated catalogue of bees of Indian region. Saini and Rathor (2012) published an Indian checklist of Halictidae family bees and reported 194 species under 27 genera. In 2017, Pannure and Belavadi published a distributional checklist of subfamily Nomiinae of South India and recorded 48 species under 13 genera. Sheeja and Jobiraj (2017) conducted studies on the bee fauna of the Vanaparvam biodiversity park, Kozhikode, Kerala and identified 18 species belong to 9 genera. In 2018, Manjusha and Jobiraj published a checklist of Nomiinae subfamily of Kerala which contains 25 species under 12 genera. Bijoy *et al.* (2019) recorded 19 species of bees belonging to 7 genera from rice ecosystems of Palakkad. In India there are 796 species of bees under 71 genera (Pannure and Belavadi, 2019). The present checklist provides a list of the bee fauna of Kerala.

MATERIALS AND METHODS

This checklist was prepared entirely based on a literature survey and no specimens are examined for this purpose. Details regarding the bee diversity

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of Kerala were collected from various sources including published articles, books, catalogues, checklists etc. Visit to KFRI, Peechi was made during this study for collecting information.

RESULTS AND DISCUSSION

The species reported from each genus from these families along with the distributions and references are given. All literature surveyed is provided in the reference section.

Family Apidae

It is the largest family of bees under superfamily Apoidea. This family consist of honey bees, bumblebees and other solitary bees and some cleptoparasites. They belong to the group of long-tongued bees. In India, there are 225 species of Apidae bees under 25 genera (Pannure and Belavadi, 2019).

Genus *Amegilla* Friese, 1897

They are medium to large-sized bees. Some members have blue metallic bands on the abdomen and are commonly called blue-banded bees. Their body and legs are hairy and face with yellow to white or reddish yellow to brown markings. Wing venation is well developed.

1. ***Amegilla zonata* (Linnaeus, 1758)**

   Source: Suresh *et al.* (1999), Mathew (2004, 2009), Erra and Shanas (2019)

   Distribution: Parambikulam wildlife sanctuary (Palakkad), New Amarambalam reserve forest (Malappuram), Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha.

2. ***Amegilla niveocincta* (Smith, 1854)**

   Source: Suresh *et al.* (1999), Mathew (2004, 2009)

   Distribution: Parambikulam wildlife sanctuary (Palakkad), New Amarambalam reserve forest (Malappuram)

3. ***Amegilla confusa* (Smith, 1854)**

   Source: Suresh *et al.* (1999), Mathew (2004)

   Distribution: Parambikulam wildlife sanctuary (Palakkad)

4. ***Amegilla pilipes* Fabricius, 1775**

   Source: Bingham (1897), Sheeja and Jobiraj (2017)

   Distribution: Vanaparvam biodiversity park, Kakkavayal (Kozhikode)

Genus *Apis* Linnaeus, 1758

They are moderate-sized bees with social lifestyle. Their colony consists of queen, workers and drones. They produce honey and wax. This genus enjoys cosmopolitan distribution.

5. ***Apis dorsata* Fabricius, 1793**

   Source: Mathew *et al.* (2004a, 2004b, 2005, 2007), Suresh *et al.* (1999), Mathew (2004, 2009), Sheeja and Jobiraj (2017), Erra and Shanas (2019).

   Distribution: Silent valley, Nelliampathy, Parambikulam (Palakkad), Neyyar wildlife sanctuary, Peppara Wildlife sanctuary (Thiruvananthapuram), Peechi-Vazhani wildlife sanctuary (Thrissur), New Amarambalam reserve forest (Malappuram), Vanaparvam biodiversity park, Kakkavayal (Kozhikode), Kollam, Alappuzha, Pathanamthitta, Kasaragod.

6. ***Apis cerana* Fabricius, 1793**

   Source: Mathew *et al.* (2004a, 2004b, 2005, 2007), Suresh *et al.* (1999), Mathew and Mohanadas (2001), Mathew (2004, 2009), Leena and Nasser (2015), Sheeja and Jobiraj (2017), Erra and Shanas (2019).

   Distribution: Silent valley, Nelliampathy, Parambikulam (Palakkad), Neyyar wildlife sanctuary, Peppara Wildlife sanctuary (Thiruvananthapuram), Shendurney wildlife

sanctuary (Kollam), Peechi-Vazhani wildlife sanctuary (Thrissur), Munnar, Wayanad, New Amarambalam reserve forest (Malappuram), Kannur, Vanaparvam biodiversity park Kakkavayal (Kozhikode), Alappuzha, Pathanamthitta, Kasaragod.

7. ***Apis florea*** **Fabricius, 1787**

Source: Suresh *et al.* (1999), Mathew (2004, 2009), Sheeja and Jobiraj (2017), Erra and Shanas (2019)

Distribution: Parambikulam wildlife sanctuary (Palakkad), New Amarambalam reserve forest (Malappuram), Vanaparvam biodiversity park, Kakkavayal (Kozhikode), Kollam, Pathanamthitta, Thiruvananthapuram.

8. ***Apis mellifera*** **Linnaeus, 1758**

Source: Sheeja and Jobiraj (2017).

Distribution: Vanaparvam biodiversity park, Kakkavayal (Kozhikode)

Genus *Braunsapis* Michener, 1969

They are very small black bees with two submarginal cells in the forewing. Most species have yellow or ivory markings on the face and scopa of female do not form tibial corbicula.

9. ***Braunsapis malliki*** **Rayes, 1991**

Source: Mathew (2004)

Distribution: Kerala

10. ***Braunsapis clarihirta*** **Rayes, 1991**

Source: Mathew (2004)

Distribution: Kerala

11. ***Braunsapis mixta*** **(Smith, 1852)**

Source: Mathew *et al.* (1987), Reyes (1991), Mathew (2004)

Distribution: Nilambur (Malappuram), Peechi (Thrissur), Aluva (Ernakulam)

12. ***Braunsapis picitarsis*** **(Cameron, 1902)**

Source: Reyes (1991), Mathew (2004)

Distribution: Ponmudi (Thiruvananthapuram)

13. ***Braunsapis cupulifera*** **(Vachal, 1895)**

Source: Sheeja and Jobiraj (2017), Bijoy *et al.* (2019)

Distribution: Vanaparvam biodiversity park, Kakkavayal (Kozhikode), Chittur (Palakkad)

14. ***Braunsapis narendrani*** **Jobiraj, 2004**

Source: Jobiraj (2004)

Distribution: Kerala

15. ***Braunsapis puangensis*** **(Cockerell, 1929)**

Source: Reyes (1991)

Distribution: Walayar (Palakkad)

Genus *Ceratina* Latreille, 1802

They are known as small carpenter bees. They are sparsely haired shiny bees and size vary from small to medium. Forewing has three submarginal cells and stigma wider than pre-stigma. Clypeus has an inverted 'T' like appearance.

16. ***Ceratina hieroglyphica*** **Smith, 1854**

Source: Mathew (2004), Leena and Nasser (2015), Sheeja and Jobiraj (2017), Erra and Shanas (2019)

Distribution: Kannur, Vanaparvam biodiversity park, Kakkavayal (Kozhikode), Thiruvananthapuram, Kollam, Pathanamthitta, Kasaragod

17. ***Ceratina binghami*** **Cockerell, 1908**

Source: Bijoy *et al.* (2019), Erra and Shanas (2019)

Distribution: Chittur (Palakkad), Thiruvananthapuram, Kollam, Pathanamthitta, Kasaragod

18. ***Ceratina vechti*** **(Baker, 1997)**

Source: Baker (1997)

Distribution: Thiruvananthapuram

19. ***Ceratina waini*** **(Shiokawa and Sakagami, 1969)**

Source: Gupta and Yanega (2003)

Distribution: Thiruvananthapuram

20. ***Ceratina unimaculata*** **Smith, 1854**

Source: Mathew and Mohanadas (2001), Mathew (2004), Erra and Shanas (2019)

Distribution: Munnar (Idukki), Thiruvananthapuram, Kollam, Pathanamthitta, Kasaragod

21. ***Ceratina simillima*** **Smith, 1854**

Source: Erra and Shanas (2019)

Distribution: Thiruvananthapuram, Kollam, Pathanamthitta, Kasaragod

Genus *Lisotrigona* Moure, 1961

They are minute stingless bees with body length varies from 2.5 to 4.2 mm. Their wing venation is greatly reduced. Submarginal cells absent in forewing and hindwing lack closed cells.

22. ***Lisotrigona chandrai*** **Viraktamath and Sajan Jose, 2017**

Source: Viraktamath and Jose (2017)

Distribution: Kanhangad (Kasaragod), Thaliparamba (Kannur)

23. ***Lisotrigona mohandasi*** **Jobiraj and Narendran, 2004**

Source: Jobiraj and Narendran (2004)

Distribution: Kerala Forest Research Institute, Peechi (Thrissur)

Genus *Tetragonul*a Jurine, 1807

They are stingless bees with size varying from 5 to 12mm. Their forewing has one or two submarginal cells and hindwing with jugal lobe. Worker bees possess vestigial stingers.

24. ***Tetragonula calophyllae*** **Shanas and Faseeh, 2019**

Source: Shanas and Faseeh (2019)

Distribution: Kumbazha (Pathanamthitta), Malayam (Thiruvananthapuram)

25. ***Tetragonula perlucipinnae*** **Shanas and Faseeh, 2019**

Source: Shanas and Faseeh (2019)

Distribution: Ayarote (Kasaragod)

26. ***Tetragonula travancorica*** **Shanas and Faseeh, 2019**

Source: Shanas and Faseeh (2019), Erra and Shanas (2019).

Distribution: Ambanad estate (Kollam), Vellayani, Attingal (Thiruvananthapuram), Alappuzha, Pathanamthitta, Kasaragod.

Remarks: Though Rahman *et al.* (2015) reported *Tetragonula laeviceps* (Smith, 1857) the species in Kerala, but Rasmussen (2008, 2013) observed that this species not found in Kerala. Hence it is not added in the check list. According to Shanas and Faseeh (2019), *Tetragonula iridipennis* (Smith, 1854), which is popularly known as *Trigona iridipennis* do not occur in India. The most widespread species in India is *Tetragonula travancorica* Shanas and Faseeh, 2019. So, *Tetragonula iridipennis* (Smith, 1854) is not included in this checklist.

Genus *Thyreus* Panzer, 1801

They are cleptoparasitic black bees with blue or white patches or spots on metasoma. Their wing venation is well-developed. Their thorax is shorter than metasoma and basitibial plate absent. Females do not possess any pollen-collecting structures.

28. ***Thyreus ramosus*** **(Lepeletier, 1841)**

Source: Suresh *et al.* (1999), Mathew (2004, 2009)

Distribution: Parambikulam wildlife sanctuary (Palakkad), New Amarambalam reserve forest (Malappuram)

Genus *Xylocopa* Latreille, 1802

They are known as large carpenter bees. They enjoy cosmopolitan distribution and are characterized by the absence of stigma in the forewing. They possess very long prestigma and marginal cell. Arolia is mostly absent.

29. ***Xylocopa violacea* (Linnaeus, 1758)**

Source: Sheeja and Jobiraj (2017)

Distribution: Vanaparvam biodiversity park, Kakkavayal (Kozhikode)

30. ***Xylocopa nasalis* Westwood, 1842**

Source: Maa (1938), Gupta and Yanega (2003), Mathew (2004, 2009), Sheeja and Jobiraj (2017)

Distribution: Kochi (Ernakulam), Thiruvananthapuram, New Amarambalam reserve forest (Malappuram), Vanaparvam biodiversity park, Kakkavayal (Kozhikode)

31. ***Xylocopa fenestrata* (Fabricius, 1798)**

Source: Maa (1938), Gupta and Yanega (2003), Sheeja and Jobiraj (2017)

Distribution: Kerala, Vanaparvam biodiversity park, Kakkavayal (Kozhikode)

32. ***Xylocopa ruficornis* Fabricius, 1804**

Source: Mathew *et al.,* (2004a, 2004b, 2005, 2007), Mathew (2004, 2009), Erra and Shanas (2019)

Distribution: Neyyar Wildlife sanctuary, Peppara Wildlife sanctuary (Thiruvananthapuram), Shendurney wildlife sanctuary (Kollam), Peechi-Vazhani wildlife sanctuary (Thrissur), New Amarambalam reserve forest (Malappuram), Alappuzha, Kasaragod.

33. ***Xylocopa aestuans* (Linnaeus, 1758)**

Source: Sheeja and Jobiraj (2017)

Distribution: Vanaparvam biodiversity park, Kakkavayal (Kozhikode)

34. ***Xylocopa auripennis* Lepeletier,1841**

Source: Maa (1938), Gupta and Yanega (2003)

Distribution: Walayar (Palakkad)

35. ***Xylocopa latipes* (Drury, 1773)**

Source: Maa (1938), Gupta and Yanega (2003)

Distribution: Thenmala (Kollam), Thiruvananthapuram

36. ***Xylocopa tenuiscapa* Westwood, 1840**

Source: Maa (1938), Gupta and Yanega (2003)

Distribution: Peechi (Thrissur)

37. ***Xylocopa amethystina* (Fabricius, 1793)**

Source: Maa (1938)

Distribution: Kerala

38. ***Xylocopa tranquebarica* (Fabricius, 1804)**

Source: Maa (1938), Mathew (1993, 2004)

Distribution: Malayatoor (Ernakulam)

Remarks: Apart from these genera from family Apidae, another genus called *Nomada* Scopoli, 1770 was also reported from Kerala (Mathew, 2004) without any species identity from literature. Bees of this genus are commonly known as cuckoo bees. This genus is included in this checklist.

Family Halictidae

They are known as sweat bees. In India, there are 216 species of Halictid bees under 14 genera (Pannure and Belavadi, 2019). They play an important role in the pollination of many crops and vegetation and have a wide range of ecological

adaptations (Saini and Rathor, 2012). According to Ascher and Pickering (2020), genera like *Austronomia, Acunomia, Curvinomia, Gnathonomia, Hoplonomia, Leuconomia, Pachynomia, Macronomia, Maynenomia, Nomiaspis* are now treated as subgenera. Species of bees belonged to these genera are now placed under different genera. The subgenus is also given for such species in this checklist.

Genus *Halictus* Latreille, 1804

This genus mostly found in Palaearctic region, but some species are reported from the Oriental region. Females are characterized by the clypeal truncation at the margins from distal to preapical fimbria, extended downward at each side of the labrum as a small and sharp projection and apex of terga with metasomal hair bands (Saini and Rathode, 2012).

39. ***Halictus tectonae* Narendran and Jobiraj, 2000**

Source: Narendran *et al.* (2000), Mathew (2004)

Distribution: Peechi (Thrissur)

Genus *Lasioglossum* Curtis, 1833

Members of this genus are either cleptoparasites or social bees forming small or large colonies. They are characterized by relatively few scopal hairs and the presence of femoral corbicula.

40. ***Lasioglossum nathanae* Pauly, 2001**

Source: Pauly (2001)

Distribution: Ponmudi (Thiruvananthapuram)

41. ***Lasioglossum serenum* (Cameron, 1897)**

Source: Bijoy *et al.* (2019)

Distribution: Chittur (Palakkad)

42. ***Lasioglossum triste* (Vachal, 1895)**

Source: Bijoy *et al.* (2019)

Distribution: Chittur (Palakkad)

43. ***Lasioglossum vagans* (Smith, 1857)**

Source: Mathew and Mohanadas (2001), Mathew (2004), Bijoy *et al.* (2019)

Distribution: Munnar (Idukki), Chittur (Palakkad)

Genus *Lipotriches* Gerstaecker, 1858

This is a widespread genus in the Oriental region. They are characterized by the presence of pronotal carina at its anterior edge and simple tegulae. The mandible is bidentate or tridentate (Saini and Rathode, 2012).

44. ***Lipotriches phenacura* (Cockerell, 1911)**

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

45. ***Lipotriches fulvinerva* (Cameron, 1907)**

Source: Manjusha and Jobiraj (2018)

Distribution: Pulpally (Wayanad)

46. ***Lipotriches aurifrons* (Smith, 1853)**

Source: Bijoy *et al.* (2019)

Distribution: Chittur (Palakkad)

47. ***Lipotriches arcuata* (Pauly, 2009)**

Subgenus: *Austronomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

48. ***Lipotriches notiomorpha* (Hirashima, 1978)**

Subgenus: *Austronomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

49. ***Lipotriches pseudoscuetellata*** **(Pauly, 2009)**

Subgenus: *Austronomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

50. ***Lipotriches antennata*** **(Smith, 1875)**

Subgenus: *Macronomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Madayipara (Kannur)

51. ***Lipotriches karnatakaensis*** **(Pauly, 2009)**

Subgenus: *Macronomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

52. ***Lipotriches walayarensis*** **(Pauly, 2009)**

Subgenus: *Macronomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

53. ***Lipotriches dilatata*** **Pauly, 2009**

Subgenus: *Macronomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Mananthavady (Wayanad)

54. ***Lipotriches chalcea*** **(Cockerell, 1920)**

Subgenus: *Maynenomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Mananthavady (Waynad)

55. ***Lipotriches keralaensis*** **(Pauly, 2009)**

Subgenus: *Maynenomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

56. ***Lipotriches nathani*** **(Pauly, 2009)**

Subgenus: *Maynenomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

57. ***Lipotriches exagens*** **(Walker, 1860)**

Source: Leena and Nasser (2015)

Distribution: Kannur

58. ***Lipotriches taprobanae*** **(Cameron, 1897)**

Source: Leena and Nasser (2015)

Distribution: Kannur

Genus *Nomia* Latreille, 1804

They are characterized by the presence of preapical tooth on the underside of the femurs in males and females with incomplete basitibial plate. The metanotum does not have double projections.

59. ***Nomia curvipes*** **(Fabricius, 1793)**

Source: Mathew (2004), Pannure and Belavadi (2017), Manjusha and Jobiraj (2018), Erra and Shanas (2019)

Distribution: Walayar (Palakkad), Thiruvananthapuram, Kollam, Pathanamthitta, Kasaragod, Alappuzha.

60. ***Nomia crassipes*** **(Fabricius, 1798)**

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Padannakkad (Kasaragod), Walayar (Palakkad)

61. ***Nomia chalybeata*** **Smith, 1875**

Source: Mathew (2004)

Distribution: Kerala

62. ***Nomia carinata*** **Smith, 1875**

Subgenus: *Hoplonomia*

Source: Bijoy *et al.* (2019)

Distribution: Chittur (Palakkad)

63. ***Nomia iridescens*** **Smith, 1857**

Subgenus: *Acunomia*

Source: Manjusha and Jobiraj (2018)

Distribution: Thamarassery (Kozhikode), Malappuram

64. ***Nomia thoracica*** **Smith, 1875**

Subgenus: *Gnathonomia*

Source: Manjusha and Jobiraj (2017)

Distribution: Thachampoyil, Thamarassery (Kozhikode)

65. ***Nomia aurata*** **Bingham, 1897**

Subgenus: *Gnathonomia*

Source: Manjusha and Jobiraj (2017)

Distribution: Kerala

66. ***Nomia elliotii*** **Smith, 1875**

Subgenus: *Hoplonomia*

Source: Mathew *et al*. (1987), Mathew (2004), Pannure and Belavadi (2017), Manjusha and Jobiraj (2018), Erra and Shanas (2019)

Distribution: Nilambur (Malappuram), Peechi (Thrissur), Ponmudi (Thiruvananthapuram), Madayipara (Kannur), Kozhikode, Kollam, Pathanamthitta, Alappuzha, Kasaragod.

67. ***Nomia interstitialis*** **Cameron, 1898**

Subgenus: *Leuconomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

68. ***Nomia rufitarsis*** **Smith, 1875**

Subgenus: *Leuconomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

69. ***Nomia brevipes*** **Friese, 1914**

Subgenus: *Leuconomia*

Source: Manjusha and Jobiraj (2018)

Distribution: Thamarassery (Kozhikode)

70. ***Nomia westwoodi*** **Gribodo, 1894**

Source: Erra and Shanas (2019)

Distribution: Thiruvananthapuram, Kollam, Pathanamthitta, Alappuzha, Kasaragod

Genus *Pseudapis* Kirby, 1900

Pseudapis is a widespread genus with enlarged tegulae, which reaches the posterior margin of scutum. Females possess complete basitibial plate.

71. ***Pseudapis oxybeloides*** **(Smith, 1875)**

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Madayipara (Kannur)

72. ***Pseudapis carcharodonta*** **(Baker, 2002)**

Subgenus: *Nomiapis*

Source: Baker (2002), Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

73. ***Pseudapis bispinosa*** **(Brulle, 1832)**

Subgenus: *Nomiapis*

Source: Mathew (2004)

Distribution: Kerala

74. ***Pseudapis aliena*** **(Cameron, 1898)**

Subgenus: *Pachynomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

75. ***Pseudapis nathani*** **(Pauly, 2009)**

Subgenus: *Pachynomia*

Source: Pannure and Belavadi (2017), Manjusha and Jobiraj (2018)

Distribution: Walayar (Palakkad)

Genus *Sphecodes* Latreille, 1804

They are cleptoparasitic bees commonly known as blood bees because a majority of members in this genus are red and black in colour. They are also known as cuckoo bees and lack pollen-collecting hairs.

76. ***Sphecodes invidus*** **(Cameron, 1897)**

Source: Bijoy *et al.* (2019)

Distribution: Chittur (Palakkad)

77. ***Sphecodes rubripes*** **Spinola,1838**

Source: Bijoy *et al.* (2019)

Distribution: Chittur (Palakkad)

78. ***Sphecodes apicatus*** **Smith, 1853**

Source: Bijoy *et al.* (2019)

Distribution: Chittur (Palakkad)

Family Megachilidae

They are long-tongued bees with a solitary mode of lifestyle. This family of bees enjoys cosmopolitan distribution. In India, there are 270 species of Megachilid bees under 27 genera (Pannure and Belavadi, 2019).

Genus *Euaspis* Gerstacker, 1858

This genus consists of cleptoparasitic bees. They are black to bluish coloured bees with red coloured metasoma. Size varies from moderate to large.

79. ***Euaspis edentata*** **Baker, 1995**

Source: Baker (1995)

Distribution: Walayar (Palakkad)

Genus *Coelioxys* Latreille, 1809

They are cleptoparasitic bees characterized by terminally tapering abdomen in both sexes. Females do not possess scopa and T_6 of males with two pairs of preapical spines.

80. ***Coelioxys cuneatus*** **Smith, 1875**

Source: Suresh *et al.* (1999), Mathew (2004)

Distribution: Parambikulam wildlife sanctuary (Palakkad)

81. ***Coelioxys perseus*** **Nurse, 1904**

Source: Bingham (1897)

Distribution: Malabar

Genus *Megachile* Latreille, 1802

They neatly cut leaves for constructing their nests, hence commonly known as leafcutter bees. They are characterized by two submarginal cells in the forewing, absence of basitibial and pygidial plates, scopa on the underside of the abdomen and T_6 of male with transverse preapical carina.

82. ***Megachile centuncularis*** **(Linnaeus, 1758)**

Source: Sheeja and Jobiraj (2017)

Distribution: Vanaparvam biodiversity park, Kakkavayal (Kozhikode)

83. ***Megachile lanata*** **(Fabricius, 1775)**

Source: Suresh *et al.* (1999), Mathew (2004,

2009), Sheeja and Jobiraj (2017), Erra and Shanas (2019)

Distribution: Parambikulam wildlife sanctuary (Palakkad), New Amarambalam reserve forest (Malappuram), Vanaparvam biodiversity park, Kakkavayal (Kozhikode), Thiruvananthapuram, Pathanamthitta.

84. ***Megachile carbonaria* Smith, 1853**

Source: Suresh *et al.* (1999), Mathew (2004), Sheeja and Jobiraj (2017)

Distribution: Parambikulam wildlife sanctuary (Palakkad), Vanaparvam biodiversity park, Kakkavayal (Kozhikode)

85. ***Megachile quartinae* Gribodo, 1884**

Source: Suresh *et al.,* (1999), Mathew (2004), Sheeja and Jobiraj (2017)

Distribution: Parambikulam wildlife sanctuary (Palakkad), Vanaparvam biodiversity park, Kakkavayal (Kozhikode)

86. ***Megachile anthracina* Smith, 1853**

Source: Mathew (2004)

Distribution: Kerala

87. ***Megachile disjuncta* (Fabricius, 1781)**

Source: Mathew (2004), Erra and Shanas (2019)

Distribution: Thiruvananthapuram, Pathanamthitta

Remarks: Apart from these three genera from family Megachilidae, another genus called ***Chelostoma* Latreille, 1809** was also reported from Kerala (Bijoy *et al.,* 2019) without any species identity from literature. This genus is added to the number of bee genera reported from Kerala.

Family Colletidae and Andrenidae

Literature and KFRI collections suggest the presence of three species of bees from the family Colletidae and one species from family Andrenidae. But bee taxonomists suggest that these two families are not found in Kerala. So, further clarifications have to be made on this by conducting taxonomic studies on these specimens. Hence those species are not included in this checklist.

This checklist was prepared entirely based on literature review and it revealed a rich diversity of bees in Kerala. Details regarding the bee diversity of Kerala were collected from various sources including published articles, books, catalogues, checklists etc. According to the literature, bees of the families Apidae, Halictidae, Megachilidae are reported from Kerala.

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Field efficacy of bio-inputs and insecticides against melon fruit fly, *Zeugodacus cucurbitae* (Coquillett) (Diptera: Tephritidae) in bitter gourd (*Momordica charantia* L.)

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ABSTRACT: Field efficacy of different bio-inputs and insecticides against melon fruit fly, *Zeugodacus cucurbitae* (Coquillett) in bitter gourd was carried out in farmer's field. The effect of different bio-inputs (ITK concoction) and insecticides were superior over control in reducing the fruit fly damage and increasing yield. The application of spinosad 45 SC and chlorantraniliprole 18.5 SC gave maximum fruit yield (12,200 and 14,540 kg/ha) and (11,780 and 13,950 kg/ha) followed by agniastram (10,950 and 13,600 kg/ha), karpurakaraisal (10,570 and 13,095 kg/ha) in *Kharif* and *Rabi*, respectively. The minimum fruit yield was recorded in ten leaf extract (9560 and 11,110 kg/ha) during *Kharif* and *Rabi.* The benefit cost ratio was maximum in spinosad 45 SC (1:2.33 and 1:2.81) and chlorantraniliprole 18.5 SC (1:2.18 and 1:2.61) followed by agniastram (1:2.14 and 1:2.56), karpurakaraisal (1:2.20 and 1: 2.40) in *Kharif* and *Rabi*.

KEY WORDS: ITK concoction, insecticides, melon fruit fly, management

INTRODUCTION

Bitter gourd (*Mormodica charantia* L.) is the most important vegetable among the cucurbitaceous crops which occupies a predominant place in Indian vegetables. The tender fruit is found to have medicinal and nutritional properties *viz.,* reducing blood glucose level, asthma and ulcer (Oishi *et al*., 2007) as it contains a steroidal compound saponins (charantin) and insulin like peptide (Altinterim, 2012). Bitter gourd is being cultivated in an area of 95.00 lakh ha, with 1087 MT/ha production and 10.87 MT/ha of productivity in India (Anon, 2018). Bitter gourd is attacked by various pests *viz.* aphids, melon fruit flies, hadda beetle, pumpkin caterpillar and gall fly during different growth stages. Among the pests of bitter gourd, melon fruit fly *Zeugodacus cucurbitae* (Coquillett) (Diptera: Tephritidae) is important as it causes yield loss of 30 to 100 per cent (Dhillon *et al*., 2005).

To meet this yield reduction, fruit fly management has to be taken in various methods. Mostly using insecticides such as spinosad 45 SC (4.67 eggs and 80.28 %) and chlorantraniliprole 18.5 SC (6.33 eggs and 73.23 %) had minimum number of eggs laid and high oviposition deterrence of melon fruit fly, respectively (Mawtham *et al*., 2019). However,

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Synthetic insecticides were found to be carcinogenic, teratogenicity to humans and pollutes the environment by upsetting the balance of nature (Jenkins *et al*., 2013) and involves huge insecticide cost (25%) (Nasiruddin *et al*., 2004). Therefore, desirable alternative methods of pest control using botanicals and traditional pest management practices has to be exploited (El-Wakeil, 2013). Botanical extracts from neem (*Azadiracta indica*), lantana (*Lantana camara*), garlic (*Allium sativam*), turmeric (*Curcuma longa*), acacia (*Acacia auriculiformis*) (Ignacimuthu, 2004: Thakur and Gupta, 2012) and bio-inputs like, cow urine, meenamilam, neem oil, ginger-garlic extracts, ten leaf extract, tobacco leaf extract, agniastram and neemastram (Priya *et al*., 2018) acted as oviposition deterrent, repellent and antifeedant against melon fruit fly (Singh and Singh, 1998). Karpurakaraisal with main compound of camphor has one of the monoterpenes; hence it is effective against pupation, adult emergence, deformation, oviposition, adult longevity and ovarian development of fruit fly (El-Minshawy *et al*., 2018). Efficacy of bio-inputs in comparison to insecticides for the management of fruit fly in bitter gourd was investigated and the results are presented.

MATERIALS AND METHODS

Two field experiments were conducted during *Kharif* and *Rabi* season, 2018-19 at Elamanam village, Tiruchirappalli district, Tamil Nadu, India under Randomised Block Design (RBD) with eight treatments and replicated thrice. The bitter gourd East west hybrid (F_1) seeds were raised in a plot size of 6m × 4m with spacing of 60cm × 200 cm. All the recommended packages of practices were followed according to TNAU crop production guide except plant protection measures. The treatments imposed for the study comprised of five bio-inputs and two insecticides *viz.,* 5% karpurakaraisal (camphor), 5% tobacco mixture (agniastram), 0.5% fish acid (mennamilam), 5% ten leaf extract (pathilaikasayam), 5% NSKE, 0.12 ml/l spinosad 45 SC and 0.4 ml/l chlorantraniliprole 18.5 SC. The melon fruit fly infestation was recorded in each plot on five randomly selected labelled plants for each observation. The foliar spray was given after 30 per cent incidence of fruit fly damage in each plot. Second spray was given after 15 days by using high volume hand operated compression knapsack sprayer. Totally two rounds of spray in *Kharif* and three rounds in *Rabi* of each treatment were given and the fruits were harvested thrice after each spraying. Observation on pre and post treatment counts was made on 1st, 5th, 10th and 15th day after each application. Mean damage percent was calculated using the formula given by Shivangi *et al*. (2017).

$$\text{Fruit damage (\%)} = \frac{\text{No of infested fruits}}{\text{Total no of harvested fruits}} \times 100$$

$$\text{Fruit Infestation over control (\%)} = \frac{\text{Yield in the treatment to be assessed} - \text{Yield in the untreated check}}{\text{Yield in untreated check}} \times 100$$

The benefit cost ratio was calculated by using the formula

$$\text{Benefit/Cost ratio} = \frac{\text{Gross returns (Rs./ha)}}{\text{Cost of cultivation (Rs./ha)}}$$

Preparation of bio-inputs

Meenamilam (Fish acid): The fish waste and jaggery were taken at the rate of one kg each and mixed well and kept in a plastic bucket. The content was stirred once in five days upto one month and then kept undisturbed for fermentation upto 40 days. After 45 days, the content was filtered using muslin cloth and kept in an airtight container for future use.

Agniastram (Tobacco extract): It is similar to the ZBNF (Zero Budget Natural Farming) agniastram, but without added to cow dung. The main constituents for 'agniastram' were green chilli, ginger, garlic and dry leaves of tobacco. 500g chilli, ginger and garlic were crushed and then 250 g of dry tobacco leaves were mixed in 10 l of country cow urine and boiled in a mud pot till one third of the total volume of the extract was obtained. The extract was kept for 24 h and then filtered and stored in an air tight plastic container under room temperature for future use.

Pathilaikasayam (Ten leaf extract): The ten leaf extract includes the leaves of Notchi (*Vitex negundo* L.), Aristolochia (*Aristolochia indica*

L.), Papaya (*Carica papaya* L.), Heartleaf moonseed (*Tinospora cordifolia* M.) and custard apple (*Annona squamosa* L.) as basic five ingredients in addition to leaves from other five plants *viz.,* Neem (*Azadirachta indica* A. juss), calotropis (*Calotropis gigantea* L.), waste land weed (*Tephrosia purpurea* L.), physic nut (*Jatropha curcas* L.), pungam (*Millettia pinnata* L.). The leaves from notchi, aristolochia, papaya, heartleaf moonseed and custard apple each of 5 kg and neem, calotropis, waste land weed, physic nut, pungam leaves each of 2 kg were taken in 200 l of water, 5 l of country cow urine and 3 kg of cow dung and stored in an airtight plastic container for three months and allowed to ferment. The plastic container was kept in a cool shaded place and stirred three times a day for efficient mixing and uniform fermentation.

NSKE (Neem seed kernel extract): The neem seed kernel (4 kg) was ground gently into powder using a blender. One kg of powdered neem seed kernel was tied in a filter cloth and soaked in one litre of water overnight. Then the extract was filtered twice or thrice and finally prepared 5 per cent of NSKE for used field experiments studies.

Karpurakaraisal (camphor mixture): The camphor mixture was prepared by mixing one litre of neem oil with 50 ml of country fresh cow urine and 5 g of camphor (pachaikarpuram), stirred gently and kept in closed containers. Prepared mixture (5%) was used for field and laboratory experiments. Since, camphor is insoluble in water, alcohol was used to dissolve the camphor and mixed with neem oil.

The collected data was statistically analysed in a Randomized Block Design of field experiments through AGRES programme. The treatment mean values were compared by Latin Square Design (LSD).

RESULTS AND DISCUSSION

Field efficacy of bio-inputs and insecticides (*Kharif* and *Rabi*, 2018-19)

After first spray, all the treatments were significantly superior to untreated control. The pre count fruit damage ranged from 37.30 to 39.01 per cent. Among the treatments, spinosad 45 SC (14.83 and 17.44 %) and chlorantraniliprole 18.5 SC (19.43 and 20.21 %) showed minimum fruit damage in *Kharif* and *Rabi*, respectively followed by agniastram (28.48 and 25.83 %). The fruit fly damage recorded maximum in ten leaf extract was 45.65 and 42.74 %. Spinosad 45 SC (73.28 and 64.94 %) and chlorantraniliprole 18.5 SC (64.99 and 59.38 %) reduced the fruit damage in *Kharif* and *Rabi,* followed by agniastram (48.69 and 48.08 %), karpurakaraisal (41.75 and 39.25 %), NSKE (34.97 and 34.71 %), fish acid (26.03 and 25.51) and ten leaf extract (17.76 and 14.09 %). Waseem *et al*. (2009) who results concordance with spinosad 45 SC (54.00 ml/I) had minimum percentage of melon fruit fly damage (6.0 %) on foliar applications in cucumber (Table 1 and 2).

Comparative analysis of bio-inputs and insecticides (*Kharif* and *Rabi*, 2018-19)

In melon fruit fly management, spinosad 45 SC and chlorantraniliprole 18.5 SC recorded minimum fruit damage (14.83, 17.44 and 19.43, 20.21 %) in *Kharif* (2018) and *Rabi* (2019), respectively. Shivangi and Swami (2017) reported similar findings that repeated application of spinosad 45 SC had significant reduction in fruit oviposition mark (1.5/five plants) and 49.02 per cent avoidable losses of cucumber against melon fruit fly. Among the bio-inputs, agniastram (25.83 %) > karpurakaraisal (30.22 %) > NSKE (32.48 %) > fish acid (37.00 %) > ten leaf extract (42.74 %) were most effective in the order of fruit damage. According to El-Minshawy *et al*. (2018) results showed camphor was completely inhibited egg deposition (0.00 No.) and female longevity (40.33 days) compared with 68.33 days in control treatment ($P < 0.05$). In addition, significantly decreased pupation and adult emergence percentages at 20 mg/kg of camphor for pupae ($P < 0.05$). Therefore, karpurakaraisal were more effective against management of fruit flies than other formulations.

In *Kharif* and *Rabi*, spinosad 45 SC and chlorantraniliprole 18.5 SC treatment gave maximum fruit yield (12,200 and 14,540 kg/ha) and (11,780 and 13,950 kg/ha) followed by agniastram

Table 1. Field efficacy of bio-inputs and insecticides against melon fruit fly in bitter gourd (*Kharif*, 2018)

Treatments	Dose (ml/l)	Fruit damage 15 DAS (%)			Fruit damage (%)*	Reduction over control (%)
		Pre count (%)	Ist spray	IInd spray		
T_1- Karpura karaisal (Camphor mixture)	30.0	39.01 (38.65)	34.07 (35.71)^{c}	30.59 (33.58)^{bc}	32.33 (34.64)	41.75
T_2- NSKE (Neem Seed Kernel Extract)	50.0	35.71 (36.70)	37.40 (37.70)^{d}	34.81 (36.16)^{cd}	36.10 (36.93)	34.97
T_3- Ten leaf extract (Pathilaikasayam)	50.0	39.01 (38.65)	46.49 (42.99)^{e}	44.82 (42.03)^{e}	45.65 (42.51)	17.76
T_4- Fish acid (Meenamilam)	5.0	37.30 (37.64)	42.27 (40.55)^{d}	39.86 (39.15)^{d}	41.06 (39.85)	26.03
T_5- Agniastram (Tobacco mixture)	50.0	39.01 (38.65)	31.24 (33.98)^{b}	25.73 (30.48)^{b}	28.48 (32.23)	48.69
T_6- Spinosad 45 SC	0.12	37.30 (37.64)	15.67 (23.32)^{a}	14.00 (21.97)^{a}	14.83 (22.64)	73.28
T_7- Chlorantraniliprole 18.5 SC	0.4	38.06 (38.09)	21.07 (27.32)^{a}	17.79 (24.95)^{a}	19.43 (26.13)	64.99
T_8- Untreated control		37.30 (37.64)	57.37 (49.24)^{f}	53.66 (47.10)^{f}	55.51 (48.17)	
SEd			1.09	1.66		
CD (p=0.05)			2.35	3.55		

*Mean of three replications, DAS-Days after spray. Figures in parentheses are arc sine transformed values.
In a column, means followed by different letters are significantly different (p=0.05) as per LSD

Table 2. Field efficacy of bio-inputs and insecticides against melon fruit fly in bitter gourd (*Rabi*, 2019)

Treatments	Dose (ml/l)	Fruit damage 15 DAS (%)				Fruit damage (%)*	Reduction over control (%)
		Pre count (%)	Ist spray	IInd spray	IIIrd spray		
T_1- Karpura karaisal (Camphor mixture)	30.0	34.07 (35.71)	34.25 (35.82)^{d}	29.51 (32.91)^{d}	26.90 (31.24)^{d}	30.22 (33.32)	39.25
T_2- NSKE (Neem Seed Kernel Extract)	50.0	33.33 (35.26)	36.86 (37.38)^{e}	32.27 (34.61)^{e}	28.33 (32.16)^{d}	32.48 (34.71)	34.71
T_3- Ten leaf extract (Pathilaikasayam)	50.0	34.25 (35.82)	46.42 (42.95)^{g}	41.95 (40.37)^{g}	39.85 (39.14)^{f}	42.74 (40.82)	14.09
T_4- Fish acid (Meenamilam)	5.0	32.54 (34.78)	40.71 (39.64)^{f}	36.87 (37.39)^{f}	33.61 (35.43)^{e}	37.06 (37.48)	25.51
T_5- Agniastram (Tobacco mixture)	50.0	34.25 (35.82)	28.56 (32.30)^{c}	25.41 (30.27)^{c}	23.53 (29.01)^{c}	25.83 (32.23)	48.08
T_6- Spinosad 45 SC	0.12	30.16 (33.31)	19.28 (26.05)^{a}	16.94 (24.30)^{a}	16.11 (23.65)^{a}	17.44 (24.67)	64.94
T_7- Chlorantraniliprole 18.5 SC	0.4	31.23 (33.98)	21.94 (27.93)^{b}	19.52 (26.22)^{b}	19.17 (25.95)^{b}	20.21 (26.70)	59.38
T_8- Untreated control		32.54 (34.78)	52.61 (46.50)^{g}	48.76 (44.29)^{h}	47.88 (43.79)^{g}	49.75 (44.86)	
SEd			0.63	0.73	0.90		
CD (p=0.05)			1.36	1.55	1.93		

*Mean of three replication. DAS-Days after spray. Figures in parentheses are arc sine transformed values
In a column, means followed by different letters are significantly different (p=0.05) as per LSD

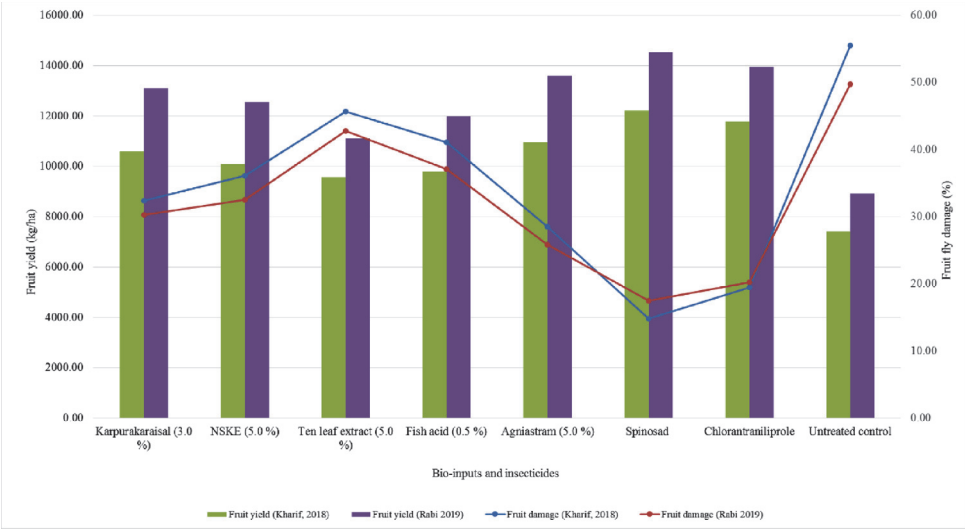

Fig. 1. Comparative analysis on the effect of bio-inputs and insecticides on melon fruit fly damage and fruit yield

(10,950 and 13,600 kg/ha), karpurakaraisal (10,570 and 13,095 kg/ha), NSKE (10,080 and 12,570 kg/ha) and fish acid (9,790 and 11,990 kg/ha) (Table 3, 4 and Fig 1). The minimum fruit yield and per cent increase in yield were recorded in ten leaf extract (9560 and 11,110 kg/ha). Abhilash (2018) reported that azadirachtin (1%) with maximum yield (91.85 q/ha) followed by 5% NSKE (84.82 q/ha), 5 % *A. calamus* (61.91 q/ha) and untreated control (39.92 q/ha) in ridge gourd. Shivangi and Swami (2017) reported similarly that repeated application of spinosad 45 SC had significantly higher fruit yield (555.56 q/ha) followed by NSKE (402.78 q/ha) and untreated control (241.26 q/ha) in cucumber.

The bio-inputs *viz.,* agniastram, fish acid and ten leaf extracts consisted of gram-positive bacteria, *Bacillus subtilis* and *Bacillus vallismortis* and absence of fungus and actinomycetes (Priya *et al*., 2018) and produce biomolecules such as kanosamines and lipopeptides are effective against insect pests (Mazid *et al*., 2011). Vivekanandan (1994) reported various indigenous plant products for traditional pest management practices. Spraying

Table 3. Comparative efficacy of bio-inputs and insecticides in enhancing fruit yield of bitter gourd (*Kharif*, 2018)

S. No.	Treatment	Dose (ml/l)	Cumulative yield (kg / ha)	Yield Increase (%)	Gross return (Rs.)	Net return (Rs.)	Cost-Benefit ratio
1	Karpura karaisal (Camphor mixture)	30.0	10570	42.45	243110	162795	1 : 2.02
2	NSKE (Neem Seed Kernel Extract)	50.0	10080	35.85	231840	150940	1 : 1.86
3	Ten leaf extract (Pathilaikasayam)	50.0	9560	28.84	219880	139230	1 : 1.72
4	Fish acid (Meenamilam)	5.0	9790	31.94	225170	144770	1 : 1.80
5	Agniastram (Tobacco mixture)	50.0	10950	47.57	251850	171550	1 : 2.14
6	Spinosad 45 SC	0.12	12200	64.42	280600	196350	1 : 2.33
7	Chlorantraniliprole 18.5 SC	0.4	11780	58.76	270940	185740	1: 2.18
8	Untreated control		7420		170660	92330	1 : 1.28

Table 4. Comparative efficacy of bio-inputs and insecticides in enhancing fruit yield of bitter gourd (*Rabi*, 2019)

S. No.	Treatment	Dose (ml/l)	Cumulative yield (kg / ha)	Yield Increase (%)	Gross return (Rs.)	Net return (Rs.)	Cost-Benefit ratio
1	Karpura karaisal (Camphor mixture)	30.0	13095	46.80	327575	231260	1 : 2.40
2	NSKE (Neem Seed Kernel Extract)	50.0	12570	40.91	314250	219125	1 : 2.30
3	Ten leaf extract (Pathilaikasayam)	50.0	11110	24.55	277750	182850	1 : 1.92
4	Fish acid (Meenamilam)	5.0	11990	34.42	299750	202850	1 : 2.09
5	Agniastram (Tobacco mixture)	50.0	13600	49.66	340000	237485	1 : 2.56
6	Spinosad 45 SC	0.12	14540	63.06	363500	266685	1 : 2.81
7	Chlorantraniliprole 18.5 SC	0.4	13950	56.39	348750	250530	1 : 2.61
8	Untreated control		8920		223000	131550	1 : 1.44

insecticides recorded lower fruit damage and higher marketable yield. Similarly, bio-inputs *viz.,* agniastram (tobacco mixture) reduced the fruit damage and increased the marketable yield followed by karpurakaraisal (camphor mixture), NSKE, fish acid (Mennamilam) and ten leaf extract.

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Spider diversity of Kerala University Campus, Thiruvananthapuram, Kerala, India

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ABSTRACT: A study of spider diversity of Kerala University Campus, conducted for a period of four months revealed a total of 116 species of spiders belonging to 20 families. Among the families, Salticidae was found as the most common family and among the species *Hersilia savignyi* and *Hippasa agelenoides* were found as the most common species. *Plexipus petersi, Plexipus pykulli, Xysticus minutes* and *Tibellus elongates* were also noted as the commonly found spider species.

KEYWORDS: Spider species, biodiversity, Salticidae

INTRODUCTION

Spiders make up the order Araneae in the class Arachnida. There are currently over 39,000 described species placed in 3,642 genera and 111 families. Major contributions to Indian Arachnology were made by Pocock (1895, 1899a, 1899b, 1900a, 1900b and 1901) and Tikader (1977, 1980, 1982 and 1987) who were responsible for bringing spider studies to the notice of other researchers. India's described spider fauna consists of about 1600 species, perhaps as little as half of the total spider fauna. World-wide, more than 40,000 species of spiders have been described (Uniyal *et al.,* 2011). Although more than 1,400 species have been described from India (and with many more still to be documented), the study on the taxonomy, biology and ecology of Indian spiders remain miserably inadequate. This has largely been due to lack of expertise in this field and the absence of sufficient literature (Sebastian and Peter, 2009). The present study of spider diversity was conducted in the Kerala University Campus, Kariavattom, laden with enchanting greenery covering about 350 acres of land.

MATERIALS AND METHODS

Study Site

Kerala University Campus, Kariavattom (8°32', 8°34'N and 76°52', 76°54' E) is situated about 10 km north of Thiruvananthapuram City, houses the various teaching departments under the University of Kerala. The campus covering about 350 acres of land is located on either side of the National Highway (NH 66). The elevation of the study area is about 57m MSL. The annual temperature variation ranges from 22°C to 34°C. For the purpose of the study the entire campus has been surveyed, by dividing the area into two sites. Site 1 is the

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north block of the campus, and the south region of the campus is selected as site 2. The sites were selected based on the habitat variation and the geographic isolation created by the National Highway (NH 66) as it divides the campus in to two regions. North campus areas are comprised of mixed habitats of wetland, grasslands, small trees and shrubs. The area possesses little or no canopy layer; some area of the north campus is devoted to farming and gardening, new construction and the rest by acacia tree plantation. There is a sacred grove present in it and is the only place that has some amount of canopy layer. Site 1 is again divided into 3 sub sites based on the habitat variation, and they are Botany Garden 1 of site 1 (S1a), Botany Garden 2 of site 2 (S1b) and Acacia tree plantation of site1 (S1c). The south campus is the largest portion of the campus and consists of roads that connect departments, and have the highest concentration of people and buildings. Even though the site possesses a large amount of acacia plantation, these sites have wide variety of habitats in it, which include grasslands, wetland, ponds and good amount of indigenous plants. For the study purpose the site 2 is again divided into 2 sub sites, medicinal garden of site 2 (S2a), Sarovara garden of site 2 (S2b) (Fig. 1).

Sampling Methods

The study was conducted from January 2017 to April 2017. The microhabitats that are likely to support the spiders in the study area such as tree trunks, foliage, water bodies, ground, litter, undergrowth and bushes were searched for spiders. Collections were made by active searching for spiders following a line transect method. Spiders were collected by handpicking method, pit fall trap and beating method.

Handpicking method: The areas around each plant along the transect were thoroughly examined from the top to bottom on leaf blades, flowers and dry leaves for spiders. The ground area near the plants was also searched. According to the collection, the location where the spiders were found was also noted. Spiders were easily collected by leading them into glass vials (5.2 cm x 2.0 cm) from the ground stratum and from the terminals of the plants. All the collected specimens were preserved in 70% ethyl alcohol with proper labeling of locality, date, crop stage and other notes. Field record was maintained throughout the study period.

The beating method: The beating method is suited for sturdier vegetation, such as tree and shrubs. A beating tray (an inverted umbrella is used as beating tray) is placed beneath the tree or shrub, and firmly tap the plant with a stick and collect the spiders that have fallen before they get away.

The pitfall trap: This is the ideal method for catching ground dwelling spiders. Pitfall traps usually consists of suitable pots or jars dug into the ground. At the bottom, the jar contains a small quantity of preserving fluid such as ethylene glycol with a drop of washing-up liquid (to reduce the surface tension). A lid is placed a little way above the trap so that crawling spiders can get by, but small vertebrates, rain, dirt, etc., are kept out of the trap (Sebastian and Peter, 2009).

Identification

The spiders were identified using field guide (Sebastian and Peter, 2009) and Tikader (1977, 1987). World spider catalogue by Platnick (2014) was used for the taxonomy and nomenclature of spiders.

Statistical analysis

Shannon- Weiner Index and Simpson index were used for statistical analysis.

Shannon- Weiner Index is calculated by using the formula,

$$H' = - \sum (p_i \ln P_i)$$

Where,

H'= General diversity index; Pi= Proportion of the ith species such that

Pi= Ni/N; Ni= Number of individuals in the ith species, N= Total number of individuals of all species in the community.

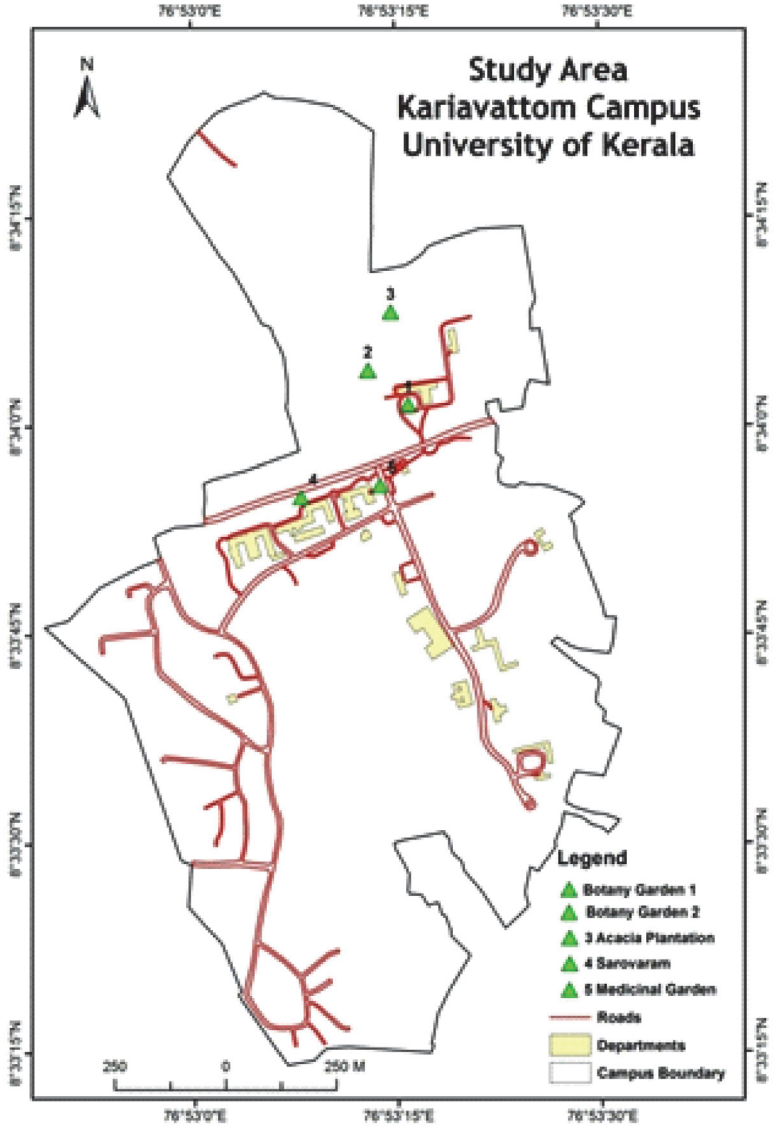


Fig.1 Study area

Simpson index is calculated by using the formula,

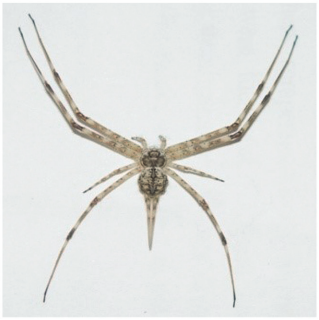
$$D = \sum n(n-1)/N(N-1)$$

Where, n = the total number of organisms of a particular species N = the total number of organisms of all species.

RESULTS AND DISCUSSION

A total 116 species of spiders (we could identify only up to 63 species of spiders at the species level) belonging to 20 families were recorded during the period of 4 months (January 2017- April 2017) study. The classification of observed species revealed that the family Salticidae was the dominant family. Among the 63 identified species, 19 species were belonging to Salticidae. The family Araneidae ranked second with 10 species, followed by the family Thomisidae with 5 species. There were four species each in the family Lycosidae and Tetraganthidae and three species under family Theridiidae and Oxiopidae. In the family Corinnidae, Pholcidae, Sparassidae and Uloboridae there were two species each. The least common families noted

Tibellus elongates



Hersilia savignyi

Hippasa agelenoides

Xysticus minutes

Plexippus paykulli

Plexippus petersi

Chylobrachys hardwicki

Siler semiglaucus

Stegodyphus sarasinorum

Plate 1. Spiders

were Erisidae, Gnaphosidae, Hersilidae, Miturgidae, Philodromidae and Theraphosidae with single species each. Among families, Salticidae was found as the most common family and among the species *Hersilia savignyi* (28 numbers) and *Hippasa agelenoides* (24 numbers) were found as the most common species. *Plexipus petersi, Plexipus pykulli, Xysticus minutes* and *Tibellus elongates* were also found as the common species of the campus (Plate 1). Shannon-Weiner index showed that the spider diversity of the Kariavattom campus as 3.668. The maximum diversity of spiders was obtained from medicinal garden (S2a) of site 2 (3.667), and the lowest measured from the Acacia plantation (S1c) of site1 (2.269). Shannon-Weiner index of site 1 was 3.847 and site 2 as 3.889. Simpson index of site 1 was 0.9686 and site 2 as 0.9755. The guild structure analysis of spider

Table 1. Checklist of spiders collected and identified from Kerala University Campus

Sl. No	Family / Species	Guild	Sl. No	Family / Species	Guild
	ARANEIDAE		25	*Oedignatha scrobiculata (Thorell, 1881)*	Ground dweller
1	*Araneus sp.*	Orb-web builders	26	*Oedignatha sp.*	Ground dweller
2	*Argiope catenulate* (Doleschall, 1859)	Orb-web builders		**ERESIDAE**	
3	*Argiope pulchella* (Thorell, 1881)	Orb-web builders	27	*Stegodyphus sarasinorum* (*Karsch, 189*1)	Space web builders
4	*Chorizopus sp.*	Orb-web builders		**GNAPHOSIDAE**	
5	*Anepsion maritatum* (O.P-Cambridge, 1877)	Orb-web builders	28	*Zelotes ashae* (Tikader & Gajbe, 1976)	Ground runner
6	*Cyrtophora citriola* (Forskal, 1775)	Orb-web builders	29	*Zelotes sp.*	Ground runner
7	*Cyrtophora sp.*	Orb-web builders		**HERSILIDAE**	
8	*Cyclosa bifida (*Doleschall, 1859)	Orb-web builders	30	*Hersilia savignyi* (Lucas, 1836)	Ambushers
9	*Cyclosa fissicauda* (Menge. 1866)	Orb-web builders	31	*Hersilia sp. 1*	Ambushers
10	*Cyclosa sp.*	Orb-web builders	32	*Hersilia sp.2*	Ambushers
11	*Eriovixia laglaisei (Simon, 1877)*	Orb-web builders		**LYNYPHIDAE**	
12	*Gasteracntha germinate (*Fabricius, 1798)	Orb-web builders	33	*Lynyphia sp.*	Sheet web builders
13	*Gasteracntha sp.*	Orb-web builders		**LYCOSIDAE**	
14	*Hypognatha sp.*	Orb-web builders	34	*Hippasa agelenoides (Simon, 1884)*	Ground runners
15	*Micrathena sp.1*	Orb-web builders	35	*Hippasa sp.*	Ground runners
16	*Micrathena sp.2*	Orb-web builders	36	*Lycosa mackenziei* (Gravely, 1924)	Ground runners
17	*Neoscona mukerjei* (Tikader, 1980)	Orb-web builders	37	*Lycosa tista (Tikader, 1970)*	Ground runners
18	*Neoscona vigilans* (Blackwall, 1865)	Orb-web builders	38	*Pardosa pseudoannulata* (Bosenberg &Strand, 1906)	Ground runners
19	*Neoscona sp.*	Orb-web builders		**MIMETIDAE**	
20	*Pasilobus sp.*	Orb-web builders	39	*Mimetus sp.1*	Miscellaneous
	CLUBIONIDAE		40	*Mimetus sp.2*	Miscellaneous
21	*Clubiona sp.1*	Foliage runner		**MITURGIDAE**	
22	*Clubiona sp.2*	Foliage runner	41	*Cheiracanthium danieli* (Tikader, 1975)	Foliage runner
23	*Clubiona sp. 3*	Foliage runner	42	*Cheiracanthium sp.1*	Foliage runner
	CORINNIDAE		43	*Cheiracanthium sp.2*	Foliage runner
24	Castianeira zetes (Simon, 1897)	Ground dweller	44	*Cheiracanthium sp.3*	Foliage runner

Sl. No	Family / Species	Guild	Sl. No	Family / Species	Guild
	OXIOPIDAE		66	*Myrmarachne orientals* (Tikader, 1973)	Stalkers
45	*Oxiopes sunanthae* (Tikader, 1970)	Stalkers	67	*Myrmarachne plataleoides* (O.P-Cambridge, 1877)	Stalkers
46	*Oxiopes swetha* (Tikader, 1970)	Stalkers	68	*Phaecius malayensis* (Wanless,1981)	Stalkers
47	*Oxiopes sp.1*	Stalkers	69	*Phintella vitata* (C.L. koch, 1846)	Stalkers
48	*Oxiopes sp.2*	Stalkers	70	*Plexippus paykulli* (Audouin, 1826)	Stalkers
49	*Peucetia viridiana* (Stoliczka 1869)	Stalkers	71	*Plexippus petersi* (karsch, 1878)	Stalkers
	PHILODROMIDAE		72	*Plexippus sp.*	Stalkers
50	*Tibellus elongates (Tikader, 1960)*	Ambushers	73	*Portia fimbriata* (Doleschall, 1859)	Stalkers
	PHOLCIDAE		74	*Ptocassius sp.*	Stalkers
51	*Crossopriza lyoni* (Blackwall, 1867)	Scattered line weavers	75	*Rhene danieli* (Tikader, 1973)	Stalkers
52	*Pholcus phalangioides* (Fuesslin, 1775)	Scattered line weavers	76	*Rhene flavicomans* (C.L. koch, 1846)	Stalkers
53	*Pholcus sp.*	Scattered line weavers	77	*Siler semiglaucus* (Simon, 1901)	Stalkers
	SALTICIDAE		78	*Telamonia dimidiate* (Simon, 1899)	Stalkers
54	*Carhottus viduus* (C.L Koch, 1846)	Stalkers	79	*Thiania bhamoensis* (Thorell, 1887)	Stalkers
55	*Cybra sp.*	Stalkers	80	*Thiania sp.1*	Stalkers
56	*Epeus sp.1*	Stalkers	81	*Thiania sp.2*	Stalkers
57	*Epeus sp.2*	Stalkers		**SPARASSIDAE**	
58	*Epeus flavobilineatus* (Doleschall, 1859)	Stalkers	82	*Heteropoda nilgirina* (Pocock, 1901)	Foliage runner
59	*Harmochirus brachiatus* (Thorell, 1877)	Stalkers	83	*Heteropoda venatoria* (Linnaeus, 1767)	Foliage runner
60	*Hasarius adansoni (*Audouin, 1826)	Stalkers	84	*Heteropoda sp.1*	Foliage runner
61	*Hasarius sp.*	Stalkers	85	*Heteropoda sp.2*	Foliage runner
62	*Hyllus semicupreus* (Simon, 1885)	Stalkers	86	*Heteropoda sp.3*	Foliage runner
63	*Hyllus lacertosis* (C.L Koch, 1846)	Stalkers	87	*Heteropoda sp.4*	Foliage runner
64	*Hyllus sp.*	Stalkers	88	*Thelicticopes sp.1*	Foliage runner
65	*Menemerus bivittatus* (Dufour, 1831)	Stalkers	89	*Thelicticopes sp.2*	Foliage runner

Sl. No	Family / Species	Guild	Sl. No	Family / Species	Guild
	TETRAGNATHIDAE			**THOMISIDAE**	
90	*Leucage pondae* (Tikader, 1970)	Orb-web weavers	102	*Amycea sp.*	Ambushers
91	*Tetragnatha elongate* (Walckenaer,1842)	Orb-web weavers	103	*Misumena chrysanthemi*	Ambushers
92	*Tetragnatha mandibulata* (Walckenaer,1842)	Orb-web weavers	104	*Strigoplus netravati* (Tikader, 1963)	Ambushers
93	*Tylorida ventralis* (Thorell, 1877)	Orb-web weavers	105	*Strigoplus sp.*	Ambushers
	THERAPHOSIDAE		106	*Thomisus pugilis* (Stoliczka, 1869)	Ambushers
94	*Chilobrachys hardwicki* (Pocock, 18950	Ground runner	107	*Thomisus sp.*	Ambushers
	THERDIIDAE		108	*Xysticus minutes* (Tikader, 1960)	Ambushers
95	*Argyrodes argentatus* (O.P-Cambridge, 1880)	Scattered line weavers	109	*Xysticus breviceps* (O.P-Cambridge, 1885)	Ambushers
96	*Argyrodes flavescens* (O.P-Cambridge, 1880)	Scattered line weavers		**ULOBORIDAE**	
97	*Argyrodes sp.*	Scattered line weavers	110	*Migrammopes sp.*	Orb web spider
98	*Ariamnes flagellum* (Doleschall, 1857)	Scattered line weavers	111	*Migrammopes extensis* (Simon, 1889)	Orb web spider
99	*Platnickina mneon* (Bosenberg & Strand, 1906)	Scattered line weavers	112	*Uloborus sp.1*	Orb web spider
100	*Theridion sp.1*	Scattered line weavers	113	*Uloborus sp.2*	Orb web spider
101	*Theridion sp.2*	Scattered line weavers	114	*Uloborus sp.3*	Orb web spider
			115	*Zosis geniculata* (Olivier, 1789)	Orb web spider
			116	*Zosis sp.*	Orb web spider
				Simpson Index	**0.9637**
				Shannon-Weiner Index	**3.668**

revealed ten types of feeding guilds (Uetz et al. 1999).

Similar type of spider diversity assessment studies were carried out at Kerala Agricultural University Campus, Thrissur, India and reported 86 species of 50 genera under 20 families of spiders. Araneidae was found to be the dominant family (Adarsh and Nameer, 2015). A study of spider diversity in Vazhappally village in Changanacherry thaluk in Kottayam, Kerala, documented about 43 species of spiders belong to 14 families and observed Salticidae as the dominant family (Sakkeena, 2012). Shamna (2015) also reported Salticidae as the dominant family with 12 species in the, Mokeri village in Thalasseri thaluk, Kannur, Kerala

A similar study done at Toranmal sanctuary, Maharashtra, India reported 117 species from 20 families and 55 genera (Archana, 2011). A study of spider diversity of Rundiv, Sidheshwar and Ramnadi area of Chandoli National Park reported a total of 58 species belonging to 38 genera and 16 families (More, 2015). Adarsh and Nameer (2016) documented 101 species of spiders belonging to 65 genera under 29 families from Chinnar Wildlife

Sanctuary, Idukki District, Kerala State in southern India. The Arachnology division of the Sacred Heart College at Ernakulam in Kerala, reported 51 species of spiders coming under 40 genera and 16 families from Mangalavanam forest (Pothalil *et al.,* 2005). A study of spider diversity from Vakoba, Devrai Region of Radhanagari Wildlife Sanctuary, Kolhapur, Maharashtra (More, 2013), reported a total of 61 species belonging to 50 genera and 19 families. Suvarna (2015) documented a total of 90 species belonging to 55 genera and 19 families in the Zolambi region of Chandoli National Park, in the western Ghats of Maharashtra.

Even though Kariavattom campus belongs to an urban area under the constant developmental and anthropogenic stresses, it supports rich diversity of spiders in various habitats of the campus. The 116 species indicate that the area still have a healthy population of spiders. The microhabitats in the campus such as ground, litter, bushes, tree trunks, foliage, and water bodies support the spider diversity. Being the first Arachnofaunal assessment study of Kariavattom Campus, University of Kerala, the study provides baseline for the future surveys and to discuss the various threats to the Arachnofauna of the Kariavattom Campus. Regular maintenance of gardens, beautification of gardens surrounding the departments and construction of roads destroys the habitat for common funnel web spiders (*Hippasa agelenoides*). All the four species reported from the family Tetragnathidae were observed from or near the artificial ponds inside the green house in the sub site (S1b) of the site 1 emphasizing that these families prefer gardens near water bodies. The only tarantula spider, *Chilobrachys hardwicki* of the family Theraphosidae was obtained from the sub site (S1c) of the site1. So it is essential to protect the spider fauna as they play an important role in ecosystem functioning.

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Pongamia oil soap for managing the cowpea aphid, *Aphis craccivora* koch

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ABSTRACT: Efficacy of pongamia oil soap against cowpea aphid, *Aphis craccivora* infesting vegetable cowpea, *Vigna unguiculata* was evaluated during *rabi* and summer seasons in comparison with neem oil soap, spinosad, soap solution and absolute control. Pongamia oil soap 2 per cent showed the highest efficacy without phytotoxicity followed by 1 per cent while neem oil soap 0.6 per cent was on par with pongamia oil soap 0.6 per cent. All treatments having pongamia oil soap were significantly superior to absolute control. © 2020 Association for Advancement of Entomology

KEYWORDS: Pongamia oil soap, neem oil soap, cowpea aphid

INTRODUCTION

The aphid, *Aphis craccivora* Koch is a threat for the vegetable cowpea, *Vigna unguiculata* (L.) infesting its tender parts including leaves, tender shoots, flowers and pods and suck the sap resulting in the malformation, wilting and drying up of plants. Chemical pesticides used widely for controlling this pest are though effective, but have certain disadvantages if not used properly causing resistance in target species (Khade *et al*., 2014). Pongamia oil is a botanical insecticide which is obtained from *Pongamia pinnata* (L.). This brownish oil extracted from the seeds of pongamia called as karanj oil or pongamia oil contains several secondary metabolites (flavonoids, chalcones, steroids and terpenoids) which serve as defence agent against insect pests (Pavela, 2007). Generally pongam oil is safe to humans and other mammals (Tripathi *et al.,* 2002).Vegetable cowpea has to be harvested very frequently wherein adopting a waiting period of 4-5 days is not possible in cowpea once yielding starts. So development of effective alternative to the chemical pesticides is very important in vegetable cowpea pest management. With this background, the efficacy of pongamia oil soap against aphid pests of cowpea was evaluated.

MATERIAL AND METHODS

Pongamia oil required for the preparation of soap was obtained from Tamil Nadu Agricultural University, and the saponification value was determined to check the purity of the oil in Soil Science and Agricultural Chemistry Lab, College of Agriculture, Padannakkad which was found to be 194 KOH/mg. It was prepared according to the technology used for the preparation of Ready to Use neem oil garlic soap. The pH value of the soap was 10.5.

A field experiment was carried out on vegetable cowpea at the instructional farm of College of Agriculture, Padannakkad for two seasons during

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October 2018 to January 2019 and February 2019 to May 2019. Cowpea variety Vellayani jyothika seeds were sown by dibbling method at a spacing of 1.5m x 0.45m during *rabi* and summer seasons with sixteen plants per treatment including four replications. So each replication of treatment had four plants. Vine trellis were fixed to trail the plants. Following seven treatments with four replications were laid under Randomized Block Design (RBD). Pongamia oil soap 0.6 per cent, 1 per cent and 2 per cent, Neem oil soap 0.6 per cent, Spinosad 45SC 0.5ml/L, Soap solution 0.5 per cent and absolute control.

Treatments were applied using a knapsack sprayer at vegetative and reproductive stages as soon as the pest infestation was seen. Observations on population density were made a day prior to spraying and post treatment population density at 1,3,5,7 and 14 DAT while damage symptoms were observed at 7 and 14 DAT, on whole plant.

The damage due to aphids, *Aphis craccivora* was assessed with total number of shoots, number of aphid infested shoots, scoring of aphid colonies based on standard scale (Egho and Emosairue, 2010). The standard scale for scoring the aphid population (Table 1) was done by observing the aphid colonies on each cowpea stands per treatment. Size of the colony was then observed visually and scored based on the scale.

% of Shoot infestation = (No. of infested shoots ÷ Total no. of shoots) X 100

Data on the population density of aphids were analysed after square root transformation and data on per cent shoot infestation were analysed after arc sine transformation. The data were analysed using analysis of variance (ANOVA). Web Agri Stat Package (WASP) was used to compare the significance of each treatment.

RESULTS AND DISCUSSION

Scoring of aphid colonies on shoots during *rabi* season

Pre count of aphid population showed no significant difference between the treatments, indicating that the population density of aphids was uniform in all the treatments prior to the first spraying. One day after first spray application, pongamia oil soap 2 per cent reduced the aphids to a minimum scoring level of 0.12 followed by same oil soap at 1 per cent (0.75) and at 0.6 per cent (1.37) as against the highest score of 2.50 in absolute control followed by soap solution 0.5 per cent (2.25) and spinosad 45SC (2.00). Neem oil soap 0.6 per cent (1.43) was statistically on par with pongamia oil soap 0.6 per cent (1.37) and soap solution 0.5 per cent and spinosad 45SC were on par with control. All the treatments were significantly superior over the control except soap solution 0.5 per cent. Minimum count of aphid population was seen in pongamia oil soap 2 per cent (0.12) followed by pongamia oil soap 1 per cent (0.75) and pongamia oil soap 0.6 per cent (1.37) on third day after first spray. Maximum aphid population score was recorded in control (2.62) followed by soap solution at 0.5 per cent (2.37) and spinosad 45SC (2.00). Absolute control (2.62) and soap solution at 0.5 per cent (2.37) were statistically on par. Treatment of neem oil soap 0.6 per cent (1.43) was statistically on par with pongamia oil soap 0.6 per cent (1.37). All the treatments were significantly superior over the

Table 1. Scale for assessing the population of aphids

Sl. No.	Rating	Number of aphids	Appearance
1	0	0	no infestation
2	1	1-4	a few individual colonies
3	3	5-20	a few isolated colonies
4	5	21-100	several small colonies
5	7	101-500	large isolated colonies
6	9	>500	Large continuous colonies

control except soap solution at 0.5 per cent. A gradual increase in the aphid population was seen on five days after spray. Minimum count of aphid population was seen in pongamia oil soap 2 per cent (0.31) followed by pongamia oil soap 1 per cent (0.87) and pongamia oil soap 0.6 per cent (1.75). Maximum aphid population score was recorded in control (3.62) followed by soap solution at 0.5 per cent (2.62) and spinosad 45SC (2.25). Treatment having neem oil soap 0.6 per cent (1.68) was statistically on par with pongamia oil soap 0.6 per cent (1.75). All the treatments were significantly superior over the control except soap solution at 0.5 per cent.

Observations at seventh day after first spray revealed that minimum count of aphid population was seen in pongamia oil soap 2 per cent (0.31) followed by pongamia oil soap 1 per cent (1.00) and neem oil soap 0.6 per cent (1.68). Maximum aphid population score was recorded in control (3.75) followed by soap solution at 0.5 per cent (3.37) and spinosad 45SC (2.25). Treatment having pongamia oil soap 0.6 per cent (2.00) was statistically on par with neem oil soap 0.6 per cent and spinosad 45SC. All the treatments were significantly superior over the control except soap solution at 0.5 per cent. At fourteenth day, minimum count of aphid population was seen in pongamia oil soap 2 per cent (0.43) followed by pongamia oil soap 1 per cent (1.06) and neem oil soap 0.6 per cent (1.75). Maximum aphid population score was recorded in control (5.06) followed by soap solution at 0.5 per cent (5.00) and spinosad 45SC (2.31). Pongamia oil soap 0.6 per cent (2.06) was statistically on par with neem oil soap 0.6 per cent and spinosad 45SC. All the treatments were significantly superior over the control except soap solution at 0.5 per cent. (Table 2)

Scoring of aphid colonies on shoots during summer

One day after first spray application, pongamia oil soap 2 per cent reduced the aphids to a minimum scoring level of 0.00 followed by same oil soap at 1 per cent (0.75) and at 0.6 per cent (2.56) as against the highest score of 9.00 in absolute control followed by soap solution 0.5 per cent (9.00) and spinosad 45SC (6.00). Neem oil soap 0.6 per cent (3.12) was statistically on par with pongamia oil soap 0.6 per cent and soap solution 0.5 per cent and spinosad 45SC were on par with control. All the treatments were significantly superior over the control except soap solution 0.5 per cent. Minimum count of aphid population was seen in pongamia oil soap 2 per cent (0.00) followed by pongamia oil soap 1 per cent (0.62) and pongamia oil soap 0.6 per cent (2.31) on 3rd day after first spray. Maximum aphid population score was recorded in control (9.00) and soap solution at 0.5 per cent (9.00) followed by spinosad 45SC (6.00).Treatment having neem oil soap 0.6 per cent (2.43) was statistically on par with pongamia oil soap 0.6 per cent. All the treatments were significantly superior over the control except soap solution at 0.5 per cent.

All the treatments were significantly superior over the control except soap solution at 0.5 per cent on five days after spray. Minimum count of aphid population was seen in pongamia oil soap 2 per cent (0.00) followed by pongamia oil soap 1 per cent (0.62) and pongamia oil soap 0.6 per cent (2.25). Maximum aphid population score was recorded in control (9.00) followed by soap solution at 0.5 per cent (8.00) and spinosad 45SC (5.50). Neem oil soap 0.6 per cent (2.31) was statistically on par with pongamia oil soap 0.6 per cent.

Observations at seventh day after first spray found that minimum count of aphid population was seen in pongamia oil soap 2 per cent (0.06) followed by pongamia oil soap 1 per cent (0.75) and pongamia oil soap 0.6 per cent (2.56). Maximum aphid population score was recorded in control (9.00) and soap solution at 0.5 per cent (9.00) and followed by spinosad 45SC (6.00). Neem oil soap 0.6 per cent (3.12) was statistically on par with pongamia oil soap 0.6 per cent. All the treatments were significantly superior over the control except soap solution at 0.5 per cent. At fourteenth day after first spray revealed that minimum count of aphid population was seen in pongamia oil soap 2 per cent (0.12) followed by pongamia oil soap 1 per cent (1.00) and neem oil soap 0.6 per cent (2.56). Maximum aphid population score was recorded in control (9.00) followed by soap solution at 0.5 per cent (8.00) and spinosad 45SC (5.50). Treatment

Table 2. Scoring of aphid colonies on shoots based on standard scale during *rabi* season from October 2018 to January 2019

Treatments	Aphids scoring on shoots (mean of 16 plants)					
	1DBFS	1DAFS	3DAFS	5DAFS	7DAFS	14DAFS
Pongamia oil soap 0.6%	1.62(1.26)	1.37(1.36)^{c}	1.37(1.36)^{c}	1.75(1.49)^{c}	2.00(1.57)^{b}	2.06(1.59)^{b}
Pongamia oil soap 1%	1.68(1.28)	0.75(1.11)^{d}	0.75(1.11)^{d}	0.87(1.16)^{d}	1.00(1.22)^{c}	1.06(1.24)^{c}
Pongamia oil soap 2%	1.62(1.26)	0.12(0.78)^{e}	0.12(0.78)^{e}	0.31(0.88)^{e}	0.31(0.88)^{d}	0.43(0.95)^{d}
Neem oil soap 0.6%	1.75(1.32)	1.43(1.39)^{c}	1.43(1.39)^{c}	1.68(1.47)^{c}	1.68(1.47)^{b}	1.75(1.49)^{b}
Spinosad 45 SC @ 0.5 ml/L	1.87(1.36)	2.00(1.57)^{b}	2.00(1.57)^{b}	2.25(1.64)^{bc}	2.25(1.64)^{b}	2.31(1.66)^{b}
Soap solution 0.5%	1.87(1.36)	2.25(1.65)^{ab}	2.37(1.69)^{a}	2.62(1.76)^{b}	3.37(1.96)^{a}	5.00(2.34)^{a}
Control	2.37(1.53)	2.50(1.73)^{a}	2.62(1.76)^{a}	3.62(2.03)^{a}	3.75(2.06)^{a}	5.06(2.35)^{a}
CD (0.05)	NS	0.08	0.09	0.19	0.20	0.20

Figures in parentheses denote square root transformed values.
Means followed by similar letters are not significantly different
DBFS- Day before first spray; DAFS- Days after first spray; NS – No Significant

having pongamia oil soap 0.6 per cent (2.75) was statistically on par with neem oil soap 0.6 per cent. All the treatments were significantly superior over the control except soap solution at 0.5 per cent (Table 3).

Aphid infestation on shoots during *rabi*

A significant reduction in aphid infestation on shoots was observed in the plot treated with pongamia oil soap 2 per cent (1.57 per cent) after seven days of first spray followed by same oil soap at 1 per cent (6.59 per cent) and neem oil soap at 6 per cent (11.34 per cent) against highest aphid infestation on shoots in absolute control (44.57 per cent) which was at par with soap solution at 0.5 per cent (38.93 per cent) followed by spinosad 45SC (21.23 per cent). Neem oil soap 0.6 per cent was statistically on par with pongamia oil soap 0.6 per cent (11.86 per cent). All the treatments were significantly superior over the control except soap solution 0.5 per cent.

The observation on infestation on shoots after fourteen days of first spray showed that treatment

Table 3. Scoring of aphid colonies on shoots during summer season from February 2019 to May 2019

Treatments	Aphids scoring on shoots (mean of 16 plants)					
	1DBFS	1DAFS	3DAFS	5DAFS	7DAFS	14DAFS
Pongamia oil soap 0.6%	4.37(2.09)	2.56(1.74) ^{c}	2.31(1.67) ^{c}	2.25(1.65) ^{c}	2.56(1.74) ^{c}	2.75(1.79) ^{c}
Pongamia oil soap 1%	4.43(2.10)	0.75(1.06) ^{d}	0.62(1.01) ^{d}	0.62(1.01) ^{d}	0.75(1.07) ^{d}	1.00(1.22) ^{d}
Pongamia oil soap 2%	4.37(2.08)	0.00(0.70) ^{e}	0.00(0.70) ^{e}	0.00(0.70) ^{e}	0.06(0.74) ^{e}	0.12(0.78) ^{e}
Neem oil soap 0.6%	4.5(2.12)	3.12(1.90) ^{c}	2.43(1.71) ^{c}	2.31(1.67) ^{c}	3.12(1.90) ^{c}	2.56(1.74) ^{c}
Spinosad 45 SC @ 0.5 ml/L	4.62(2.14)	6.00(2.54) ^{b}	6.00(2.54) ^{b}	5.50(2.44) ^{b}	6.00(2.54) ^{b}	5.50(2.44) ^{b}
Soap solution 0.5%	4.62(2.14)	9.00(3.08) ^{a}	9.00(3.08) ^{a}	8.00(2.91) ^{a}	9.00(3.08) ^{a}	8.00(2.91) ^{a}
Control	5.12(2.26)	9.00(3.08) ^{a}	9.00(3.08) ^{a}	9.00(3.08) ^{a}	9.00(3.08) ^{a}	9.00(3.08) ^{a}
C.D. (0.05)	NS	0.28	0.23	0.25	0.26	0.19

Figures in parentheses denote square root transformed values.
Means followed by similar letters are not significantly different
DBFS- Day before first spray; DAFS- Days after first spray; NS – No Significant

having pongamia oil soap 2 per cent (5.32 per cent) found with minimum per cent of aphid infestation on shoots which was on par with pongamia oil soap 1 per cent (8.48 per cent) and neem oil soap 0.6 per cent (13.87 per cent). Maximum per cent of aphid infestation on shoots was recorded in control (56.83 per cent) which was at par with soap solution at 0.5 per cent (40.21 per cent) followed by spinosad 45SC (24.59 per cent). Treatment having neem oil soap 0.6 per cent was statistically on par with pongamia oil soap 0.6 per cent (15.87 per cent) and pongamia oil soap 1 per cent. All the treatments were significantly superior over the control except soap solution at 0.5 per cent (Table 4).

Aphid infestation on shoots during summer

A significant reduction in aphid infestation on shoots was observed in the plot treated with treatment pongamia oil soap 2 per cent (0.20 per cent) after seven days of first spray followed by same oil soap at 1 per cent (3.22 per cent) and at 0.6 per cent (14.69 per cent) against highest aphid infestation on shoots in absolute control (89.00 per cent) which was at par with soap solution at 0.5 per cent (88.08per cent) followed by spinosad 45SC (44.42 per cent). Pongamia oil soap 0.6 per cent was statistically on par with neem oil soap 0.6 per cent (16.13 per cent). All the treatments were significantly superior over the control except soap solution at 0.5 per cent.

After fourteen day of spray, minimum per cent of aphid infestation on shoots was recorded in pongamia oil soap 2 per cent (0.54 per cent) which was at par with pongamia oil soap 1 per cent (5.62 per cent) followed by pongamia oil soap 0.6 per cent (18.94 per cent). Maximum per cent of aphid infestation on shoots was recorded in soap solution at 0.5 per cent (87.75 per cent) which was at par with control (85.58 per cent) followed by spinosad 45SC (49.27 per cent). Treatment having neem oil soap 0.6 per cent (32.45 per cent) was statistically on par with pongamia oil soap 0.6 per cent and spinosad 45SC. All the treatments were significantly superior over the control except soap solution at 0.5 per cent (Table 4).

Table 4. Mean per cent of aphid infestation on shoots during *rabi* and summer seasons 2019-20 (mean of 16 plants)

Treatments	Infestation during *rabi*			Infestation during summer		
	1 DBFS	7 DAFS	14 DAFS	1 DBFS	7 DAFS	14 DAFS
Pongamia oil soap 0.6%	18.33 (25.08)	11.86 (20.14)^{c}	15.87 (23.37)^{cd}	64.97 (53.93)	14.69 (22.52)^{c}	18.94 (25.79)^{d}
Pongamia oil soap 1%	18.28 (24.60)	6.59 (14.84)^{d}	8.48 (16.83)^{de}	60.87 (51.47)	3.22 (9.05)^{d}	5.62 (13.51)^{d}
Pongamia oil soap 2%	20.51 (26.91)	1.57 (1.57)^{e}	5.32 (11.53)^{e}	66.98 (55.35)	0.20 (1.69)^{e}	0.54 (3.25)^{e}
Neem oil soap 0.6%	21.10 (27.23)	11.34 (19.68)^{c}	13.87 (21.83)^{d}	69.29 (56.58)	16.13 (23.66)^{c}	32.45 (33.90)^{bc}
Spinosad 45 SC @ 0.5 ml/L	18.36 (25.30)	21.23 (27.43)^{b}	24.59 (29.68)^{c}	57.50 (49.34)	44.42 (41.78)^{b}	49.27 (44.57)^{b}
Soap solution 0.5%	17.17 (24.41)	38.93 (38.56)^{a}	40.21 (39.27)^{b}	67.38 (55.68)	88.08 (69.81)^{a}	87.75 (69.53)^{a}
Control	20.68 (26.86)	44.57 (41.88)^{a}	56.83 (48.95)^{a}	67.85 (55.57)	89.00 (70.64)^{a}	85.58 (67.70)^{a}
C.D. (0.05)	NS	3.48	7.01	NS	3.88	11.50

Figures in parentheses denote arc sine transformed values.
Means followed by similar letters are not significantly different
DBFS- Day before first spray; DAFS- Days after first spray; NS – No Significant

From the results obtained, it is noticeable that all the treatments except soap solution 0.5 per cent was effective in reducing aphid population during both *rabi* and summer seasons from October 2018 to January 2019 and February 2019 to May 2019 respectively. In general, the efficacy of pongamia oil soap at 0.6, 1 and 2 per cent and neem oil soap 0.6 per cent were significantly superior over control. Similar findings were reported by Ranawat (2018) who stated that karanj oil 1 per cent and neem oil 1 per cent showed significant reduction in cowpea aphid *Aphis craccivora* population over the control. Balikai (2001) that *Pongamia pinnata* kernel 2 per cent and *Pongamia pinnata* leaves 5 per cent showed significant reduction in sorghum aphid *Melanaphis sacchari* over the control. This reduction may be due to insecticidal property of pongamia oil in the pongamia oil soap. Pongamia oil contains secondary metabolites which show insecticidal activity (Pavela, 2007).

It was also seen that efficacy of pongamia oil soap increased with the increase in concentration of the oil and pongamia oil soap 2 per cent showed highest efficacy. The neem oil soap 0.6 per cent and pongamia oil soap 0.6 per cent showed statistically similar reduction in aphid population. Similar findings were reported by Akash *et al.,* (2013), they stated that 83.6 per cent decline in aphid population was recorded with 1 per cent karanj oil treatment which was statistically at par with 1 per cent neem oil (81.03).There is an increase in the population of aphids as can be seen from 7 days to 14 days after application of treatments. Singh (2013) found similar results when he treated pongamia oil 1 per cent against the peach leaf curl aphid *Brachycaudus helichrysi*. Soap solution 0.5 per cent always showed results similar to control indicating that the reduction in aphid population was solely due to the insecticidal properties of the oil rather than the soap solution which is a component of pongamia oil soap.

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Identification of redgram resistant genotypes and morphological bases of resistance to pod fly, *Melanagromyza obtusa* (Malloch)

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ABSTRACT: Screening of 49 redgram genotypes conducted to identify pod fly resistant genotypes and morphological basis of resistance to pod fly revealed consistently resistance reaction of ICP 8864 (mean PSI 3.0) and VRG–59-1(mean PSI 3.3) to redgram pod fly. Pod length of various redgram germplasm ranged between 3.55 and 4.84 cm. Pod width ranged from 0.64 to 1.28 cm. Pod wall thickness ranged from 0.21 to 0.43 mm. Trichome density ranged between 302 and 375 per 9 mm^2. Redgram pod width was the important morphological factor that influenced the redgram pod fly seed damage to a tune of 34.2 per cent. Pod length and width were positively correlated with the redgram pod fly seed damage while pod wall thickness and trichome density were negatively correlated. However, relationship between pod width and seed damage only was found to be significantly positive and rest of the morphological factors were not significant.

Keywords: Redgram pod fly, resistant genotypes, pod length, pod width, pod wall thickness and trichome density

INTRODUCTION

Redgram pod fly, *Melanagromyza obtusa* (Malloch) (Agromyzidae: Diptera), a potential threat in redgram, the most important pulse crop after chickpea in India is considered as a very serious insect pest inflicting 100 per cent pod damage resulting in 85 per cent seed damage in india (FAO/ RLAC, 1989). The young maggots damage by feeding on the soft seed just below the epidermis, burrow deeper down, consuming the starchy food as well as the embryo and deposit excreta become unfit for human consumption. According to Shanower *et al.*, 1998, redgram pod fly seed damage varied from 2 to more than 90 per cent with large variation across locations, seasons, and genotypes. In certain situations where, the target insect is exposed for only a brief period of its life cycle, host plant resistance has significant advantages over the other pest control strategies (Shanower *et al.*, 1998). These conditions ideally apply to redgram pod fly because, egg stage is the only exposing stage of pod fly and after hatching of egg, pod fly maggot enters in to the pod through the pod wall and feed on the seed and insecticides sprayed cannot reach the maggot to kill them. As

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different redgram cultivars have different levels of damage, identifying the cultivars with less pod fly damage appears to be a viable management option. In this context, the present investigations were carried out to screen and identify morphological resistant genotypes to pod fly.

MATERIALS AND METHODS

Screening of 49 redgram germplasm entries were conducted at National Pulses Research Centre, TNAU, Vamban, Pudukottai district, Tamil Nadu for a period of three years during kharif season 2016, 2017and 2018 for finding the sources of resistance to redgram pod fly, *Melanagromyza obtusa*. As the peak infestation of pod fly observed during the pod maturation stage, per cent pod fly seed damage was recorded once during that stage and another 15 days after the first observation while post harvest observations on pod fly seed damage by sampling 300 seeds were taken separately for each entry to calculate per cent damage. Based on the pod fly seed damage in the entries and check (VBN 3), pest susceptibility per cent (PSP) and pest susceptibility index (PSI) were calculated as indicated below for each entry. Redgram entries consistently performing in all the three years were selected as the resistant entries. Pest susceptibility per cent (PSP) was calculated by the following formula -

$$PSP = \frac{\text{per cent damage in check} - \text{per cent damage in entry}}{\text{Per cent damage in check}} \times 100$$

Following scale was followed for categorizing the resistance in various germplasm entries (Lateef and Reed, 1985).

PSP	PSI	Category of resistance
100	1	Highly Resistant
75 to 99.9	2	Resistant
50 to 74.9	3	Moderately Resistant
25 to 49.9	4	Moderately Resistant
10 to 24.9	5	Moderately Susceptible
(-10) to (9.9)	6	Moderately Susceptible
(-25) to (-9.9)	7	Susceptible
(-50) to (-24.9)	8	Highly Susceptible
Less than -50	9	Highly Susceptible

Redgram entries which recorded the mean pod fly seed damage less than the check, more than the check and slightly more/less than the check were selected to correlate some morphological basis of resistance *viz.*, pod length, pod width, trichome density and pod wall thickness to the pod fly incidence levels. For this, twenty uniformly developed pods from each entry were collected randomly at pod maturation stage and their length and width was assessed with the help of graph paper and expressed in centimetre per pod. Trichome density was measured in accordance with Jackai and Oghiakhe (1989). The pod was cut into bits of 0.25 cm^2 and number of trichomes present on the epidermis of pods was counted under a stereo zoom trinocular microscope (Leica S6D). Thickness of pod wall in ten pods was measured by using the Vernier calipers and expressed in millimetre per pod.

RESULTS AND DISCUSSION

A. First year screening of redgram germplasm (kharif 2016)

During the crop period at early maturity stage, among the germplasm, seed damage of pod fly ranged between 4 and 48 per cent while during the post maturity stage, 10 and 43 per cent as against the post harvest seed damage with between 9 and 63 per cent. Among the 49 entries, ICP 13918-A was the entry which showed moderately resistant reaction (PSI 3) to pod fly. ICP 8864 and VRG-59-1 entries were categorized as moderately resistant with the PSI of 4 (Table 1).

B. Second year screening of redgram germplasm (kharif 2017)

During kharif 2017, among the germplasm, pod fly seed damage was 1 to 38 per cent and 4 to 36 per cent (Table 1) at early maturity stage and post maturity stage respectively. At harvest, post harvest observations were taken and among the germplasm screened, pod fly seed damage ranged from 0.0 to 65.0 per cent. Sivakumar *et al.* (2015) assessed the redgram pod fly damage in forty entries and reported that the pod damage among the cultivars ranged from 24.67 to 88.67 per cent. Among the entries, ICP 14887 recorded least damage (24.67%)

Table 1. Incidence of pod fly in various redgram germplasm in field and at harvest (kharif)

Germplasm	Seed damage (%) – *kharif*											
	2016				2017				2018			
	Early Maturity	Post Maturity	Post Harvest	Resistance	Early Maturity	Post Maturity	Post Harvest	Resistance	Early Maturity	Post Maturity	Post Harvest	Resistance
ICP 3689	28.0	36.0	37.0	HS	9.0	13.0	8.0	MS	19.0	31.0	15.0	MS
ICP 7984	32.0	38.0	31.0	HS	13.0	11.0	8.0	MS	18.0	28.0	16.0	MS
ICP 12942	28.0	32.0	28.0	S	5.0	11.0	6.0	MR	14.0	20.0	12.0	MR
ICP 12569	29.0	37.0	39.0	HS	16.0	20.0	14.0	HS	21.0	29.0	15.0	MS
ICP 11174	30.0	26.0	31.0	HS	11.0	15.0	8.0	MS	23.0	32.0	20.0	S
ICP 9274	24.0	26.0	22.0	MS	20.0	22.0	13.0	HS	20.0	26.0	14.0	MS
ICP 6698	48.0	40.0	29.0	HS	1.0	5.0	4.0	MR	11.0	23.0	9.0	MR
ICP 13575	21.0	25.0	24.0	MS	23.0	19.0	15.0	HS	13.0	22.0	11.0	MR
ICP 941114	25.0	37.0	25.0	MS	16.0	22.0	16.0	HS	9.0	21.0	10.0	MR
ICP 11007	26.0	32.0	48.0	HS	15.0	17.0	10.0	MS	10.0	19.0	13.0	MR
ICP 11957	29.0	35.0	63.0	HS	10.0	8.0	7.0	MR	12.0	18.0	11.0	MR
ICP 13208	19.0	25.0	21.0	MS	17.0	25.0	14.0	HS	11.0	20.0	12.0	MR
ICP 11206	22.0	26.0	19.0	MS	2.0	10.0	6.0	MR	18.0	29.0	18.0	MS
BAHAR	41.0	35.0	46.0	HS	15.0	21.0	15.0	HS	23.0	32.0	14.0	MS
ICP 7085	36.0	34.0	41.0	HS	28.0	32.0	28.0	HS	19.0	28.0	22.0	S
P 3474	29.0	31.0	28.0	S	19.0	25.0	13.0	HS	21.0	35.0	15.0	MS
VRG 17	27.0	31.0	28.0	S	26.0	28.0	20.0	HS	22.0	29.0	25.0	HS
SMR 1693	35.0	41.0	30.0	HS	20.0	26.0	20.0	HS	17.0	26.0	23.0	HS
ICP 13938	26.0	32.0	24.0	MS	11.0	17.0	10.0	MS	10.0	19.0	12.0	MR
ICP 8864	7.0	11.0	14.0	MR	3.0	7.0	5.0	MR	8.0	15.0	4.0	R
RG 50	32.0	26.0	34.0	HS	15.0	21.0	12.0	S	22.0	27.0	15.0	MS
ICP 13918-A	4.0	10.0	9.0	MR	15.0	19.0	9.0	MS	16.0	23.0	12.0	MR
RG 83	25.0	31.0	18.0	MS	0.0	4.0	0.0	HR	12.0	16.0	10.0	MR
RG 129	22.0	28.0	26.0	S	16.0	22.0	12.0	S	19.0	31.0	21.0	S
ICP 11119	36.0	40.0	29.0	HS	11.0	13.0	9.0	MS	16.0	36.0	17.0	MS
ICP 10175	41.0	43.0	30.0	HS	10.0	16.0	11.0	MS	18.0	35.0	19.0	S
ICP 763-C	26.0	34.0	28.0	S	21.0	27.0	20.0	HS	26.0	29.0	32.0	HS
ICP 12116	25.0	29.0	27.0	S	16.0	14.0	16.0	HS	22.0	25.0	26.0	HS
IIRG 101	25.0	25.0	28.0	S	26.0	32.0	32.0	HS	21.0	28.0	33.0	HS
PL 59176	35.0	31.0	45.0	HS	22.0	24.0	23.0	HS	19.0	29.0	31.0	HS
ICP 12727	50.0	42.0	59.0	HS	3.0	9.0	7.0	MR	18.0	31.0	16.0	MS
ICP 6997	30.0	32.0	30.0	HS	15.0	19.0	11.0	MS	22.0	29.0	20.0	S
ICP 7624	28.0	32.0	41.0	HS	10.0	12.0	9.0	MS	25.0	31.0	17.0	MS
DA 322	26.0	20.0	29.0	HS	12.0	12.0	10.0	MS	23.0	38.0	16.0	MS
BRG 959-1	40.0	38.0	58.0	HS	19.0	17.0	15.0	HS	22.0	36.0	24.0	HS
VRG 59-1	7.0	13.0	12.0	MR	8.0	10.0	6.0	MR	11.0	16.0	3.0	R
CORG 9900134	31.0	33.0	31.0	HS	18.0	24.0	17.0	HS	28.0	29.0	26.0	HS
VRG 08-003	18.0	26.0	19.0	MS	16.0	20.0	14.0	HS	22.0	26.0	22.0	S
VRG 07-001	20.0	22.0	26.0	S	11.0	13.0	15.0	HS	18.0	25.0	21.0	S
VRG 06-013	27.0	23.0	27.0	S	12.0	18.0	18.0	HS	21.0	31.0	29.0	HS
VRG 06-004	27.0	31.0	29.0	HS	28.0	36.0	28.0	HS	18.0	38.0	35.0	HS
VRG 08-004	24.0	20.0	23.0	MS	19.0	29.0	20.0	HS	29.0	36.0	38.0	HS
VRG 54	26.0	24.0	23.0	MS	10.0	16.0	11.0	MS	20.0	27.0	21.0	S
VRG 60-001	31.0	25.0	25.0	MS	10.0	12.0	12.0	S	19.0	31.0	23.0	HS
VRG 06-002	18.0	24.0	25.0	MS	12.0	18.0	21.0	HS	25.0	29.0	36.0	HS
VRG 07-002	33.0	41.0	35.0	HS	17.0	19.0	14.0	HS	22.0	32.0	26.0	HS
VRG 05-008	25.0	31.0	18.0	MS	4.0	6.0	6.0	MR	26.0	34.0	15.0	MS
VRG 12-003	21.0	23.0	28.0	S	38.0	36.0	65.0	HS	23.0	28.0	47.0	HS
VRG 12-005	22.0	24.0	21.0	MS	0.0	6.0	4.0	MR	9.0	10.0	12.0	MR
VBN 3 (Check)	17.0	19.0	23.0		13.0	17.0	10.0		15.0	22.0	18.0	

H R - Highly Resistant; M R - Moderately Resistant; R – Resistant; M S - Moderately Susceptible; S – Susceptible; H S - Highly Susceptible

and was on par with ICP 14770 (27.33%) and BDN 2 (28.33%). Highest per cent pod damage was observed in ICP 9150 (88.67%) followed by ICP 12083 (84.33%), ICPL 15225 (81.33%), ICP 15580 (76.33%), TRG 59 (75.67%) and ICP 12082 (75.67%). The check cultivars, LRG 41 and TRG 22 recorded 57.33 and 60.67 per cent pod damage, respectively.

Based on the pest susceptibility index (PSI) entries RG 83 (HR with PSI 1), ICP 6698, ICP 8864 and VRG 12-005 (MR with PSI 3) and ICP 12942, ICP 11957, ICP 11206, ICP 12727, VRG 59-1, VRG 05-008 (MR with PSI 4) were found to be promising against pod fly.

C. Conformational screening study of redgram germplasm (kharif 2018)

During kharif 2018 among the germplasm, pod fly seed damage was 9 to 29 per cent at early maturity stage and 10.0 to 38.0 per cent (Table 1) at post maturity stage. At harvest, among the germplasm screened, pod fly seed damage ranged from 3.0 to 47.0 per cent. Maneesh Kumar Singh *et al. (*2017) screened twenty nine redgram genotypes against pod fly and recorded the population of pod fly on different genotypes ranged from 0.61 maggots/10 pods in IVT-520 to 1.57 maggots/10 pods in IVT-510. Pod damage significantly varied from 22.33 per cent in genotype IVT-520 to 46.67 per cent in genotype IVT-510. Highest grain damage was recorded in IVT-510 (20.96%) while the lowest grain damage was recorded in IVT-520 (10.67%). They concluded that among the twenty nine genotypes, IVT-520, IVT-509 and AVT-603 were found to be most tolerant against pod fly damage.

In the present study, based on the pest susceptibility index (PSI) entries ICP 8864 and VRG – 59 - 1 (Resistant with 3 PSI) and ICP 6698 (MR with 3 PSI) and ICP 12942, ICP 13575, ICP 941114, ICP 11007, ICP 11957, ICP 13208, ICP 13938, ICP 13918 – A, RG 83 and VRG – 12 – 005 (MR with PSI 4) are found to be promising against pod fly. During the three year screening study from 2016 – 19, two entries ICP 8864 and VRG – 59 – 1 showed consistently resistance reaction to redgram pod fly (Table 2).

Table 2. Categories of resistance and mean PSIs of the selected genotypes

Name of the genotypes	Category of resistance to pod fly			Pest Susceptibility Index (PSI)			Mean PSI
	2016	2017	2018	2016	2017	2018	
ICP 8864	M R	M R	R	4	3	2	3.0
VRG – 59 - 1	M R	M R	R	4	4	2	3.3
ICP 6698	H S	M R	M R	9	3	3	5.0
ICP 12942	S	M R	M R	7	4	4	5.0
ICP 13575	M S	H S	M R	5	8	4	5.7
ICP 941114	M S	H S	M R	5	9	4	6.0
ICP 11007	H S	M S	M R	9	6	4	6.3
ICP 11957	H S	M R	M R	9	4	4	5.7
ICP 13208	M S	M S	M R	5	8	4	5.7
ICP 13938	M S	M S	M R	5	6	4	5.0
ICP 13918 – A	M R	M S	M R	4	5	4	4.3
RG 83	M S	H R	M R	5	1	4	3.3
VRG–12 – 005	M S	M R	M R	5	3	4	4.0

H R - Highly Resistant; M R - Moderately Resistant; R – Resistant; M S - Moderately Susceptible; S – Susceptible; H S - Highly Susceptible

D. Identification of morphological bases of resistance to redgram pod fly

Pod length of various redgram germplasm ranged between 3.55 and 4.84 cm. Pod width ranged from 0.64 to 1.28 cm. Pod wall thickness ranged from 0.21 to 0.43 mm. Trichome density ranged between 302 and 375 per 9 mm^2 (Table 3). In the present study it was found that, pod length and width were positively correlated with the redgram pod fly seed damage while pod wall thickness and trichome density were negatively correlated. However,

Table 3. Redgram pod morphological characters in the genotypes and pod fly seed damage with their correlation

Name of the germplasm	Mean seed damage (%) #	Pod length (cm)	Pod width (cm)	Pod wall thickness (mm)	Trichome density/ 9 mm^2
ICP 8864	7.7	3.71	0.70	0.42	372.0
VRG – 59 - 1	7.0	3.55	0.64	0.43	375.0
ICP 6698	14.0	4.01	0.95	0.34	353.0
ICP 12942	15.3	4.34	1.00	0.25	321.0
ICP 13575	16.7	4.20	1.06	0.28	328.0
ICP 941114	17.0	4.14	1.05	0.31	342.0
ICP 11007	23.7	4.62	1.21	0.22	312.0
ICP 11957	27.0	4.24	1.08	0.29	330.0
ICP 13208	15.7	4.40	1.10	0.24	319.0
ICP 13938	15.3	4.41	1.12	0.23	315.0
ICP 13918 – A	10.0	4.40	1.14	0.25	318.0
RG 83	9.3	4.19	1.00	0.30	338.0
VRG–12 – 005	12.3	4.50	1.18	0.24	320.0
VBN 3	17.0	4.84	1.28	0.21	302.0
Correlation Coefficient r		0.519*	0.585*	-0.5226*	-0.5287*

#Mean of three years; Correlation coefficient values between pod fly seed damage and morphological characters of redgram pod; * - significant

Table 4. Backward regression model for the relationship between pod fly seed damage and morphological characters of redgram pod

Model	Pod fly seed damage and morphological characters of redgram pod		R^2
	Variables entered	Variables removed	
1	Pod length, pod width, pod wall thickness, trichome density	—	0.392
2	Pod length, pod width, trichome density	Pod wall thickness	0.377
3	Pod length, pod width	Trichome density	0.373
4	Pod width	Pod length	0.342

relationship between pod width and seed damage only was found to be significantly positive (Table 3) and rest of the morphological factors were not significant. Backward regression analysis was carried out to identify the relationship between pod fly seed damage and morphological characters of redgram pod. In model 1, where all the morphological parameters were correlated with pod fly seed damage, R^2 value was 0.392. In model 2, pod wall thickness was the excluded variable and the R^2 value was 0.377 and this showed that pod wall thickness had the effect of 1.5%. In model 3, trichome density was excluded with R^2 value of 0.373 and this revealed 0.4% influence of the variable, trichome density on pod fly seed damage. In model 4, pod length was the excluded variable and 0.342 was the R^2 value. So in the present study, it can be concluded that, redgram pod width was the important morphological factor that influenced the redgram pod fly seed damage to a tune of 34.2 per cent (Table 4).

The present findings are in line with the findings of Sivakumar *et al.* (2015) who studied the correlation between the pod characters and pod fly incidence and reported that redgram pod length (r=0.389*) and pod width (r=0.380*) were positively correlated with per cent pod damage, whereas pod wall thickness (r= -0.762**) and trichome density (r= -0.745**) had significant negative correlation with pod fly damage. Negative correlation of redgram pod wall thickness and trichome density with the susceptibility to pod fly damage was reported by Moudgal *et al.* (2008). Yadav and Rohilla (2010) observed more trichome density on green pods in redgram resistant varieties when compared to the susceptible varieties.

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Insects infesting *Hibiscus rosa-sinensis* Linn. in Karnataka, India

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ABSTRACT: Survey conducted on *Hibiscus rosa-sinensis* Linn. growing in Karnataka revealed 20 species of insect pests. Of these, five species are new records.

KEY WORDS: Shoe flower, coccids, insect pests

Hibiscus rosa-sinensis Linn. (Malvaceae), also known as shoe flower is a glabrous shrub widely cultivated in the tropics as an ornamental plant and has several forms with varying colour of flowers and distributed throughout tropical and subtropical regions. It also has medicinal properties and used in many herbal mix and drinks. Adhirajan *et al.* (2003) reported that the leaf extract of *H. rosa-sinensis* has a potential effect on maintaining the hair growth and treatment of scalp. It acts as an antioxidant and helps in the reduction of cholesterol levels (Esa, 2010); as emollients and aperients to treat burning sensations, skin disease, and constipation (Kirtikar and Basu, 1999), and has anti inflammatory and astringent properties (Yazan *et al*., 2011). In India, flowers and leaves are used for the abortion, antifertility, contraceptive, diuretic, menorrhagia, bronchitis, emmengogue, demulcent and cough (Jadhav *et al.,* 2009). Various parts of the plant are also used in the preparation of jams, spices, soups, and sauces (Baranova *et al*., 2011).

In this context survey was undertaken in parks, gardens of medicinal plants and home-yards in Karnataka for two years (2017 to 2019) to study the insect pests infesting *H. rosa-sinensis* and the findings are presented in this communication.

The survey revealed the occurrence of 20 species of insects representing three orders viz., Hemiptera, Lepidoptera and Coleoptera infesting *H. rosa-sinensis* in Karnataka, which comprises two species of defoliators and 18 species of sap suckers (Table 1). Among the sucking pests, coccids are dominant with seven species representing four families viz., Pseudococcidae by three species, Coccidae by two species and Cerococcidae and Monophlebidae each by one species. Sundararaj *et al.* (2016) reported dominance of coccids among the insect pests on sandalwood in agroforestry conditions. One species each from families, Coreidae, Eurybrachidae, Lygaeidae, Pyrrhocoridae and Scutelleridae and two species each of the families, Aphididae, Aleyrodidae and Cicadellidae were recorded as pests of *H. rosa-sinensis* .

Among the coccids the infestation of *Coccidohystrix insolita* (Fig. a), *Paracoccus marginatus* (Fig. c) and *Phenacoccus solenopsis* (Fig. b) were often severe resulting in yellowing

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Table 1: Insects infesting *H. rosa-sinensis* in Karnataka

Sl. No.	Common name of Insect pest	Scientific name	Family: Order
	Defoliators		
1	Cotton leaf roller	*Haritalodes derogata* (Fabricius)	Crambidae: Lepidoptera
2	Ash weevil	*Myllocerus viridanus* Fabricius*	Curculionidae: Coleoptera
	Sap suckers		
3	Black/ cow pea Aphid	*Aphis craccivora* Koch	Aphididae: Hemiptera
4	Cotton aphid	*Aphis gossypii* Glover	Aphididae: Hemiptera
5	Spiraling whitefly	*Aleurodicus dispersus* Russell	Aleyrodidae: Hemiptera
6	Whitefly	*Beimisia tabaci* (Gennadius)	Aleyrodidae: Hemiptera
7	Yellow scales	*Cerococcus indicus* (Maskell)	Cerococcidae: Hemiptera
8	Leafhopper	*Hecalus arcuatus* (Mots.)	Cicadellidae: Hemiptera
9	Sharp shooter Leafhopper	*Kolla ceylonica* (Melichar)	Cicadellidae: Hemiptera
10	Green scale / soft scale	*Hemilecanium imbricans* (Green)*	Coccidae: Hemiptera
11	Pomegranate scale	*Parasaissetia nigra* (Nietner)	Coccidae: Hemiptera
12	Squash bug	*Acantocoris scabrator* (Fabricius)	Coreidae: Hemiptera
13	Eurybrachid bug	*Eurybrachys tomentosa* (Fabricius)*	Eurybrachidae: Hemiptera
14	Dusky cotton bug	*Oxycarenus laetus* Kirby	Lygaeidae: Hemiptera
15	Mango mealybug	*Drosicha* sp*.	Monophlebidae: Hemiptera
16	Egg plant mealybug	*Coccidohystrix insolita* (Green)	Pseudococcidae: Hemiptera
17	Hibiscus /Papaya mealybug	*Paracoccus marginatus* Williams and Granara de Willink	Pseudococcidae: Hemiptera
18	Cotton mealybug	*Phenacoccus solenopsis* Tinsley	Pseudococcidae: Hemiptera
19	Red cotton stainer	*Dysdercus similis* (Freeman)*	Pyrrhocoridae: Hemiptera
20	Jewel bug	*Chrysocoris stollii* (Wolf)*	Scutelleridae: Hemiptera

Note: * indicate the insect reported for the first time on *Hibiscus rosa-sinensis* from India

and premature shedding of leaves, loss in plant vigour, reduction in flowering and formation of deformed flowers. Nymphs and adults of aphids, *Aphis craccivora* and *A. gossypii* were found congregating on succulent stems and under surface of leaves, buds and flowers of *H. rosa-sinensis*. Curling and crinkling of leaves and flowers which become shiny and sticky due to honey dew excreted by the aphids and growth of sooty mold are the common symptoms of infestation by aphids. The symptoms of infestation by other sucking pests are negligible. The defoliators are *Haritalodes derogata* and *Myllocerus viridanus.* Among the 20 species of insects found breeding on *H. rosa-sinensis* the record of five species of sap suckers viz., *Hemilecanium imbricans* (Fig. d), *Drosicha* sp. (Fig. e), *Dysdercus similis* (Fig. f), *Eurybrachys tomentosa* (Fabricius) and

Fig. a. *Coccidohystrix insolita* (Green)

Fig. b. *Phenacoccus solenopsis* Tinsley

Fig. c. *Paracoccus marginatus* Williams and Granara de Willink

Fig. d. *Hemilecanium imbricans* (Green)

Chrysocoris stollii (Wolf) and the defoliator *Myllocerus viridanus* (Plate g) are first report on *H. rosa-sinensis.*

Dysdercus cingulatus (Fab.) and *D. koenigii* (Fabricius) were reported to infest on *H. rosa-sinensis* and other hibiscus species (Shukla and Upadhyaya, 1972). *D. similis* was reported to attack other malavaceous plants like cotton and okra (Singh and Pathak, 2010; Rajendran *et al.,* 2018). Species of *Chrysocoris* are phytophagous

Fig. e. *Drosicha* sp.

Fig. f. *Dysdercus similis* (Freeman)

Fig. g. *Myllocerus viridanus* Fabricius

Fig. h. *Parasaissetia nigra* (Nietner)

(Parveen *et al.,* 2013) and *E. tomentosa* is polyphagous nature (Janarthanan *et al.,* 1992). *M. viridanus* was reported on cotton (Rajendran *et al*., 2018).

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Mango: A new host plant for the lycaeinid *Anthene lycaenina lycaenina* (R. Felder, 1868)

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ABSTRACT: *Anthene lycaenina lycaenina* (R. Felder, 1868) is reported on mango for the first time.

KEY WORDS: Mango, Inflorescence, Lepidoptera, *Anthene lycaenina lycaenina*

Mango, the king of fruits, is an important seasonal fruit crop found growing in the tropical and subtropical countries of the world (Abdullah and Shamsulaman, 2008).This crop belonging to the Anacardacean family holds a rich diversity in the country. Despite the fact that India is one among the leading mango producers, the productivity is much lower compared to countries like China where insect pests form a major reason for this. (Ahuja *et al*., 2011).

Mango inflorescence houses a number of insect and non-insect pests including thrips, mites, aphids, mealy bugs along with numerous lepidopterans. Infestation of various pests in the inflorescence led to damage and eventually yields loss affecting the flower retention and fruit set (Kannan *et al.,* 2002). A varied set of lepidopteran complex was earlier identified from the mango inflorescence in Karnataka (Verghese and Jayanthi, 1999). Inflorescence sample were collected from the different parts of Thiruvananthapuram district as a part of the study and different lepidopteran species were noticed. The incidence of Dakhan Pointed Ciliate Blue *Anthene lycaenina lycaenina* (R. Felder, 1868) in mango was noticed for first time from the sample collected from Thiruvallam in the month of November, 2019.

The larva (Fig. 1) was stout reddish brown in colour with two rows of yellowish pattern on the dorsal surface. The larva was found feeding on the flowers of inflorescence which becomes voracious in the

Fig. 1 Caterpillar feeding on mango inflorescence

* Author for correspondence

Fig. 2 Adult-Dorsal view

Fig. 3 Adult-Ventral view

later stages leaving behind only stalks. The incidence varied with season and the sample collected in the month of November showed the presence of about one to five larva per panicle. The adult lycaenid (Fig. 2) was metallic navy blue in colour having a blackish tinge along the outer margin with a black spot in the ventral surface near the costal margin in hind wing and another black spot towards the anal angle with an orange coloured spot topping them (Fig. 3).

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Report of a new host plant for *Eligma narcissus* Cramer (Lepidoptera: Nolidae)

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ABSTRACT: *Oroxylum indicum* (L.) Benth. ex Kurz is reported as a new host plant for *Eligma narcissus* (Cramer) from Kerala, India. This is the first record of Bignoniaceae as host plant for the genus *Eligma* Hubner.

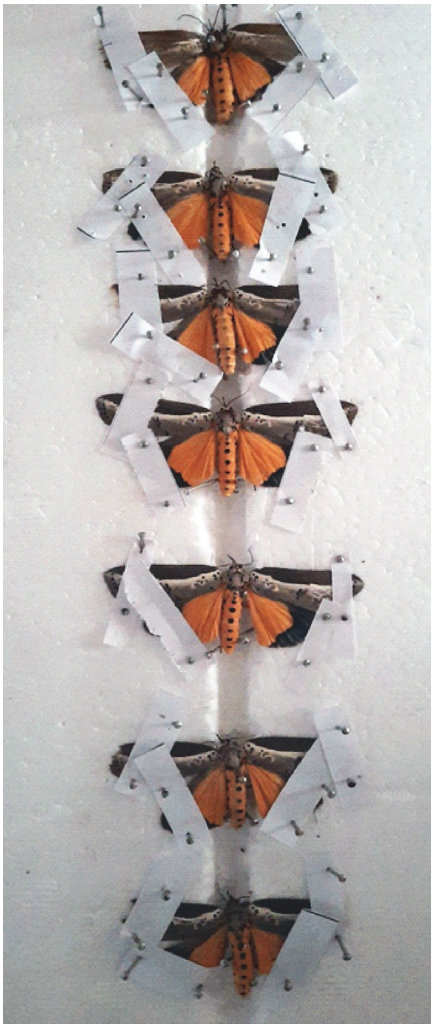
KEYWORDS: Bignoniaceae, host plant, India, Nolidae

Family Nolidae (Lepidoptera) includes moths that are widely distributed with 1879 living species under 206 genera (Catalogue of Life, 2020). Though occurring worldwide, Nolidae shows primarily palaeotropical distribution (Kitching and Rawlins, 1998). Several species of this group are agricultural pests. Family Nolidae includes 8 subfamilies viz., Diphtherinae, Risobinae, Collomeninae, Beaninae, Eligminae, Westermanniinae, Nolinae and Chloephorinae (Zehari *et al.*, 2012b). Earlier, Nolinae was either treated as subfamily of Arctiidae or Noctuidae by many workers (Gardener, 1941, 1943, 1948, Holloway and Miller, 1995, Poole 1989). Later molecular and phylogenetic studies of Zehari *et al.* (2011, 2012a) revised the status of Nolinae and treated as a subfamily of Nolidae.

Adult moths of family Nolidae are small in size, mostly dull coloured with tufts of scales on forewings. Moths of this group are easily identified from their morphological characters like elongation of the forewing retinaculum in a bar-like or digitate condition and possession of a post spiracular counter-tympanal hood (Zehari *et al.,* 2012b). Another interesting feature of the larva of many genera of Nolidae is the presence of swollen, bulbous- like structure on the head which is nothing but the stack of moulted old caterpillar head capsules for defense (Petah *et al*., 2016). The cocoons of this moth family are boat-shaped and pupae lack cremasters. Larvae feed leaves, stem, pods and seeds.

Genus *Eligma* Hubner belongs to the subfamily Nolinae of superfamily Noctuoidea. A total of 9 species are known globally. Only one species is known from India (Catalogue of Life, 2020). Though phytophagous, biology of many species of *Eligma* is still unknown. *Eligma narcissus* (Cramer) 1775 is a serious pest of *Ailanthus* in Southern India (Roonwal. 1982). The life cycle consists of egg, larva, pupa and adult. Eggs pale white, larva bright sulphur yellow with black and red patches, pupa dark brown. Moths oviposit in clusters,

* Author for correspondence



Figures. 1-3 *Eligma narcissus* (Cramer) and host plant *Oroxylum indicum* (L.) Benth. ex Kurz. 1 & 2) Caterpillar and host plant; 3) Adult moths

incubation period 3-4 days, larval period 22-23 days and pupal period 15-17 days. There are 8-9 generations a year (Chatterjee *et al*., 1969).

Live specimens of larvae were collected on 3rd January 2020. They were found feeding on the leaves of a young plant, *Oroxylum indicum* (L.) Benth. ex Kurz. Larvae were reared in the laboratory at room temperature. In the lab, larvae were provided with fresh leaves of *O. indicum* (Bignoniaceae). Additional specimens were collected and reared in separate rearing cages and all the instars were fed with leaves. Larva stopped feeding and pupated on 23rd January 2020. Out of the 12 larvae collected and reared, 11 emerged out as adults (10th February 2020) and one was found dead. Four adult male moths were dissected according to standard procedures to study the genitalia (Robinson, 1976). The genitalia study is important to confirm the species identity. Adult specimens (2 males and 5 females) were mounted, dried and identified as *E. narcissus* based on the morphological and genital features available in published literatures (Chatterjee *et al*., 1969; Ueda and Saigusa, 1982).

Host record for *E. narcissus* in India shows preference to plants of Simaroubaceae. Other

previous host records included are flora of Rosaceae and Meliaceae from China (Shao *et al*., 2012). *O. indicum* is an ornamental plant widely distributed in India and South East Asia, commonly known as midnight horror, broken bones, Indian caper, or tree of Damocles. It is also a medicinal plant locally known as Bhatghila, Tona, Bhut-vriksha, Shyonaka, and Hanyu pinyin. Roots, leaves and stems of *O. indicum* have been used as a single drug or as a component of certain compound drug preparations in the Indian Ayurvedic system of medicine for treatment of various disorders as well as used as a tonic and Rasayana drug (Lawania *et al*., 2010). This is the first report of an additional host plant for *E. narcissus* and also the first record of Bignoniaceae as host plant for the genus *Eligma*. This finding widens the host range of *E. narcissus,* commonly known as ailanthus defoliator in India.

Preserved specimens will be deposited in the Zoological Survey of India, Kozhikode, Kerala, India. Material Examined: 2 Males, 5 Females, India, Kerala, Nilambur, October 2006, reared from larva on *Ailanthus excelsa,* Coll. Abhilash (ZSI); 1 Male, 3 Females, India, Kerala, Peechi, July 1986, reared from larva on *Ailanthus excelsa,* Coll. Varma (KFRI).

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