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OBITUARY

DR. ASHISH KUMAR GHOSH (1938-2018)

Dr. Ashish Kumar Ghosh (b. 1938) former Director, Zoological Survey of India and founder Director, Centre for Environment and Development (ENDEV), Kolkata passed away in Kolkata on April 1, 2018 at the age of 81. A prolific reader and an orator, *par excellence*, he became silent for a brief period and was battling throat cancer.

A bachelor, Dr. Ghosh had his early education in Rourkella, Odisha, and later had his graduation (1957), Masters (1959) and Ph. D. (1964) from the University of Calcutta. After teaching in an undergraduate college in Kolkata for a brief period, he moved to the Department of Plant Pathology and Entomology, University of Wisconsin, Madison, USA as a 'Fulbright Scholar and Rockfeller Foundation Grantee' where he continued his research on 'Long range dispersal of aphid-vectors of plant viruses'. After returning to India, Dr. Ghosh again joined the University of Calcutta as a Reseach Officer in a PL 480 Project and continued his researches extensively on the taxonomy of aphids (insects).

On joining the Zoological Survey of India in 1972, besides taxonomic works, he became more interested in environmental and biodiversity related works and biodiversity conservation. The first Environmental Monitoring Wing in ZSI (Kolkata and Chennai) was started under Dr. Ghosh's leadership in early 1980's. Between 1992-1996, he led delegations to the Ramsar Convention in Japan and acted as a Member of Indian deligation to the Asian Wetland Conference to Malaysia, Indo- Russia Forest Meet to Russia, IUCN General Assembly to Argentina and also other International meet in Kenya, China, France, Mexico and Spain. He also served as a Member of the Biodiversity Authority of India and took active and important role in formulating Indian Biodiversity Act- 2002 and its Rules in 2004. An outspoken Environmental Activist, Dr. Ghosh had the courage to submit an affidavit supporting the public in wetland case while still he was in office.

Under the leadership of Dr. Ghosh, ENDEV was actively engaged in biodiversity exploration and documentation, exploring old and indigenous varieties of crops, fruits etc. at block level. The first People's Biodiversity Register (PBR) in West Bengal on the biodiversity of Kolkata was prepared through his leadership. After the Sundarban was devasted by cyclone Aila in 2009, Dr. Ghosh worked on the field with the affected people and launched several projects. Out of these, the revival of long-forgotten traditional paddy seeds that grow in brackish water, became a life saver This endeavor won the World Bank honour for best innovation among more than 100 contestant countries.

Dr. Ghosh had written extensively on biodiversity conservation, natural resource management, on different dimensions of environment and development along with his basic interest on aphids taxonomy. He has more than 400 research papers in his credit besides about 10 books and monographs. He also authored 7 volumes of 'Fauna Volumes' on Indian Aphids published by the Zoological Survey of India. He won several prestigious honours and prizes and became the President of the Aphidological Society of India.

Dr. Ghosh was also Visiting Faculty Member of several premier institutions. He also supervised a dozen of Ph. D. students. He had also keen interest in literature, film and other social activities. His death caused profound grief among a large number of students, academics, environmental scientists and scholars in Kolkata and abroad.

Prof. Samiran Chakrabarti
UGC Emeritus Fellow & Professor & Head (Retd.)
Department of Zoology, University of Kalyani, Kalyani 741235
Email: chakrabarti32b@gmail.com

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THE DIGESTIVE INDEX AS A BENCHMARK TO QUANTIFY THE DIGESTIVE CAPABILITIES OF HONEY BEES (APIS MELLIFERA)

K. GRUENWALD AND J. GRUENWALD*

Karl-Franzens-University, Department of Zoology,
Universitaetsplatz 2, 8010 Graz, Austria
**Gruenwald Laboratories, Taxberg 50, 5660 Taxenbach, Austria*
**Email: jgruenwald@g-labs.eu*

ABSTRACT

An easy method to obtain the digestive index as a benchmark number for measuring the digestion capabilities of *Apis mellifera* is developed and presented in this paper. The aim of this method is to provide an entity that allows to quantifying digestion efficiency of the western honey bee. This will enable a fundamental understanding of digestive illnesses in bee hives as well as a general insight into the biological mechanisms into the digestive apparatus. Although the methodology presented in this work is based on experimental data of honey bees it can, in principle, be applied to other insects as well, provided that the necessary experimental data can be made available. A small number of seven bees is used to provide an example of how to calculate the digestive index. The bowels were extracted from these seven dead honey bees and their mass in fresh and dried condition was used for the determination of the digestive index. The mathematical model for the calculation of the digestive index is described. Thus, it is demonstrated that the digestion capability of honey bees can be quantified by the simple method outlined in this paper.

Key words: European honey bee, digestive index, characteristic number, quantification, digestive capability, bowel extraction, mathematical model

The western honey bee (*A. mellifera*) is of immense importance for ecologic and economic systems due to its pollination activities. Human food security and biodiversity are heavily dependent on these insects (Brotschneider and Crailsheim, 2011; Tautz and Heilmann, 2007).The health of a bee hive along with its capability to survive is a priority for bee keepers. A key factor concerning the health of bee hives is an adequate nutrition of the bees, which has a strong connection to the bees' capability of digesting their fodder (Brotschneider and Crailsheim, 2010). Additionally, irregularities in the bees' digestive patterns can be an indicator of diseases of the digestive system. Such illnesses can be caused by insufficient or otherwise flawed nutrition of the honey bees (Brotschneider and Crailsheim, 2013).

The experimental investigations in this manuscript are carried out with conventional bee fodder (i. e. a saccharose solution in water). This kind of feedstock is rich in carbohydrates that are essential for the well being of the bees (Brotschneider and Crailsheim., 2010; Haydak, 1970). Another widely used food source, viz. honey, is not included in this study as it has numerous disadvantages over saccharose solution (e.g. higher financial costs, a stronger tendency to crystallise and possibly pathogens that can be contained in the honey) (Papachristoforou et al., 2013).

To aim upon a reliable indicator of the functionality of the digestive system of *A. mellifera*, a novel characteristic number, the digestion index, is developed along with a simple method of how to obtain it. The computation of this index is based on statistically evaluated experimental data on the mortality of caged honey bees. Thus, the main focus is on the mathematical method rather than getting the exact value of the digestive index. Such are refinement would require a more extensive data pool, which is beyond the scope of this work. Nevertheless, it will be shown that the idea of the digestive index is based on experimental techniques that allow to obtain a reproducible, comparable number determining the functionality of the digestive system in a quantitative manner. This quantification of the digestive capability could lead to a better understanding and an early recognition of illnesses of the digestive tract of *A. mellifera*, such as the Nosema disease (Li et al., 2016; Holt and Grozinger, 2016; Maes et al., 2016; Snow, 2016) and others.

MATERIALS AND METHODS

All experiments were conducted between early July and the end of August with worker bees (*A. mellifera),* <24 hr of age, obtained from the hives of the biological institute of the University of Graz. All bees were kept in single use cages and fed *ad libitum* with the saccharose solution. The saccharose solution consisted of 50% by weight saccharose, 50% by weight water and a pH value of 6.84. Generally, a saccharose based feed is usually prepared either as a 1:1 or as a 3:2 solution in water (Barker and Lehner., 1973; Herbert, 1992; Hüsing and Nitschmann, 1987). The bees were continuously fed in 24 hr intervals and the cages checked on a daily basis for dead specimen. Each cage was initially populated by 100 bees and the experiment continued until only 20 bees were still alive.

By weighing the fodder containers with a high precision scale before feeding and after 24 hr, the amount of fodder, incorporated by the bees, was determined (the partially empty fodder containers were replaced with fresh ones, containing 2 ml of saccharose solution daily). At no instance a completely emptied food container was to be found during any of the experiments (i.e. the bees did not use all the feed during the course of a day).Taking into account the fact that caged honey bees do not empty their bowels, it was concluded that the entire content of the end bowel represents indeed all the undigested part of the fodder. Following the procedures given by Carreck et al. (2013), the head of the dead bee was removed with dissecting scissors. After that the abdomen and the intestine channel was entirely pulled out with suitable tweezers (Fig. 1).

After removing the ventriculus, proventriculus and the honey bladder, the mass of the fresh rectum was weighed with a high precision scale (Mettler Toledo®; electronic balance - accuracy 1%). Afterwards, the end bowels were incubated for five days at 70°C in a hot cabinet (Heraeus Instruments®) and weighed again to obtain the dry mass of the end bowel. The results of the average fodder intake /bee /day and the weight intestines are depicted in Figs. 2 and 3, respectively.

It seems to be surprising that the maximum value of the wet bowel mass at the end of day 10 (~ 34 mg) seems to be too low for a considered average fodder intake of 20 mg saccharose solution/bee /day. However, it has to be taken into account that 50% of the solution is water, which is generally not digested and ends up only partially in the end bowel. Hence, roughly half of the mass of the fodder (~ 100 mg in ten days) will not

Fig. 1. Extracted end bowel (rectum), middle bowel (ventriculus), proventriculus with valvula cardiaca and honey bladder. The mass of the end bowel was used in this work

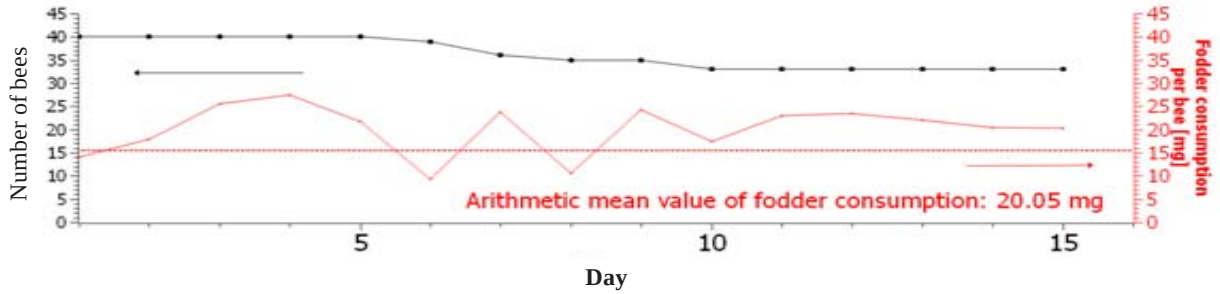

Fig. 2. Number of living bees (black) and average daily fodder intake (50% saccharose solution) / bee (red) with 1% error bars (defined by the accuracy of the high precision scale) as a function of time. The number of bees decreased from 40 to 33 over a course of 15 days. The arithmetic mean value of fodder consumption was 20.05mg

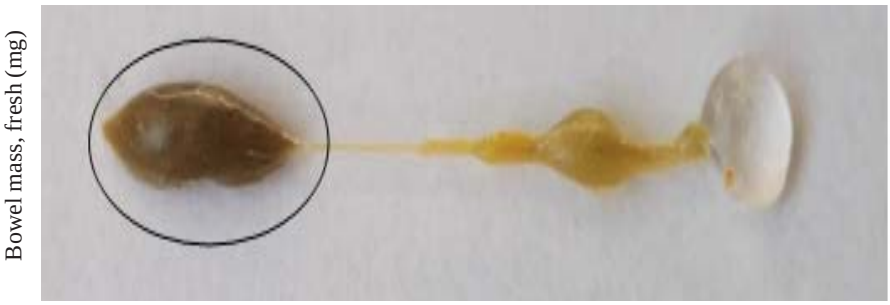

Fig. 3. Fresh (black) and dried (red) bowel mass as determined from the seven dead specimens obtained in the experiment. Arithmetic mean values: Fresh: 26.7 mg; Dry: 17.16 mg.- Error bars 1%. The numbers in brackets denote the life time of each specimen in days. After 10 days no more bees died and the experiment was terminated after 15 days

be stored in the bowels. Furthermore, a considerable quantity of saccharose will either be metabolised and incorporated in the bees' body mass (and, thus, not reaching the bowel), used for building honey combs or burnt in the cells and exhaled as CO_2. With the data gained so far, it is possible to quantify the digestion capability of *A. mellifera* with the simple model that is outlined in the results and discussion below.

RESULTS AND DISCUSSION

The mathematical model to determine the digestive index proposed herein is based the weight of the rectum of caged *A. mellifera* specimen after their natural death. The rectum was chosen because of following: 1. The caged honey bees did not empty their intestines while being held in the cages, and thus, total amount of fodder administered ends up in the rectum and remains there as the digestion activity stops after the death of the bee. 2. The content of the rectum has the highest mass compared to the mass of the rectum itself and compared to some minor undigested fodder remaining in the other parts of the intestines (Fig. 1). This ensures that the measurement error is minimised (determined by the accuracy of the electronic balance-1%).

For the calculation of the digestive index, several parameters are required: the amount of fodder on the i-th day (f_i), and the number of days from the start of the experiment until the natural death of the honey bee (t). From these first two entities the total amount of ingested fodder (F) can be calculated as:

$$F = \sum_i f_i \approx f \cdot t \qquad ...(1)$$

Equation (1) indicates that the fodder consumption of each day has to be summed up properly after the bee's death for each of the i days of the bee's life in the experiment. If the fodder intake has only marginal variations from day to day, it can be considered as constant over time and (1) reduces to the product of average fodder intake/day, multiplied with the number of days the specimen was alive.

After the death the rectum has to be extracted as soon as possible and its mass has to be measured in the fresh condition (M_f) as well as after drying the rectum and its content (M_d). With these values, two varieties of the digestive index (DI_f and DI_d) can be calculated:

$$DI_f =: \frac{M_f}{F} = \frac{M_f}{\sum_i f_i} \approx \frac{M_f}{f \cdot t} \qquad ...(2)$$

$$DI_d =: \frac{M_d}{F} = \frac{M_d}{\sum_i f_i} \approx \frac{M_d}{f \cdot t} \qquad ...(3)$$

Definitions (2) and (3) guarantee a normalisation of the digestive index by mapping $DI_{f,d}$ onto an open interval (0,1), so that $0 < DI_{f,d} < 1$ always holds. This is necessary to specifically exclude the limiting cases (i.e. $DI_{f,d} \rightarrow 0$ and $DI_{f,d} \rightarrow 1$), which are not likely to be observed in nature. The former case indicates that $M_d = 0$, which would mean that either the total amount of fodder was metabolized or it didn't enter the rectum in the first place (this could be theoretically possible if the insect dies immediately after the forage but in such a case the specimen should not be included into the analysis at all). The latter case would hold if the metabolic activity of the bee was completely disabled, which, in turn, would not allow the evaluation of the digestive ability. It shall also be emphasised here that the determination of two variations of DI is not futile, as it allows drawing some conclusions about the H_2O household of the bees.

In order to do that, the following ratio (W) is

defined:

$$W \equiv \frac{DI_d}{DI_f} = \frac{M_d}{M_f} \quad ...(4)$$

It describes how much water is still present in the content of the rectum. By comparison with the water content of the fodder (i.e. mass- % H_2O in the sugar solution) the water intake of *A. mellifera* can also be studied in detail. The results of these formulae are depicted in Figs. 4 and 5 (the numbers in brackets, again, denote the lifetime of each specimen in days).

These observations reveal that maximum discrepancy between the exact calculation and the calculation with average fodder intake is only 6%, which is considered to be already quite good, taking into the small amount of samples. It shall be pointed out that this paper presents a new method, which is made more clear with an exemplary calculation based on the aforementioned seven end bowel samples, rather than aiming at minimising the statistical error of the procedure. Thus, the small sample number is not regarded as an inaccuracy.

This simple concept allows to accurately quantify the digestion capabilities and the water intake of European honey bees for the first time, provided a sufficiently large number of samples is investigated, so enough that the standard statistical methods could apply.

A simple method to quantify the digestion capabilities of *A. mellifera*, in the form of the digestive index, has been presented herein. This is an important step forward in the diagnosis and understanding of diseases of the digestive system of European honey bees. This method might in principle be applied similarly on other insects, and the statistical inaccuracy of this technique is only about 6% even for a sample number as low as 7. However, more data is needed to gain insight into which interval of the digestive index can be considered be a benchmark for a healthy digestive system of *A. mellifera* and which values of the DI are a signal for diseases of the intestinal tract. In order to get a comprehensive database for such diagnosis, it is necessary to gain regional and seasonal measurements

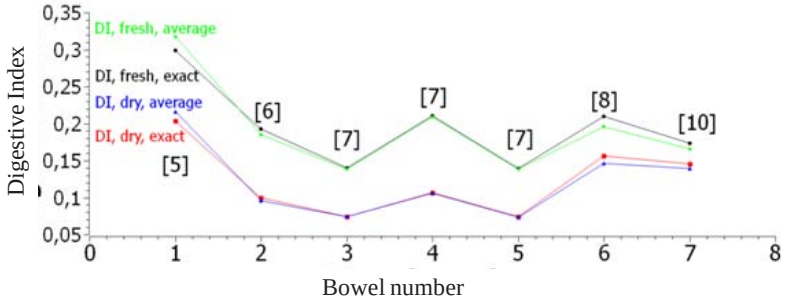

Fig. 4. Digestive Index (DI) computed for each of the seven end bowels, according to equations (2) and (3). The indices "exact" and "average" indicate that the calculation was performed with the summation over the fodder intake for each day and the average (20.05 mg) taken from Fig. 2.

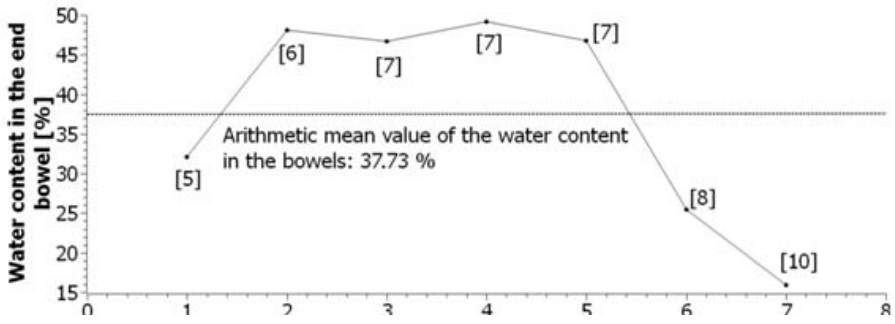

Fig. 5. Water content of the extracted end bowels, calculated with equation (4). It can be seen that the water content reaches nearly 50% in the samples.

from different varieties of honey bees, which is far beyond the scope of this paper. Nevertheless, as the presented method is a very robust and easy one, the collection of relevant data should be feasible in the near future. However, the exemplary calculations reveal that the digestive index of a healthy honey bee in Austria might be around 0.23 with a water content of 37.7% on an average. Values >0.3 or < 0.15 could in this case be considered to be a sign of a dysfunctional digestive capability of *A. mellifera*.

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EVALUATION OF SOME ESSENTIAL OILS AGAINST MAIZE WEEVIL *SITOPHILUS ZEAMAIS* (L.)

MIHIRET MEKONNEN*AND BEGASHAW MANAHLIE**

Wondo Genet Agricultural Research Center
Ethiopian institute of Agriculture Research, P.O.Box.198, Shashemene, Ethiopia
***Hawassa University, College of Natural and Computational Sciences*
P.O. Box 5, Hawassa, Ethiopia
**Email: hanamihiret0@gmail.com (corresponding author)*

ABSTRACT

Maize is the most important cereal in Africa, and in Ethiopia, it is the second widely grown cereal. Post harvest losses due to the maize weevil *Sitophilus zeamais* is an important constraint, with grain losses ranging from 20- 90%. This study evaluates the efficacy of essential oils against this weevil as an alternative to pesticides. Adult *S. zeamais* were bred in jars in the laboratory at 60–65% RH and 27±2°C. Five treatments viz., eucalyptuss, citronella grass and lemon grass essential oils each at 2.5, 5.0, 7.5 and 10.0µ ℓ/ℓ were poured into petri dishes containing diatomaceous earth (DE). Ethiolathion (Malathion 5%) and 95% ethanol were used as a standard check and as control, respectively. Ten pairs of adults S. *zeamais* were introduced into each treatment containing maize grains. Treatments were arranged in a complete randomized design (CRD) with four replications. The numbers of dead insects in each petri dish were counted at 24h, 48h, 72h, 96h, and 120h to estimate mortality rate. Grain weight losses were determined after seven days. The results revealed significant differences among treatments effects in the rate of mortality. All essential oil significantly affected weevil mortality compared to untreated control. The results showed that grain weight loss can be 18-60% after seven day due to weevil damage.

Key words: *Sitophilus zeamais*, maize, aromatic essential oils, eucalyptus, citronella, lemon grass, mortality rate, grain weight loss

Maize (*Zea mays* L.) or corn is a major source of dietary carbohydrate as well as the most important cereal in Africa (Rangari, 2009). Maize weevil (*Sitophilus zeamais* (Motsch.) (Coleoptera: Curculionidae), is a major pest of stored maize grain in many regions of the world (Qadry, 2009). In Ethiopia, maize is the second widely grown cereal crop, and *S. zeamais* is an important pest in stored maize, as in other parts of the world and causes severe loss in dry weight (Hayashi et al., 2004; Obeng- Ofori and Amiteye, 2005; Rees, 2004). Infestation by this weevil commences in the field, but most damage is done during storage (Demisse et al., 2008). Post harvest losses due to the S. zeamais are an important constraint, with grain losses ranging from 20 - 90% (Tefera et al., 2011). Grain weight loss of 12"20% caused is common, and up to 80% loss might occur in traditional storage structures in tropical countries. Weevil damage also affects grain saved grain as seed, a practice that accounts for about 70% of all maize planted in eastern and southern Africa.

Lemon grass, *Cymbopogon citrates* (DC) Stapf is a perennial aromatic grass in the family Poaceae, and it grows in many parts of tropical and subtropical South East Asia and Africa (Rangari, 2009; Joy et al., 2006; Qadry, 2009), and it can be used as insect repellant (Joy et al., 2006). In Ethiopia, three varieties of lemon grass are registered and available with the variety names of Lomisar-I, WG-Lomisar-UA and WG-Lomisar-Java. *Eucalyptus globules*, known as tasmanians is one of the dominant highland exotic spices in Ethiopia. It is a highland tree, rarely grown in altitude < 1300m, and grows up to 55m, with blue grey bark. Its essential oil possesses a wide spectrum of biological activity, including anti-microbial, fungicidal, insecticidal/ insect repellent, herbicidal, acaricidal and nematicidal properties (Batish et al., 2008). Citronella grass

*****The first author is the Principal Investigator; second contributed equally from proposal development to the final manuscript writeup.

(*Cymbopogon winterianus* L.) is one of the aromatic grasses belonging to the Poaceae family. Citronella oil was selected as a positive control in all repellency tests because it is a renowned natural insect repellent, with a non toxic mode of action.

Insecticides being expensive are out of reach of small farmers , and indiscriminate application of these results in various problems like residues, pollution, and resistance (Martins, 2006). There is a need for ecofriendly, cheap, sustainable, and safe plant protection agents for use as grain protectants. This study, therefore, evaluates the efficacy of essential oils against maize weevil as an alternative to pesticides for sustainable management.

MATERIALS AND METHODS

The experiment was carried out in Wondo Genet Agricultural Research Center's Plant Protection laboratory in 2016. Adult *S. zeamais* were mass reared in the laboratory at 27±2°C, 60–65% RH and 12h:12h light: dark regime. Stock culture was obtained from the Crop Protection Laboratory, Hawassa Maize Research subcenter. In the medium of healthy maize grains, ten pairs of *S. zeamais* were introduced in one litre glass jars containing 200 g of weevil susceptible maize grains (BH 60). The jars were then covered with nylon mesh held in place with rubber bands. Freshly emerged adults were subsequently used for the experiments. The essential oils from eucalyptus, citronella grass and lemon grass were extracted by hydro- distillation method (Guenther, 1972) and stored at 4°C.

Five treatments namely eucalyptuss, citronella grass and lemon grass essential oils each at 2.5, 5.0, 7.5 and 10.0µl/l were poured into petri dishes containing diatomaceous earth (DE). Ethiolathion (Malathion 5%) and 95% ethanol were used as a standard check and as control, respectively. Ten pairs of adults were introduced into each treatment containing maize grains. Treatments were arranged in a completely randomized design (CRD) with four replications. Aluminum foils with perforations were used as lids to secure the petri dish and served to ensure aeration while preventing entry or exit of insects. The contents of the petri dish were then mixed gently for proper and uniform mixing.

The numbers of dead insects in each petri dish were counted at 24, 48, 72, 96, and 120 hr to estimate mortality rate,, and grain weight losses were determined after seven days. Grains were sieved and the numbers of live and dead pests were counted from each petri dish to obtain weevil mortality, after applying Abbott's formula (Abbott, 1925). The data were statistically analyzed using SAS software version 9.2, and means were separated using LSD at p= 0.05.

RESULTS AND DISCUSSION

The results obtained with doses of the essential oils and the expressed toxicity towards *S. zeamais*, revealed significant mortality ranging from 73 to100% with citronella. The dose for each oils to get mortality from 66 to 100% was observed to be 2.5- 10µl (Table 1). However these were not as effective as malathion 5% dust at 24 hr. The superior ones were citronella grass+ DE, followed by lemon grass+ DE, when compared to eucalyptus+ DE, at dose of 2.5µl to 10µl, reaching 70% and 100% mortality 24 and 48 hr, respectively (Table 1, 3). Mortality rate due to lemon grass+ DE and citronella+ DE was 70% after 24 h, and 90% after 48 hr. Mortality varied from 20 to 100% after 72 hr of application of lemon grass, eucalyptus and citronella, at 2.5 to 10µl, and eucalyptus was the most efficient, causing 100% mortality at the lower lethal concentration 2.5µl in 24 hr.

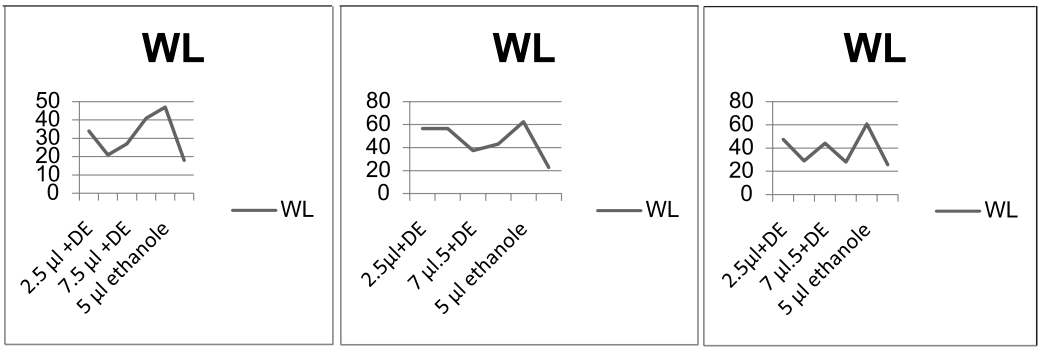
The results showed that grain weight loss was 18-60% in 96 hr and the treated grains had lowest weight loss ranging 20-40% (Fig. 1). The result obtained from this study indicated that weight loss in stored maize grains is related to the number of insects present and this finding is also in agreement with Jembere et al. (1995). In 96 hr, least damage was observed with eucalyptus oil @ 5µl+DE.

Insect mortality due to these oils is due to their active volatiles mostly monoterpenes is known earlier (Huang et al., 2000; Kouninki, 2005; Ferreira and Fonteles, 1989; Simoes and Spitzer, 2004; Araya, 2007; Yang et al., 2005). The maximum mortality with *C. citratus* essential oil might be due to higher concentration of citral (63%) in comparison with *Z. officinale* in which the most concentrated component was 41%. In *Mentha* sp., without citral, there was only menthol (91%), and L-menthol had been shown to have insecticidal activities against *Tribolium castaneum* Herbst, with LD_{50} of 108.4 ppm. In view of the control exhibited by *C. citrodora* leaf dust against *S. zeamais*, treatment of field infested maize grains with any of the two powders will kill all eggs thereby preventing the buildup of the weevil and subsequent damage in storage**.** Also, this leaf powder is locally available, cheap, and environmental friendly. Thus, essential oils provide significant promise against maize weevil and can be adopted by small scale farmers.

Table 1. Effect of lemon grass, eucalyptus and citronella essential oils with diatomaceous earth (DE) on mortality (%) of *Sitophilus zeamais*

	Lemon grass oil					Eucalyptus globules					Citronella grass				
Treat	24hr	48hr	72hr	96hr	120hr	24hr	48hr	72hr	96hr	120hr	24hr	48hr	72hr	96hr	120hr
T1- 2.5µlEO+DE	70.00^{b}	90.00^{ab}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	73.33^{b}	90.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
T2- 5µlEO +DE	66.67^{b}	83.33^{b}	100.00^{a}	100.00^{a}	100.00^{a}	70.00^{b}	86.67^{b}	93.33^{a}	100.00^{a}	100.00^{a}	73.33^{b}	93.33^{a}	100.00^{a}	100.00^{a}	100.00^{a}
T3 - 7µl.5EO+DE	73.33^{b}	93.33^{ab}	100.00^{a}	100.00^{a}	100.00^{a}	63.33^{b}	83.33^{b}	93.33^{a}	100.00^{a}	100.00^{a}	70.00^{b}	93.33^{a}	100.00^{a}	100.00^{a}	100.00^{a}
T4- 10µlEO +DE	73.33^{ab}	93.33^{ab}	100.00^{a}	100.00^{a}	100.00^{a}	66.67^{b}	86.67^{b}	100.00^{a}	100.00^{a}	100.00^{a}	80.00^{b}	100.00 ^{a}	100.00^{a}	100.00^{a}	100.00^{a}
T5- Ethanol 95%	10.00^{c}	13.33^{c}	16.67^{b}	26.67^{b}	33.33^{b}	10.00^{c}	10.00^{c}	20.00^{b}	26.67^{b}	36.67^{b}	10.00^{c}	10.00^{b}	20.00^{b}	36.67^{b}	56.67^{b}
T6- Malathion 5%	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
LSD	19.66	16.55	3.88	3.88	3.88	14.44	13.07	13.82	7.76	3.88	16.16	15.85	6.72	19.41	20.54

Means with the same letter within the same column not statistically different ($p < 0.05$); EO, essential oil and DE, Diatomaceous earth.
After 72hr the efficacy of lemongrass, eucalyptus and citronella grass was the same (100%) as malathion.



Citronella Eucalyptus Lemon grass

Fig. 1. Weight loss in grain maize due to *S. zeamais*-: x axis- treatments and y axis- mortality %

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DIAGNOSIS OF CRIME REPORTER FLIES IN FORENSIC ENTOMOLOGY: A REVIEW

SHYAMASREE GHOSH*[$], WALIZA ANSAR**[$], AND DHRITI BANERJEE*[$]**

**School of Biological Sciences*
National Institute of Science Education and Research (NISER), Bhubaneswar 752050;
Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai 400094
***Department of Zoology, Behala College, Parnasree, Banamali Naskar Road, Kolkata 700060*
****Diptera Section, Zoological Survey of India, Ministry of Environment & Forests (GoI)*
M Block, New Alipore, Kolkata700053
[$]Authors have equal contributions, and declare no conflict of interest
**Email: shyamasree_b@yahoo.com (corresponding author)*

ABSTRACT

Accurate identification of forensically important insects still remains a major challenge to the forensic entomologists. Conventionally morphological identification methods are used, which suffer from the disadvantage of not being able to distinguish between immature stages of species. Hence, DNA based molecular methods are being employed, and such species-specific data collected herein. Nearly 350 papers from PUBMED and Google Scholar are included, of which 120 were cited in the references list. More than 400 papers reviewed and strategies of morphological, biochemical, and molecular approaches reviewed.

Key words: Insects, forensics, flies, review, developmental stages, identification, morphological, molecular, light microscopy, SEM, families, PUBMED, Google Scholar

The post mortem interval (PMI) estimation is essential in unnatural death investigation, detected by body colour, muscle, and post-mortem lividity. However in both soil and water such investigations sometimes suffer disadvantages of difficulty in analysis due to autolysis, decay, bloating, putrefaction and skeletal bone decomposition or diagenesis of the corpse. However, necrophagous arthropods growing in succession on the decaying corpse can serve as an essential clue to determination of PMI and finds importance in forensics. Number, types, developmental stages and pattern of arthropod colonization on corpse are parameters employed to estimate the PMI (Amendt et al., 2011; Amendt et al., 2007).

Starting with the first fly laying its eggs on the body, it is measured by recognizing the developmental stage of the oldest colonizing species and the subsequent discovery of the corpse. The duration to attain the last stage, with its particular stage of decay, gives a best accurate measure, of the possible span of time elapsed since the person's death (Amendt et al., 2004). The geographical location and conditions of the body, and its accessibility to flies at the scene of the crime further enables PMI estimation. However precise methodology should be used to collect, kill, preserve and label the forensically important fly isolated from crime scenes to maintain the accuracy of evidence (Amendt et al., 2011). In decaying corpse in water, corpse feeding aquatic insects, chironomid larvae, water snails and some colonizing terrestrial insects grow. In forensic cases of neglect or physical abuse, insects are valuable indicators as some insects are always attracted towards urine or faecal matter attached to the body (Amendt et al., 2004) .

Forensic entomology requires the fast and accurate identification of insects collected from a corpse for estimation of the PMI. Identification of specimens is performed using morphological features of the insect. Arthropod specimens of the members of the Arachnida (Families: Parasitidae, Mesostigmata, Prostigmata, Astigmata, Endeostigmata, Oribatida, Ixodida and Sarcoptiformes etc); Coleoptera (Families: Dermestidae, Cleridae Silphidae, Staphylinidae, Histeridae etc); Diptera (Families: Calliphoridae, Stratiomyidae, Fanniidae, Piophillidae, Milichiidae, Sarcophagidae, Muscidae, Syrphidae, Phoridae etc) and also their juvenile stages are found in corpses and in and around death scenes, and are useful entomological tools in forensic investigations (González Medina et al., 2013; Braig and Perotti, 2009; Boehme et al., 2013;

Tarone et al., 2007). The diversity of specimens with application in forensic entomology has developed recently with quite a few candidate species identified. The importance of many other species with their role in forensic entomology is still under investigation.

Conventional methods used to identify the forensically important closely related species of Chrysomya ru?facies (Macquart) and Chrysomya villeneuvi Patton include both detection of the morphology of their larvae and puparia, cuticular sculpture of tubercles along the dorsal and lateral segments observed under scanning electron microscopy (SEM) and their aggressive feeding behavior (Sukontason et al., 2006a). However morphological identification may be complicated by the physical similarity between different species, numerical diversity of species and particularly indistinguishable immature stages. Thus along with traditional morphological identification, molecular characterization was performed as the prospective basis of a diagnostic technique. (Molecular identification is employed as an important strategy in species identification). DNA and RNA sequences of many forensically important species from Sarcophagidae and calliphoridae families have been recently used for diagnosis (Boehme et al., 2012 ; Zehner et al., 2004).

Mitochondrial Cytochrome oxidase subunit I (COI) and subunit II (COII) gene sequences from various larval and adult specimens have been reported to differentiate between the species and families of forensic flies thereby revealing COI gene sequence as promising molecular markers for species identification in insects (Tan et al., 2010 ; Tan et al., 2009). The mitochondrial DNA (mtDNA) sequences of sarcophagid flies have been used in species identification (Tan et al., 2010 ; Guo et al., 2010 ; Guo et al., 2012). A combination of DNA-based sequencing, phylogenetic analysis and complement morphological characterization is more effective for identification of Sarcophagidae (Tan et al., 2010). Despite promises, the DNA based methods suffers from the disadvantage of loss of genetic material due to improper storage of specimen, transportation without refrigeration, limited number of samples analyzed, and short DNA fragments, inconsistency for nuclear and mitochondrial marker gene trees, samples analysis from geographically restricted areas leading to false results and misleading and inaccurate identification (Sonet et al., 2012). Besides, phylogenetic trees of species based on the assumption of monophyletic alleles, suffers from the disadvantage of species-level paraphyly or polyphyly leading to inaccurate species characterization (Daniel et al., 2003).

Although different approaches are being tested for identification of forensic flies, various questions remain unanswered. Various post-mortem carrion fauna showing seasonal variation are still to be catalogued. Pupal and other immature life stage of many forensically important sarcophagids is still a mystery. Identification of closely related species of calliphorids and the role of most commonly found house fly (Muscidae) is still a difficulty (Li et al., 2011).

Thus at this juncture, to explore the scope of the forensic flies in crime prediction, it is important to undertake an integrated study on such important flies. In this review we focus on the different strategies employed by different research groups to identify, forensically important flies probing different morphological, biochemical and molecular markers required for species identification.

IDENTIFICATIONS OF FORENSIC ARTHROPODS

Taxonomic identification of each arthropod species found on corpses is essential for the reconstruction of events surrounding criminal cases. Morphological, genetic, biochemical, reproductive processes including oviposition, larviposition, developmental phases are essential parameters for taxonomic identification and also for play important role in forensics (Park et al., 2003). However, the early developmental phases are morphologically indistinguishable from each other (Cook and Dadour, 2011). Other parameters like biochemical, genetic and reproductive mode contribute to evaluation of proper role of the insect in estimating PMI (Harvey et al., 2008).Screening of all these parameters helps to screen differences between sister species and to rule out inter or intra-specific variations among different species leading to the construction of a phylogenetic tree that helps in taxonomic identification of species (Harvey et al., 2008).

a. Morphological identification

Identification of species of forensic flies is an essential requirement. The morphological identifying features of 48 forensically important species listed under families are in Table 1. The important parameters used for molecular identification is also listed. The details of developmental stages are given in Table 2. The Fig. 1 depicts the molecular aspects and their relationship with identification.

Table 1. Species of importance in forensic entomology-morphological and molecular approaches

S.No.	Species	Identification tool	
		Morphological	Molecular
A. Family Calliphoridae			
1	*Lucilia cuprina* (Wiedemann, 1830) (Australian sheep blow fly)	1. SEM ultrastructure has been used to identify the morphological character of eggs and the immature stages in China (Sukontason *et al*., 2004). 2. Ultrastructure of sensilla associated with mouthparts and antennae of male and female flies to reveal its importance in ethno-veterinary medicine (Hassan *et al*., 2013). 3. Morphology of male internal reproductive organs, spermatozoa, and spermiogenesis of 3 blow flies was described using LM and TEM (Name *et al*., 2012).	1. Direct sequencing of the304-bp cytochrome oxidase I gene fragment of 75 specimens belonging to 19 species of Calliphoridae, Sarcophagidae and Muscidae families. Nucleotide sequence divergences were calculated by Kimura two-parameter distance model and a neighbor-joining phylogenetic tree was generated (Aly *et al*., 2013). 2. Phylogenetic analysis of 119 specimens from 22 countries of calliphorid species based on 1167 base pairs of the COI gene (Harvey *et al*., 2008).
2	*Lucilia ampullacea* (Villeneuve,1922)	1. Pseudocephalon, antennal complex, maxillary palpus, facial mask, cephaloskeleton, thoracic and abdominal spinulation, spiracular field, and posterior spiracles of first instars of the European and Mediterranean blow flies were identified with SEM images, LM photographs and line drawings (Szpila *et al*., 2013).	1. Cytochrome b locus of this fly has been used as diagnostic tool as it is one of the most common species of cadaveric entomofauna on the Atlantic seaboard of the Iberian Peninsula (Gilarriortua *et al*., 2008). 2. From the developmental gene bicoid sequences of 12 blow fly species, a phylogenetic tree was constructed that discriminates the subfamilies of Calliphoridae (Luciliinae, Chrysomyinae, and Calliphorinae) and most blow fly species (Park *et al*., 2013).
3	*Lucilia caesar* (Linnaeus, 1758)	1. Pseudocephalon, antennal complex, maxillary palpus, facial mask, cephaloskeleton, thoracic and abdominal spinulation, spiracular field, and posterior spiracles of first instars of the European and Mediterranean blow flies were identified with SEM images, LM photographs and line drawings (Szpila *et al*., 2013).	1. Direct sequencing of the304-bp cytochrome oxidase I gene fragment of 75 specimens belonging to 19 species of Calliphoridae, Sarcophagidae and Muscidae families. Nucleotide sequence divergences were calculated by Kimura two-parameter distance model and a neighbor-joining phylogenetic tree was generated (Aly *et al*., 2013).
4	*Lucilia sericata* (Meigen, 1826)	1. Grows better when fed on dead porcine tissues like heart, lungs and liver than bovine tissues (Clark *et al*., 2006). 2. Pseudocephalon, antennal complex, maxillary palpus, facial mask, cephaloskeleton, thoracic and abdominal spinulation, spiracular field, and posterior spiracles of first instars of the European and Mediterranean blow flies were identified with SEM images, LM photographs and line drawings (Szpila *et al*., 2013). 3. Diagnostic features to separate the third instar larvae of closely related forms of blow flies of medico-veterinary importance were described (Erzinclioglu, 1987).	1. From the developmental gene bicoid sequences of 12 blow fly species, a phylogenetic tree was constructed that discriminates the subfamilies of Calliphoridae (Luciliinae, Chrysomyinae, and Calliphorinae) and most blow fly species (Park *et al*., 2013). 2. Sequencing focused on a section of the cytochrome oxidase I encoding region of mt DNA of three species of calliphorid (Harvey *et al*., 2003; Harvey *et al*., 2008).
5	*Lucilia silvarum* (Meigen, 1826)	1. Adults found on human corpse on the altitude of 3350m in the month of June in the Colorado Rocky mountains (Adair and Kondratieff, 2006). 2. Pseudocephalon, antennal complex, maxillary palpus, facial mask, cephaloskeleton, thoracic and abdominal spinulation, spiracular field, and posterior spiracles of first instars of the European and Mediterranean blow flies were identified with SEM images, LM photographs and line drawings (Szpila *et al*., 2013).	1. Mitochondrial DNA cytochrome oxidase I gene "barcoding region" as a universal marker for molecular identification of 111 specimens belonging to 13 species originating from Germany of Calliphoridae (Boehme *et al*., 2012).

6	*Lucilia eximia* (Wiedemann, 1819)	1. SEM ultrastructure has been used to identify the morphological character of eggs and the immature stages in China (Mendonca *et al*., 2012). 2. Morphology of male internal reproductive organs, spermatozoa, and spermiogenesis of 3 blow flies was described using LM and TEM (Name *et al*., 2012).	1. Evolution, structural organisation and phylogenetic usefulness of mtDNA control region (called the A+T-rich region in insects) were determined by molecular characterization in five myiasis-causing flies (Lessinger *et al*., 2000).
7	*Lucilia illustris* (Meigen, 1826)	1. Pseudocephalon; antenna; maxillary palpus; facial mask; labial lobe; thoracic and abdominal spinulation; spiracular field; posterior spiracles, anal pad and cephaloskeleton of first instar larva were identified by SEM LM and illustrations (Szpila *et al*., 2008).	1. From the developmental gene bicoid sequences of 12 blow fly species, a phylogenetic tree was constructed that discriminates the subfamilies of Calliphoridae (Luciliinae, Chrysomyinae, and Calliphorinae) and most blow fly species (Park *et al*., 2013). 2. Mitochondrial DNA cytochrome oxidase I gene "barcoding region" as a universal marker for molecular identification of 111 specimens belonging to 13 species originating from Germany of Calliphoridae (Boehme *et al*., 2012).
8	*Calliphora graham* (Aldrich, 1930)	1. Spines of the body segments of the third instar larva were the identification characters by LM (Velásquez *et al*., 2010). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. From the developmental gene bicoid sequences of 12 blow fly species, a phylogenetic tree was constructed that discriminates the subfamilies of Calliphoridae (Luciliinae, Chrysomyinae, and Calliphorinae) and most blow fly species (Park *et al*., 2013).
9	*Calliphora vomitoria* (Linnaeus, 1758)	1. Grows better when fed on dead porcine tissues like heart, lungs and liver than bovine tissues (Kaneshrajah and Turner, 2006; Ireland and Turner, 2006). 2. Pseudocephalon, antennal complex, maxillary palpus, facial mask, cephaloskeleton, thoracic and abdominal spinulation, spiracular field, and posterior spiracles of first instars of the European and Mediterranean blow flies were identified with SEM images, LM photographs and line drawings (Szpila *et al*., 2013).	1.Cytochrome b locus of this fly has been used as diagnostic tool as it is one of the most common species of cadaveric entomofauna on the Atlantic seaboard of the Iberian Peninsula (Gilarriortua *et al*., 2013).
10	*Calliphora vicina* (Robineau-Desvoidy, 1830)	1. Pseudocephalon; antenna; maxillary palpus; facial mask; labial lobe; thoracic and abdominal spinulation; spiracular field; posterior spiracles, anal pad and cephaloskeleton of first instar larva were identified by SEM LM and illustrations (Szpila *et al*., 2013; Szpila *et al*., 2008).	1. From the developmental gene bicoid sequences of 12 blow fly species, a phylogenetic tree was constructed that discriminates the subfamilies of Calliphoridae (Luciliinae, Chrysomyinae, and Calliphorinae) and most blow fly species (Park *et al*., 2013).
11	*Calliphora stygia* (Fabricius,1781)	1. Diagnostic features to separate the third instar larvae of closely related forms of blow flies of medico-veterinary importance were described by LM (Erzinclioglu, 1987). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. Phylogenetic analysis of 119 specimens from 22 countries of calliphorid species based on 1167 base pairs of the COI gene (Harvey *et al*., 2008).
12	*Calliphora dubia* (Macquart, 1855)	1. Female fly size and the number of live larvae carried has strong correlation. First report of the ability of female flies to resorb some of their own live larvae (Cook and Dadour, 2011). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	Sequencing focused on a section of the cytochrome oxidase I encoding region of mt DNA of three species of calliphorid (Harvey *et al*., 2003).
13	C*alliphora albifrontalis* (Mauoch, 1932)	1. Thorax of adult is non-metallic blue-black in colour but the abdomen is predominantly brown or brown-yellow in colour as seen by LM. The third-stage larvae are of veterinary interest possess a cephalopharngeal skeleton with a pigmented accessory oral sclerite (Wall and Shearer, 1997). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. Phylogenetic analysis of 119 specimens from 22 countries of calliphorid species based on 1167 base pairs of the COI gene (Harvey *et al*., 2008).

14	*Chrysomya megacephala* (Fabricius, 1794)	1. Morphology and identification of fly eggs of different flies based on morphometric quantitation of mean length, width of median area and darkness staining of hatching pleats by SEM (Sanit *et al*., 2013).	1. From the developmental gene bicoid sequences of 12 blow fly species, a phylogenetic tree was constructed that discriminates the subfamilies of Calliphoridae (Luciliinae, Chrysomyinae, and Calliphorinae) and most blow fly species (Park *et al*., 2013). 2. Direct sequencing of the304-bp cytochrome oxidase I gene fragment of 75 specimens belonging to 19 species of Calliphoridae, Sarcophagidae and Muscidae families originating from China. Nucleotide sequence divergences were calculated by Kimura two-parameter distance model and a neighbor-joining phylogenetic tree was generated (Aly and Wen, 2013). 3. Evolution, structural organisation and phylogenetic usefulness of mtDNA control region (called the A+T-rich region in insects) were determined by molecular characterization in five myiasis-causing flies (Lessinger *et al*., 2000).
15	*Chrysomya putoria* (Wiedemann, 1830) (African latrine fly)	1. SEM ultra structure has been used to identify the morphological character of eggs and the immature stages in China (Mendonca *et al*., 2012). 2. Diagnostic features to separate the third instar larvae of closely related forms of blow flies of medico-veterinary importance were described by LM (Erzinclioglu, 1987).	1. Karyotypes, constitutive heterochromatin, and genomic DNA values in the genera *Chrysomya*, *Lucilia*, and *Protophormia* were assessed. All flies had 5 large chromosome pairs showed similar relative DNA contents. The data suggest that the interspecific DNA differences in most species are mainly due to quantitative variation of (repetitive) sequences lying outside the centromeric heterochromatin blocks of the large chromosomes (Ullerich *et al*., 2006).
16	*Chrysomya rufifacies* (Macquart, 1843)	1. Pupa were parasitoid by larvae and Hymenoptera species on monkey carcass in indoor and outdoor costal environment of Malaysia (Chin *et al*., 2009). 2. Diagnostic features to separate the third instar larvae of closely related forms of blow flies of medico-veterinary importance were described by LM (Erzinclioglu, 1987). 3. Morphology and identification of fly eggs of different flies based on morphometric quantitation of mean length, width of median area and darkness staining of hatching pleats by SEM (Sanit *et al*., 2013).	1. Direct sequencing of the304-bp cytochrome oxidase I gene fragment of 75 specimens belonging to 19 species of Calliphoridae, Sarcophagidae and Muscidae families originating from China. Nucleotide sequence divergences were calculated by Kimura two-parameter distance model and a neighbor-joining phylogenetic tree was generated (Aly and Wen, 2013). 2. Sequencing focused on a section of the cytochrome oxidase I encoding region of mtDNA of three species of calliphorid (Harvey *et al*., 2003).
17	*Chrysomya varipes* (Macquart, 1851)	1. Appears as a secondary fly in possum carcass and the enormous variability in the numbers of all secondary/tertiary fly species is negatively correlated with the proportion of all flies to emerge that were primary, and with the mean size of adult *L. sericata* (Lang *et al*., 2006). 2. Face wholly yellow; middle and hind femora broadly reddish basally; male frons extremely broad, almost as broad as in females, male front femur mostly whitish with prominent, long whitish hairs dorsally by LM (James, 1971). 3. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. Karyotypes, constitutive heterochromatin, and genomic DNA values in the genera *Chrysomya*, *Lucilia*, and *Protophormia* were assessed. All flies had 5 large chromosome pairs showed similar relative DNA contents. The data suggest that the interspecific DNA differences in most species are mainly due to quantitative variation of (repetitive) sequences lying outside the centromeric heterochromatin blocks of the large chromosomes (Ullerich *et al*., 2006).
18	*Hypopygiopsis violacea* (Macquart, 1835)	1. Cephalopharyngeal skeleton, anterior and posterior spiracles of the second and third instar larvae were examined using LM (Ahmad *et al*., 2010). 2. No data on morphological identification of the fly and its stages by SEM were	1. The sequence of the barcode region Cytochrome oxidase subunit 1 (COI or COX1) were done for molecular characterization (Encyclopedia of Life, 2014).

19	*Cochliomyia macellaria* (Fabricius, 1775)	1. Flies, pupas and larvae can fed on deeply buried corpse and can emerge from burial of nearly 50 cm of soil (Balme *et al*., 2012). 2. Morphological identification of the spermatheca of the flies from other related species by LM (Name *et al*, 2012). 3. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. Utilization and characterization of microsatellite loci were determined for species identification (Balme *et al*., 2012).
20	*Protophormia terraenovae* (Robineau-Desvoidy, 1830)	1. Flies, pupas and larvae can fed on deeply buried corpse and can emerge from burial of nearly 120 cm of soil (Balme *et al*., 2012). 2. Pseudocephalon; antenna; maxillary palpus; facial mask; labial lobe; thoracic and abdominal spinulation; spiracular field; posterior spiracles, anal pad and cephaloskeleton of first instar larva were identified by SEM, LM and illustrations (Szpila *et al*., 2008; 2013).	1. Karyotypes, constitutive heterochromatin, and genomic DNA values in the genera *Chrysomya, Lucilia,* and *Protophormia* were assessed. All flies had 5 large chromosome pairs showed similar relative DNA contents. The data suggest that the inter-specific DNA differences in most species are mainly due to quantitative variation of (repetitive) sequences lying outside the centromeric heterochromatin blocks of the large chromosomes (Ullerich *et al*., 2006).
21	*Hemipyrellia ligurriens* (Wiedemann, 1830)	1. The morphology and developmental rate of all stages of flies characterized for forensic purpose (Bunchu *et al*., 2012; Sukantoson *et al*., 2008). 2. Morphometric analysis of the length and width of puparia, along with the length of the gaps between the posterior spiracles of seven fly species, displayed differences among them (Sukantoson *et al*., 2007).	1.From the developmental gene bicoid sequences of 12 blow fly species, a phylogenetic tree was constructed that discriminates the subfamilies of Calliphoridae (Luciliinae, Chrysomyinae, and Calliphorinae) and most blow fly species (Park *et al*., 2013).
22	*Phormia regina* (Meigen, 1826)	1. Response of flies to temperature in colonizing carcasses and oviposition is corelated (Matuszewski *et al*., 2013). 2. Pseudocephalon; antenna; maxillary palpus; facial mask; labial lobe; thoracic and abdominal spinulation; spiracular field; posterior spiracles, anal pad and cephaloskeleton of first instar larva were identified by SEM, LM and illustrations (Szpila *et al*., 2008).	1. From the developmental gene bicoid sequences of 12 blow fly species, a phylogenetic tree was constructed that discriminates the subfamilies of Calliphoridae (Luciliinae, Chrysomyinae, and Calliphorinae) and most blow fly species (Park *et al*., 2013).
B. Family Muscidae			
23	*Hydrotaea ignava* (Harris, 1780)	1. Morphology of adult flies and oviposition varies with an abrupt and large increase in a narrow range of low temperatures and no response in a broad range of high temperatures (Matuszewski *et al*., 2013). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. COI barcode was used for clear differentiation and identification of forensically relevant Diptera in Germany (Boehme *et al*., 2012).
24	*Hydrotaea similis* (Meade,1887)	1. Morphology of adult flies and oviposition varies with an abrupt and large increase in a narrow range of low temperatures and no response in a broad range of high temperatures (Matuszewski *et al*., 2013). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. COI barcode was used for clear differentiation and identification of forensically relevant Diptera in Germany (Boehme *et al*., 2012).

25	*Fannia fusconotata* (Rondani, 1868)	1. The abundance of flies, time of occurrence and residency time at the pig carcasses varies with season and environment. Grow maximally when pig carcasses were kept in sun (Aballay *et al*., 2012). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. The sequence of the barcode region Cytochrome oxidase subunit 1 (COI or COX1) were done for molecular characterization (Encyclopedia of Life, 2014).
26	*Fannia albitarsis* (Stein, 1911)	1. Identified in pig carcasses in semi-arid climate (Aballay *et al*., 2012). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. No concrete records were found on Pubmed. 2. Mitochondrial DNA cytochrome oxidase I gene "barcoding region" as a universal marker for molecular identification of forensically important Diptera (Encyclopedia of Life, 2014).
27	*Fannia femoralis* (Stein, 1896)		1. No concrete records were found on Pubmed. 2. Mitochondrial DNA cytochrome oxidase I gene "barcoding region" as a universal marker for molecular identification of forensically important Diptera (Encyclopedia of Life, 2014).
28	*Fannia heydenii* (Wiedemann, 1830)		1. No concrete records were found on Pubmed. 2. Mitochondrial DNA cytochrome oxidase I gene "barcoding region" as a universal marker for molecular identification of forensically important Diptera (Encyclopedia of Life, 2014).
29	*Hydrotaea aenescens* (Wiedemann, 1830) (black dump flies)	1. Salivary gland hypertrophy were not significant as compared to *Musca domestica* (Geden *et al*., 2011). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. GC-MS analysis used to characterize puparia cuticular lipids (hydrocarbons, waxes) and to compare the molecular distribution patterns in the extracts from either recent or older puparia. Showed change in puparia lipid composition over time, thus potentially providing new indices for estimating PMI (Frere *et al*., 2014).
30	*Hydrotaea rostrata* (Robineau-Desvoidy, 1830)	1. Appears as a tertiary fly in possum carcass and the enormous variability in the numbers of all secondary/tertiary fly species is negatively correlated with the proportion of all flies to emerge that were primary, and with the mean size of adult *L. sericata* (Lang *et al*., 2006). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. The sequence of the barcode region Cytochrome oxidase subunit 1 (COI or COX1) were done for molecular characterization (Encyclopedia of Life, 2014).
31	*Synthesiomyia nudiseta* (Wulp, 1883)	1. Morphology and identification of fly eggs of different flies based on morphometric quantitation of mean length, width of median area and darkness staining of hatching pleats by SEM (Sanit *et al*., 2013). 2. Morphology of all larval instars was documented by using a combination of LM and SEM (Velásquez *et al*., 2010).	1. Direct sequencing of the304-bp cytochrome oxidase I gene fragment of 75 specimens belonging to 19 species of Calliphoridae, Sarcophagidae and Muscidae families. Nucleotide sequence divergences were calculated by Kimura two-parameter distance model and a neighbor-joining phylogenetic tree was generated (Aly and Wen, 2013).
32	*Musca domestica* (Linnaeus, 1758) Muscidae	1. Maggots first observed (day 33) in dry decomposed monkey carcass in Malaysia. Now, *M. domestica* has forensic important role in insect succession (Chen *et al.*, 2010). 2. Morphology and identification of fly eggs of different flies based on morphometric quantitation of mean length, width of median area and darkness staining of hatching pleats by SEM (Sanit *et al*., 2013). 3. Morphometric analysis of the length and width of puparia, along with the length of the gaps between the posterior spiracles of seven fly species, displayed differences among them (Sukontason *et al*., 2007).	1. Direct sequencing of the 304-bp cytochrome oxidase I gene fragment of 75 specimens belonging to 19 species of Calliphoridae, Sarcophagidae and Muscidae families. Nucleotide sequence divergences were calculated by Kimura two-parameter distance model and a neighbor-joining phylogenetic tree was generated (Aly and Wen, 2013).

C. Family Sarcophagidae			
33	*Sarcophaga albiceps* (Meigen, 1826)	1. Costal spine small, 6th tergite dorsally divided (Encyclopedia of Life, 2014). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. Direct sequencing of the304-bp cytochrome oxidase I gene fragment of 75 specimens belonging to 19 species of Calliphoridae, Sarcophagidae and Muscidae families. Nucleotide sequence divergences were calculated by Kimura two-parameter distance model and a neighbor-joining phylogenetic tree was generated (Aly and Wen, 2013).
34	*Sarcophaga dux* (Thomson, 1869)	1. Posterior spiracle, number of papillae on the anterior spiracle of the third instars; characteristic of adult males were noted among Sarcophagidae (Sukontason *et al*., 2010).	1. The use of partial mitochondrial COI and COII genes for discrimination of forensically important Sarcophagidae from Egypt and China. Phylogenetic tree was constructed from nucleotide sequence divergence to identify each species separately (Aly *et al*., 2013). 2. A 189 bp fragment of cytochrome coxidase subunit II (COII) gene was used to discriminate between Sarcophagidae species (Guo *et al*., 2010).
35	*Sarcophaga martellata* (Senior-White, 1924)	1. Male genitalia offer unambiguous species identification characteristics in flesh flies but the female flies are very similar to one another in general morphology (Tan *et al*., 2010). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. Female flies of sarcophagidae are very similar to one another in general morphology. Female of *S. martellata* was determined by DNA sequencing (COI and COII) and PCR-RFLP (COI) analysis. Identified females were carefully compared with the morphologically similar species, *S ruficornis* (Tan *et al*., 2010).
36	*Sarcophaga ruficornis* (Fabricius,1914)	1. Posterior spiracle, number of papillae on the anterior spiracle of the third instars; characteristic of adult males were noted among Sarcophagidae (Sukontason *et al*., 2010).	
37	*Sarcophaga impatiens* (Walker, 1849)	1. Male genitalia and larval stages were identified (Encyclopedia of Life, 2014). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. DNA was extracted and COI barcode sequences obtained for molecular identification of each immature life stage of this forensically important Australian flesh fly (Meiklejohn *et al*., 2013).
38	*Sarcophaga caerulescens* (Zetterstedt, 1838)	1. Male abdomen with long and dense hair, female scutellum with an additional lateral bristle (Encyclopedia of Life, 2014). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. No concrete records were found on Pubmed. 2. Mitochondrial DNA cytochrome oxidase I gene "barcoding region" as a universal marker for molecular identification of forensically important Diptera (Encyclopedia of Life, 2014).
39	*Sarcophaga peregrina* (Robineau-Desvoidy, 1830)	1. Pteridine fluorescence analysis has a potential value in determining the age of adult males and females (Zhu *et al*., 2013). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. COI and 289-bp segment of the 16S rDNA regions are sequenced for identification of sarcophagid species. 2. 14,922 bp circular mitochondrial genome contains 13 protein-coding genes, 22 transfer RNA genes, 2 ribosomal RNA genes and contains one non-coding A + T-rich region (Zhong *et al*., 2014).
D. Other relevant families			
Family Fanniidae			
41	*Fannia sanihue* (Domínguez and Aballay, 2008)	1.Grow maximally when pig carcasses were kept in shade (Aballay *et al*., 2012). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. No concrete records were found on Pubmed. 2. Mitochondrial DNA cytochrome oxidase I gene "barcoding region" as a universal marker for molecular identification of forensically important Diptera (Encyclopedia of Life, 2014).
42	*Euryomma peregrinum* (Meigen, 1826)	1.Identified in pig carcasses in semi-arid climate (Aballay *et al*., 2012). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1.No concrete records were found on Pubmed. 2.Mitochondrial DNA cytochrome oxidase I gene "barcoding region" as a universal marker for molecular identification of forensically important Diptera (Encyclopedia of Life, 2014).

Family Milichiidae			
43	*Desmometopa* sp.	1. Breed on indoor human carrion, human excrement and manure with other Sarcophagidae (Kumara *et al*., 2010). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. No concrete records were found on Pubmed. 2. Mitochondrial DNA cytochrome oxidase I gene "barcoding region" as a universal marker for molecular identification of forensically important Diptera (Encyclopedia of Life, 2014).
Family Phoridae			
44	*Conicera tibialis* (Scmitz, 1925) (coffin flies)	1. Detected in an 18 year old buried corpse. Adult fly, newly matured flies and puparia were frequently found in old buried corpse (Martín-Vega *et al*., 2011). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. 658-bp-long region of the cytochrome oxidase I gene (COI), the most common molecular marker was amplified and used in DNA barcode approaches for suitable identification of scuttle flies (Boehme *et al*., 2010).
Family Piophillidae			
45	*Parapiophila vulgaris* (Fallen, 1820)	1. Occurrence time, activity period of some taxa insect succession in pig carrion decomposition were studied in pine-oak forest, hornbeam-oak forest, and alder forest in Europe (Matuszewski *et al*., 2008). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. COI barcode was used for clear differentiation and identification of forensically relevant Diptera in Germany (Boehme *et al*., 2012).
Family Encyrtidae Hymenoptera			
46	*Exoristobia phillipinensis* (Ashmead, 1904)	1. Predates on pupa of *Chrysomya* sp on monkey carcass in Malaysia (Chen *et al*., 2010). 2. Body more or less uniform metallic black, antenna with yellowish scape, legs yellowish brown, femora slightly darker; wings hyaline. Mandibles with three nearly equal teeth. Antenna with 6-segmented funicle, compound eyes with conspicuous, dense hairs. Mesoscutum with deep reticulate sculpture, scutellum with much shallower reticulate sculpture. Cercal plates situated at about middle of gaster Fore wing with marginal vein longer than broad; postmarginal vein much shorter than stigmal vein (Ashmead, 1904). 3. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. No concrete records were found on Pubmed. 2. Mitochondrial DNA cytochrome oxidase I gene "barcoding region" as a universal marker for molecular identification of forensically important Diptera (Encyclopedia of Life, 2014).
Family Stratiomyidae			
47	*Hermetia illucens* (Linnaeus,1758) (Black soldier fly)	1. Fly and larva has been used to determine PMI of cadaver in northern Brazil (Pujol-Luz *et al*., 2010). 2. Arrangement and shape of spiracular openings, structures of the anal segment and the cephalopharyngeal skeleton were used for the identification of third instars of the species present in the Iberian Peninsula (Velásquez *et al*., 2010). 3. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. Molecular features and expression pattern of two serine proteases (SPs) of the larvae were cloned, characterized, multiple sequence alignments and phylogenetic tree analysis of the deduced amino acid sequences revealed that Hi-SP1 may be a larval specific chymotrypsin-like protease involved with food digestion, while Hi-SP2 may be a trypsin-like protease with diverse functions at different stages (Kim *et al*., 2011).
Family Syrphidae			
48	*Ornidia obesa* (Fabricius, 1775)	1. Female genitalia segments tawny pilose, female mesonotum almost entirely tawny pilose, 2 male abdomen shiny except black pollinose on most of 2nd tergum in male (Thompson, 1991). 2. No data on morphological identification of the fly and its stages by SEM were available on Pubmed.	1. No concrete records were found on Pubmed. 2. Mitochondrial DNA cytochrome oxidase I gene "barcoding region" as a universal marker for molecular identification of forensically important Diptera (Encyclopedia of Life, 2014).

[a]PMI=Post Mortem Interval, COI=cytochrome oxidase subunit I, COII=cytochrome oxidase subunit II, LM=Light microscopy, SEM= Scanning Electron Microscopy, TEM=Transmission Electron Microscopy. The identification of forensically important flies mostly from Calliphoridae, Sarcophagidae, Muscidae and other important families were represented based on some important reported research on them. The identification methods and importance of all these flies in forensic entomology is still under research.

[a]Table 2. Morphological identification of developmental stages

Developmental stages	Morphological parameters and techniques used	
	LM	SEM
Eggs	1. Examination by 1% KMnO4 solution for 1 min, steps of dehydration in 15, 70, and 95%, absolute alcohol (each solution for 1 min) and permanent mounting. 2. Measurement of egg mean length, width of median area. 3. Darkness staining of hatching pleats, width of plastron, morphology of plastron area surrounding the micropyle (Sanit *et al*., 2013). 4. Chorionic sculpturing (Sukontason *et al*., 2004).	1. Eggs were collected, fixed in alcoholic Bouin, prepared according to SEM routine processing. 2. Measurement of mean length, median area & width of eggs. 3 Hatching pleats, structure of chorion, body appearance of eggs were observed (Sanit *et al*., 2013). 4. Anastomosis or holes at the top of the islands (Mendonca *et al*., 2008). 5. Chorionic sculpturing, width of plastron (Sukontason *et al*., 2007). .
Maggots	1. Measurement of mean body length of all instar larvae. 2.Observance of body appearance, cephalopharyngeal skeleton, dorsal cuticular spines between the prothorax and mesothorax, feature of the posterior spiracle, pseudocephalon, antennal complex, maxillary palpus, facial mask, cephaloskeleton, thoracic and abdominal spinulation, spiracular field and posterior spiracles (Szpila *et al*., 2013).	1. Observance of anterior and posterior spiracles, cephalopharyngeal skeleton, characteristics of the dorsal spines between the prothorax and mesothorax of all instar larvae. 2. Quantitation of number of sensory papillae on the anterior spiracle, oral grooves, posterior spiracular hairs. 3. observation of pseudocephalon, antennal complex, maxillary palpus, facial mask, cephaloskeleton, thoracic and abdominal spinulation,spiracular field and posterior spiracles (Szpila *et al*., 2013).
Pupa	1.Clearing technique to pale the integument of fly puparia, allowing visible observation of second to fourth segments (anterior end), posterior spiracle and oral grooves (Sukontason *et al*., 2007). 2. Measurement of length and width of puparia, posterior spiracular hairs length, width of puparia, number of papillae in theanterior spiracle, length of the gaps between the posterior spiracles (Sukontason *et al*., 2007).	1. Observation of cuticular sculpture of tubercles along the dorsal and lateral segments; bubble membrane on the dorso-lateral border of the fifth segment; the morphology of integument; presence of spines on integument; structure of the posterior spiracle and its hair; oral grooves and pupal respiratory horns (Sukontason *et al*., 2006a; 2006b; 2006c).
Winged adult	1. Observance of body appearance and colour. 2. Measurement of female size 3.Quantitation of the number of live larvae carried, time taken to larviposit live larvae, mean length &width of fly. 4. Morphology and measurement of male internal reproductive organs, spermatozoa, and spermiogenesis (Name *et al*., 2012). 5. Shape of the intersegmental spines between the pro- and mesothorax, posterior spiracles, number of papillae on the anterior spiracles, oral grooves, and posterior spiracular hairs (Sukontason *et al*., 2006a; 2006b; 2006c).	1. Observing the differences in antennal sensilla, adhesive device (pulvilli) between the tarsal claws of the legs. 2. Measurement of mean length of adult fly. 3. Differences in antennal and maxillary palps of male and female. 4. Trichoid, basiconic, coeloconic, styloconic and sensory pit in antennal scape, pedicel and flagellum and in maxillary palps 5. Morphology and measurement of male internal reproductive organs, spermatozoa, and spermiogenesis (Name *et al*., 2012). 6. Shape of the intersegmental spines between the pro- and mesothorax posterior spiracles, number of papillae on the anterior spiracles, oral grooves, and posterior spiracular hairs (Sukontason *et al*., 2006a; Sukontason *et al*., 2006b; Sukontason *et al*., 2006c).

[a]LM=Light microscopy, SEM=Scanning Electron Microscopy. Identification represented based on some important research on their morphological characters as observed by LM and SEM. Sample preparation for the developmental stages in LM and SEM are quite different. Some morphological features (like body size of male and female, appearance, colouration) were used as identifying markers and several morphological features (like the number of sensory papilla, sensory pits etc.) were quantified for inter or intraspecific specific identification.

Although the early developmental phases reveal difficulty in being distinguished morphologically, all stages of the life cycle of the flies including eggs, larvae (all instars), pupae and the adult have found profound importance in species identification and thereby estimation of PMI (Harvey et al., 2008). Of these immature stages, puparia with a long developmental time is most useful stage for species identification but because of typically similar general appearance, with coarctate and light brown to dark brown, makes their identification difficult. However, in order for forensic entomologists to use puparia effectively, it is crucial that they are able to accurately identify the species of fly found in a corpse (Harvey et al., 2008).

Among all the instars, the third instar larvae have

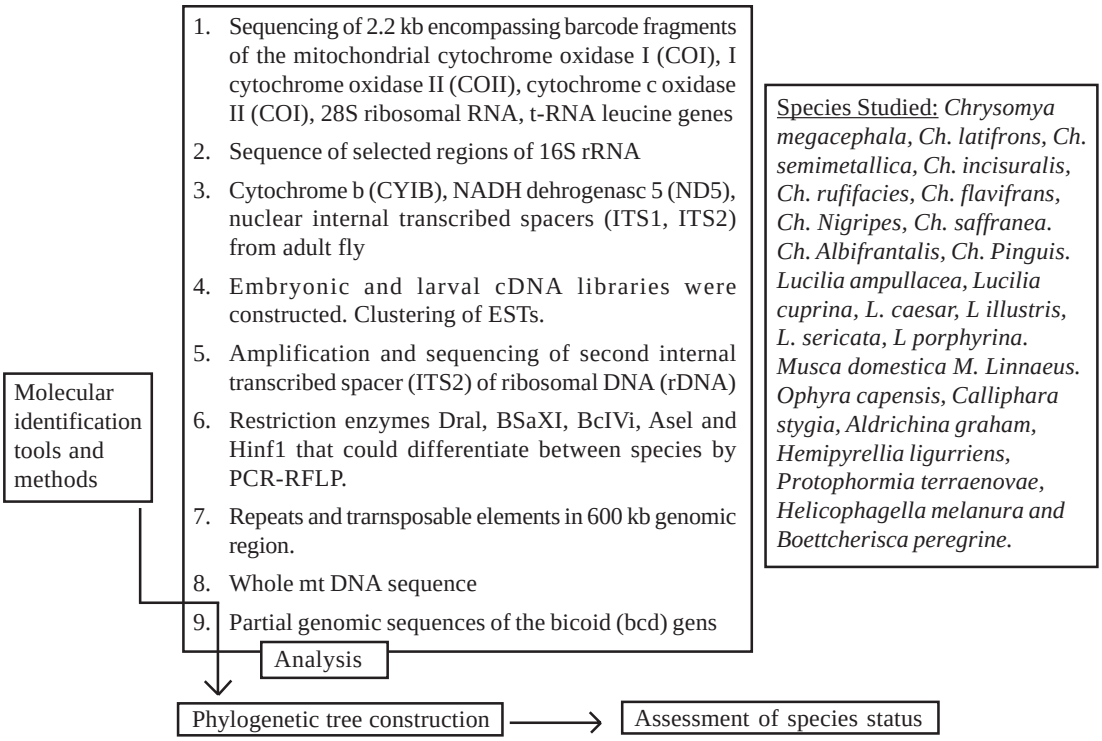

Fig. 1. Molecular identification of forensic fly and its immature stages

Molecular identification methods are based on DNA sequencing or PCR-RFLP analysis. Sequential differences are helpful in phylogenetic tree analysis to rule out intra- and inter-specific variations (Lee *et al*., 2011; Sonet *et al*., 2012; Park *et al*., 2013 ; Harvey *et al*., 2008; Preativatanyou *et al*., 2010; Gilarriortua *et al*., 2013; Chin *et al*., 2009; Lang *et al*., 2006; Balme *et al*., 2012; Griffiths *et al*., 2009; Kavitha *et al*., 2012; Nelson *et al*., 2008; Yang *et al*., 2010; Negre and Simpson, 2013; Zaidi *et al*., 2011).

been reported to be important for proper species identification. SEM and light microscopic (LM) studies have highlighted different morphological parameters enabling identification of inter or intraspecific variations among different species (Ahmad et al., 2010). SEM ultrastructure has been used to identify the eggs and the morphological character of immature stages (including pupae) of *Chrysomya nigripes, Sarcophaga ruficornis, Sarcophaga dux, Megaselia scalaris Lucilia cuprina, Lucilia eximia, Ophyra aenescens* and other sarcophagids along with sand flies in China (Sukontason et al., 2006a; Mendonça et al., 2008; Singh et al., 2012; Mendonça et al., 2012; Sukontason et al., 2003a; 2003b; 2003c; Guo et al., 2004; Sukontason et al., 2005a; 2005b; 2006b; 2006c).

The initial characterization of first and second instar larvae of *Hypopygiopsis violacea* is based on its heavily pigmented cephalopharyngeal skeleton and eight-nine anterior and posterior spiracles arranged in a single row. Characteristics of cuticular spines, spiracular peritreme and sclerites had also been studied (Ahmad et al., 2010). The first indoor cadaver occurrence of Sarcophaga caerulescens has been reported along with the occurrence of *Lucilia sericata, Calliphora vicina* and *Protophormia terraenovae* (Pohjoismäki et al., 2010) . Based on morphology studies *Hemipyrellia ligurriens* and *Chrysomya villeneuvi* (Calliphoridae) had been described under ambient and natural conditions (Sukontason et al., 2005a; 2008; Bunchu et al., 2012).

The external morphological differences and density of four major types of surface sensilla on the antennae is studied in latrine fly (*Fannia scalaris*) and lesser house fly (*Fannia canicularis*) using varied array of microscopic techniques (Zhang et al., 2013) .Variations on wing morphometrics between *Chrysomya albiceps* and *C. megacephala* showed significant differences in wing isometric size, localization on subcosta rupture, joining of R(2+3) with wing border and to support the identification of these two forensic species (Vásquez and Liria, 2012). Differences in male and female terminalia of both *Microcerella antofagastensis* and *M. quimaliensis* provide a tool for correct identification of both species (Mulieri et al., 2012).

Staining of the cuticle in third instar larvae of externally very similar larval *Lucilia sericata* and *L. illustris* along with common saprophagous blow fly species of Europe *Calliphora vomitoria* and *C. vicina*,

revealed the patterns of five segmental clusters, located in the second, third and fourth segments of larvae. This method was primarily applied for PMI calculations using interspecific morphological similarity of the larvae (Niederegger and Spiess, 2012).

Morphological ultrastructures studied by SEM, including anterior and posterior spiracles, the labium and mouth hooks were useful for specific identification of first and second instar larvae of myiasis producing phorid fly *Megaselia scalaris* (Mazyad and Soleman, 2006). Morphology of puparia of *Megaselia scalaris* (Diptera: Phoridae) showed the characteristic of the intersegmental spines, pupal respiratory horn, sculpture of the puparia as studied by SEM might be useful tool to distinguish it from other closely related species (Sukontason et al., 2006c). The development time of *Paralucilia paraensis* (Mello) (Calliphoridae) including hatching time, the time to complete larval and pupal stages were associated with the decomposition of a partially submerged swine carcass. The morphology of adult and immature stages of *P. paraensis* in Amazon forest was implemented for forensic studies (Sales et al., 2013).

Conventional morphological identification methods, despite promising, however suffers from the limitation of differentiating the sibling/sister and closely related species and identification of immature developmental stage, quality of the specimen used and proper preservation of morphological features of the fly specimen and identification of closely related species. Morphological identification of each developmental stage of forensic flies under microscopic examination at times suffers from inaccuracy of identification due to indistinguishable and near similar structural parameters (Preativatanyou et al., 2010).

Although different protocols for optimal preservation of different fly specimens are being reported, like hot-water-killing, followed by ethanol preservation and hematoxylin and eosin staining enables clear visualization of internal features with potential for age estimation of different pupal sections in *Calliphora vicina* and *Lucilia sericata* pupae (Davies and Harvey, 2013) , but no single protocol has been known in preservation of other flies. To circumvent these problems, molecular approaches are being employed to identify species.

b. Molecular identification

To circumvent the problems associated with morphological identification of forensically important fly species, molecular approaches of DNA and RNA sequencing are being employed. Partial or total sequencing of different genes along with morphological identification of species enabled removal of morphological ambiguity. Autosomal DNA markers like bicoid gene in 12 blow fly species including *Aldrichina grahami, Calliphora vicina, Calliphora lata, Triceratopyga calliphoroides, Chrysomya megacephala, Chrysomya pinguis, Phormia regina, , Lucilia caesar, Lucilia illustris, Hemipyrellia ligurriens, Lucilia ampullacea* and *Lucilia sericata* have been determined and analyzed (Park et al., 2013).

Genetic sequences clubbed with morphological characteristics of sister species and geographically localized intra-species finds application in construction of phylogenetic tree and are important in the evolution of insect developmental biology and are potentially useful for identifying insect species in forensic science (Harvey et al., 2008). The first instar larvae of *Lucilia sericata, Calliphora vicina* and *Calliphora vomitoria* were identified by their differential 'fingerprint' of cuticular hydrocarbon analyzed by gas chromatography spectrometry and principal component analysis (Moore et al., 2014).

Insect mtDNA enriched with A-T sequences in the non-coding control region, in the COI and COII gene loci is known to regulate mtDNA replication and RNA transcription (Campobasso et al., 2005). Sequencing of mtDNA COI gene of 13 fly species including *Calliphora vicina, vomitoria, Lucilia ampullacea, caesar, illustris, sericata, silvarum, Phromia regina, Protophormia terraenovae, Parapiophila vulgaris, Hydrotaea dentipes, ignava* and *similis* had revealed nil intraspecific variance (Boehme et al., 2012; Tarone and Foran, 2011).

However, the potential data source for identifying smaller units of developmental stages of such flies can change throughout the process of development. Thus gene expression should be studied althrough development. Expression of three genes (bcd, sll, cs) in blow fly species during the developmental process revealed linear trends throughout maturation and enabled feasibility of predicting age (Boehme et al., 2012; Tarone and Foran,2007; Linville et al., 2004). Identification of immature stages of European flesh flies (Sarcophagidae), had been reported by applying the DNA based analysis and sequencing data of some chosen mtDNA of the COI and ND5 genes (Zehner et al., 2004).

Genetic analysis reveal that the newly separated sister species of *L. caesar* and *L. illustris* had shown high divergence percentage overlap (Boehme et al., 2012; Tarone and Foran,2007; Linville et al., 2004).To identify nearly 245 new blow flies under subfamily Chrysomyinae associated with a human corpse, and phylogenetic analysis of DNA sequence of COI segment was used to identify chrysomyine species wherein representatives of non-chrysomyine genera were included to rule out false positive sequence data (Wells and Williams, 2007) .

The DNA polymorphism of *Aldrichina grahami, Lucilia sericata, Sarcophaga crassipalpis, Chrysomya megacephala* and *Musca domestica* had been recorded using inter simple sequence repeat (ISSR) method. Different band pattern produced in species using some primers could be utilized to identify these species. For the molecular diagnosis of these five species, a method was adopted to convert species-specific ISSR fragments into the sequence-characterized amplified region markers (He et al., 2007; Nelson et al., 2012). An innovative technique to detect post-mortem relocation of the corpse has been introduced by detecting sib-ship genetic test of the fly larva left at the original location and the larva on the body by comparing relatedness coefficient of amplified fragment length polymorphism for nine samples of *Phormia regina* (Picard and Wells, 2012; Nelson et al., 2012).

However, molecular biology identification tool suffers from limitations associated with degradation of nucleic acid, understanding of appropriate preservation techniques, inadequate availability of sample, and improper extraction of genetic material leading to loss of genetic material thereby leading to false results (Harvey et al., 2008). For DNA based species identification, different approaches of preservation methods for the pupae stage are being studied on *Calliphora vicina* (Harvey et al., 2012; Brown et al., 2012).

Besides genetic analysis, analysis of different biochemicals on the body of the fly with relation to its age and developmental stages are being explored. Alterations of cuticular hydrocarbons composition in developing calliphorid larvae of *Chrysomya rufifacies* and *C. megacephala* is being employed as an indicator for post-feeding larvae age determination (Zhu et al., 2007;Ye et al., 2007; Brown et al., 2012). Pupal hydrocarbons are being employed to differentiate between six species of necrophagous flies Aldrichina grahami, *Chrysomya megacephala*, *Lucilia sericata*, *Achoetandrus rufifacies*, *Boertcherisca peregrina* and *Sarcophaga crassipalpis* (Wood et al., 2003) .

The use of ecdysteroid measurement in the course of pupal development could be a tool in forensic entomology (O'Brien and Turner, 2004; Gaudry et al., 2006). Differences in the composition of the surface hydrocarbons from the vitelline membranes surface of dechorionated eggs of the different forensic flies was species dependant as reflected by presence of n-nonacosane (C29) in *Cochliomyia hominivorax* (secondary screwworm; 40%), *Cochliomyia macellaria* (green bottle fly; 43%), *Lucilia cuprina* (38%), *Musca domestica* (39%) and *Phaenicia sericata* (60%); and 2-methyloctacosane (32%) in *Anastrepha ludens* (mexical fruit fly). Expression of heat shock proteins including hsp70, hsp83, small hsps (Lchsp23 and Lchsp24) in *Lucilia cuprina* revealed the high constitutive expression of Lchsp83 RNA with only moderate inducible effects by heat shock (Concha et al., 2012).

However, a number of contrasting reports reveal that some environmental factors of the ecological niche of the dead, chemicals like paint etc on the dead, decaying corpse etc. effect the colonization and thereby identification of forensically important flies while others do not. Volatile chemicals, like paint, drugs on dead could repel insect colonization. House hold insect repellants could repel significantly the colonization of female *Calliphora vicina* (Calliphoridae) flies on dead mice (*Mus musculus*) (Charabidze et al., 2009).

The extent of retention of drugs in corpse or in the body of the developing flies, its effect on successive levels of the food chain, the presence of detectable drugs in beetles feeding off fly larvae is quite crucial in forensic entomology (Pounder, 1991). Presence of drugs like paracetamol in the dead body could hamper initial larval development thereby dampening the estimation of PMI (George et al., 2012). Cocaine overdosing could prevent colonization of adult *Ornidia obesa* (Diptera: Syrphidae) in southeastern Brazil, on bullet killed pig carcass (Martins et al., 2010) and ketamine drug affected the larval body length and weight and over all morphology during the development of *Lucilia sericata* (Meigen) (Calliphoridae) (Zou et al., 2013). Morphine affected the rate of development of larvae, puparia and emerging adult flies of *Lucilia sericata* thus altering estimation of PMI (Bourel et al., 1999). Presence of malathion in liver and muscle

retarded the normal larval growth rate of Chrysomya megacephala (Liu et al., 2009). Longer pupation and adult emergence time interval was reported in larvae of *Chrysomya albiceps* and *C. putoria* colonies fed on tissues from diazepam drug dosed rabbits than for the control ones (Carvalho et al., 2001).

On the other hand, drugs like hydrocortisone and sodium methohexital drugs had been reported to have minimal effects on the development of *Sarcophaga* (*Curranea*) *tibialis* Macquart (Sarcophagidae) implying no involvement in estimating PMI (Carvalho et al., 2001). Also larvae of *Sarcophaga tibialis* fed on different lethal doses of barbiturate showed no effect on PMI determination by steroids (Musvasva et al., 2001). High concentration of butylscopolamine retarded growth and promoted differential morphology of *C. megacephala* of the larva and pupa feeding on it and increasing mortality (Zhu et al., 2006). The morphine accumulation from the dead and excretion capability of the *Dermestes frischi*, *Thanatophilus sinuatus* and *Calliphora stygia* indicated their potential as toxicological indicators (Musvasva et al., 2001; Oliveira et al., 2009; Parry et al., 2011; Bourel et al., 2001a; Bourel et al., 2001b; Gunn et al., 2006).

DISCUSSION

A decomposing body is a huge resource waiting to be explored or colonized by animals and microbes. The body not only provides a food source, but also it is the habitat/ niche or a place to reproduce in ambient conditions. The first pioneering insect to appear on a decomposing corpse make it more lucrative to succeeding insect groups enabling ecological succession. The process continues until the body is fully decomposed.

In forensic investigations, immature stages of the fly (egg, larva, or puparia) could be used as entomological evidence at death scenes, not only to estimate the PMI, analyze toxic substances, and to determine the manner of death but also to indicate the movement of a corpse in homicide cases. Traditional identification based on morphological characteristics could be complicated due to physical similarities between different species, especially at immature stages. Genetic analysis provides a fast and reliable identification method. The use of DNA for identification of new species has opened a new chapter in the field, helping in the understanding of the genetical elements of the larval gut content, illustrating the last meal of the larvae collected from a corpse, its particular larval stage in the corpse, locality of local food sources and linking insect species to the scene of crime by its DNA analysis, the dynamics of insects colonizing the corpse, carrion dynamics and ecology of the corpse, their local interactions and relationship between species and habitats.

A detailed investigation of identification of forensically significant flies in the last decade has seen molecule based identification of immature and damaged specimens become a routine complement to traditional morphological identification as a preliminary to the accurate estimation of PMIs, which depends on the use of species-specific developmental data. Published molecular studies have tended to focus on generating data for geographically localized communities of species of importance, which has limited the consideration of intraspecific variation in species of global distribution. Phylogenetic analysis to assess the species status of forensically important species based on different base pairs of the COI gene of many specimens from various countries, had confirmed the utility of the COI gene in identifying most species. The concoction of both nuclear and mitochondrial genes for species identification is gradually gaining importance to conform the differences between intraspecific convergence and interspecific divergence.

Published molecular sequencing studies have tended to focus on generating data for geographically localized communities of species. Identification of phylogenetically young species always requires a faster evolving molecular marker. Most species could be unambiguously characterized taxonomically by sampling a few conspecific arthropods if they were from distant localities (Harvey et al., 2008).

Our study revealed that many species of forensic flies and their morphology had been reported by employing strategies from morphological and molecular approaches. However, neither approach singly appears to be full proof in identification. What remains to be known is there a common marker or group of markers by which all forensically important flies could be identified. Therefore the need of the hour is an integrative study of markers to identify the forensically important species. Multidisciplinary approach involving species identification by taxonomic keys, structural, morphological, developmental, genetic and biochemical analysis together with proper preservation techniques for samples needs to be carried out towards characterization of these flies and their correlation with PMI.

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CHARACTERIZATION OF POTENTIAL NATIVE *BACILLUS THURINGIENSIS* STRAINS ISOLATED FROM INSECT CADAVERS AGAINST COTTON APHID *APHIS GOSSYPII* GLOVER (HEMIPTERA: APHIDIDAE)

MANDLA RAJASHEKHAR, ANUBHAV MITTAL, VEERANNA DHARAVATH AND VINAY K. KALIA*

Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi 110012
**Email: vkalia@iari.res.in (corresponding author)*

ABSTRACT

The cotton aphid *Aphis gossypii* is one of the important sucking pests of cotton. Studies on toxicity of *Bacillus thuringiensis* (*Bt*) against hemipterans are rare. In the present study, five native *Bt* strains viz., VKK-AC1, VKK-AC2, VKK-BB1, VKK-BB2 and VKK-PX1 isolated from insect cadavers showed consistent mortality of adults of *A. gossypii* in pre-solubilized, solubilized as well as in trypsinized form. The LC50 values for these showed that VKK-AC2 and VKK-BB1 were the most effective followed by VKK-PX1 and VKK-BB2. SDS-PAGE gel analysis of toxins showed 20-135 kDa bands in pre-solubilized and 20-106 kDa in solubilized form. As regards trypsinized form protein profiling of all the five native *Bt* strains showed two bands each in the range of 60-66 kDa which were highly toxic. All the shortlisted *Bt* strains *viz.*, VKK-AC1, VKK-AC2, VKK-BB1, VKK-BB2 and VKK-PX1 amplified novel band of 275-292 bp with *cry4* gene specific primers.

Key words: *Bacillus thuringiensis*, strains, *Aphis gossypii*, adults, *cry* proteins, *cry* gene, pre-solubilized, solubilised, trypsinized forms, LC50 values, protein profile

Bacillus thuringiensis (*Bt*) is an aerobic, gram positive, spore forming, facultative bacteria that produces parasporal crystals containing one or more insecticidal crystal (Cry) proteins, which are selectively toxic to insects. The activity spectrum of a *Bt* strain is a function of additive and/or synergistic interactions of individual *cry* proteins present in their proportional amounts. Some *cry* proteins can synergize the activity of other *cry* proteins (Sayyed *et al*., 2001). Earlier, *Bt* was considered to be toxic only to lepidopterans until Goldberg and Margalit (1977) reported the isolation of *Bt* var. *israelensis*, active against mosquitoes. Since then, other isolates had been reported against Coleoptera (Krieg *et al.*, 1983), and both Lepidoptera and Diptera (Haider *et al.*, 1986). Pathogenicity and specificity are determined by the functional *cry* gene types that an isolate possesses.

Insect protective crops with *Bt* toxin gene are grown over 28.8 m ha (James, 2014). The large scale cultivation of these crops might increase the selective pressure on the insect pest, which may result in the development of resistance (Tabashnik *et al*., 2008; 2013). So there is a need for the discovery of novel *Bt* strains with host specificity. Moreover, sucking pests *viz.*, aphids, hoppers and whiteflies on *Bt* cotton have attained serious status due to reduction in application of insecticides. Cotton aphid *Aphis gossypii* Glover is an important pest (Aheer *et al.*, 2006; Khattak *et al.*, 2007). This paper presents characterization of the native *Bt* strains effective against this pest.

MATERIALS AND METHODS

Culture of test insect and bioassay: Cotton aphid *A. gossypii* initially collected from cotton field of the ICAR- Indian Agricultural Research Institute, New Delhi was reared on cotton twigs (18± 2°C, 70 ± 10% RH and 16:8 L:D in the biochemical oxygen demand (BOD) incubator was used. The twigs were changed on alternate days and one day old adults were used for bioassays. Six potential *Bt* strains *i.e.*, VKK-AC1, VKK-AC2, VKK-BB1, VKK-BB2, VKK-PX1 and one reference strain HD-1 were shortlisted for full bioassays as a result of preliminary screening of 34 *Bt* strains using acetone precipitated spore crystal complex in three different forms *viz.*, pre-solubilized form (spore crystal), solubilized form (pre-toxin form), trypsinized form (toxin form) by diet incorporation method at single concentration (10 µg $g^{-1}$of diet) on the basis of total protein concentration against adults of *A. gossypii* (Mandla, 2015).

Five concentrations *viz.*, 0.1, 0.5, 1.0, 5.0, and 10 µg g^{-1} (on the basis of total protein concentration) of

each strain were used. 10 µl of stock suspension of acetone precipitated spore crystal complex/solubilized/ trypsinized form (10,000 µg ml^{-1}) was mixed with 100 µl of sterile distilled water (sdw) and incorporated in 10 g diet to get a concentration of 10 µg ml^{-1} similarly other concentrations were prepared. Each container containing three gram of diet served as one replicate, with three replications. Ten adults were released on the treated diet formed a replication and fed for four days. All the bioassays were performed with their respective buffer based controls (at 18±2°C, 70±10% RH and 16:8 L:D) against adult aphids. A minimum of 180 neonates were used for each bioassay. Mortality data was recorded after every 24 h till 96 h. LC_{50} values were calculated using maximum likelihood programme (MLP) 3.01 (Ross, 1987). The significance of difference was determined on the basis of overlap of 95% fiducial limits.

Amplification of *cry* genes: DNA extraction was performed following Bravo *et al*. (1998). DNA present in supernatant and 10ìl of the supernatant was used as the DNA template for PCR reaction. PCR characterization was performed to identify the toxin-encoding genes using ten oligonucleotide pairs specific for *cry* genes. The primers were procured from Integrated DNA Technologies, Inc. (Coralvillae, I.A., USA). Their sequences and the expected sizes of the PCR products are shown in Table 4. All PCR reactions were carried out in 25 µl reaction volumes. DNA template, 10 µl was mixed with reaction mixture containing 4.3 µl Taq assay buffer (10x) with $MgCl_2$ (15 mM),1 µl dNTPs (10 mM), 1 µl of each primer (10 pM), 0.2 µl Taq DNA polymerase (5 U/µl) and 7.5 µl nuclease free water.

The reactions were placed in a thermocycler (Genepro, BIOER) programmed for all *cry* genes An initial denaturation step was applied for 5 min at 94 ºC and followed by denaturation for 1 min at 94ºC, annealing for 1 min at different temperature (varied according to specificity of *cry* primers as given) then extension for 2 min at 72 ºC. Thirty-five cycles were carried out for the amplification of *cry* gene fragments. Finally, an extra extension step was applied for 5 min at 72 ºC. After amplifications, 2µl of loading buffer (0.5% bromophenol blue in glycerol 50%) was added to 5µl each sample of amplified PCR product and electrophoresed (80v for 10 min. followed by 120v for 30 min) on a 1x Tris-acetate-EDTA (TAE with ethidium bromide) buffer in 1.2% agarose gel. Gels were visualized in a gel documentation system (Alphaimager™) and analysed with AlphaEaseFC.

Analysis of *cry* toxins by SDS-PAGE: Acetone precipitated spore-crystal complex of reference strains *Bt.* subsp. *kurustaki* (HD-1), *Bt.* subsp. *tolworthi* and *Bt* subsp. *israelensis* as well as selected native *Bt* strains were prepared. After that 20 mg of acetone powder was dissolved in 200 µl of solubilization buffer (50 mM sodium carbonate buffer, 10 mM dithiothreitol, pH 10.5). These were sonicated twice at 0.5 cycle, 50% amplitude; timer on 2 min (UP 100H, Ultrasonic processor, Hielscher, Germany) and incubated at 37°C for 3 to 4 hours at 100 rpm. Solubilized samples were centrifuged (10,000 rpm for 10 min). The supernatant containing solubilized crystal protein were transferred in new autoclaved micro centrifuge tubes and stored at -20°C, and used for estimation and characterization.

Total protein concentration of spore-crystal suspensions of all the shortlisted *Bt* strains along with reference strain *Bt tolwarthi* and HD-1was quantified by Coomassie brilliant blue dye binding method as described by Bradford (1976) using bovine serum albumin (BSA) as a standard. Quantification of protein was carried out before doing SDS-PAGE. The protein profiles of *Bt* spore-crystal toxins were studied by SDS-PAGE according to the discontinuous system of Laemmli (1970). Alphaimager™ Documentation and analysis system was used for gel analysis. The molecular weights of bands of proteins were calculated by comparing the relative mobility and log molecular weight of protein standard markers using Alpha EaseTM Stand Alone Software computer programme.

RESULTS AND DISCUSSION

Toxicity of *Bt* strains: From the preliminary screening bioassays results, five native *Bt* strains (VKK-AC1, VKK-AC2, VKK-BB1, VKK-BB2, VKK-PX1) and one reference strain (HD-1) were identified which gave 50% mortality in all the three forms of feeding assays. In terms of toxicity of *Bt* strains in pre-solubilized form against adults of *A. gossypii* based on the LC_{50} values on 4th day after treatment, VKK-BB1 and VKK-AC2 (LC_{50} =0.041 and 0.049µg/g of diet) followed by VKK-PX1 (LC_{50} =1.09 µg/g of diet) were found to be the most effective and significantly different as their fiducial limits were not overlapping. LC_{50} values varied from 0.041µg/g of diet to 56.93 µg/g of diet (*Btk strain* HD-1). VKK-BB1 strain was found to be 1388 folds more effective than reference strain (Table 1).

Table 1. Toxicity of selected *Bt* strains (pre-solubilized form) against adults of *Aphis gossypii*

Toxin name	LC50 µg/g of diet on 4th day	95 % Fiducial limit		Slope ± Standard error	Chi square value	Degrees of freedom
		Lower	Upper			
VKK-AC1	2.24	0.81	11.26	0.51 ± 0.15	0.716	3
VKK-AC2	0.049	0.002	0.145	0.76 ± 0.19	2.20	3
VKK-BB1	0.041	0.00	0.2076	0.44 ± 0.16	0.324	3
VKK-BB2	11.96	3.26	550.86	0.43 ± 0.16	1.62	3
VKK-PX1	1.09	0.45	2.43	0.67 ± 0.16	1.86	3
Btk HD-1	56.93*	_	_	0.22 ± 0.15	0.509	3

*Unable to attain 50% mortality with highest concentration (10 µg/g of diet) used.

Similarly, LC_{50} values varied from 0.029 µg/g of diet (VKK-AC2) to 13.34 µg/g of diet (*Btk strain* HD-1) against adults of *Aphis gossypii* in the solubilized form of *Bt* strains (Table 2). VKK-AC2 strain was found to be 460 folds more effective than reference strain. VKK-AC2 strain was similar with VKK-BB1 but these strains were found to be significantly different.

However, LC_{50} values varied from 0.075 µg/g of diet (VKK-AC2) to 96.08 µg/g of diet (VKK-AC1) in the trypsinized form. VKK-AC2 strain was found to be 1290 folds more effective thanVKK-AC1 but only 217 fold against reference strain (Table 3). VKK-AC2 strain was found to be significantly different. Besides, VKK-BB1 as well as VKK-PX1 were found to be significantly different from reference strain HD-1.

Table 2. Toxicity of selected *Bt* strains (solubilized form) against adults of *Aphis gossypii*

Toxin name	LC50 µg/g of diet on 4th day	95 % Fiducial limit		Slope ± Standard error	Chi square value	Degrees of freedom
		Lower	Upper			
VKK-AC1	_*	_	_	0.14 ± 0.16	0.038	3
VKK-AC2	0.029	0.001	0.16	0.46 ± 0.16	0.909	3
VKK-BB1	0.09	0.0013	0.3105	0.50 ± 0.16	0.258	3
VKK-BB2	2.22	0.831	10.07	0.52 ± 0.15	0.878	3
VKK-PX1	0.576	0.20	1.17	0.71 ± 0.16	2.79	3
Btk HD-1	13.34	4.95	240.23	0.65 ± 0.19	1.85	3

*Unable to attain 50% mortality with highest concentration (10 µg/g of diet) used. Mortality was at par in all the tested concentrations.

Table 3. Toxicity of selected *Bt* strains (trypsinized form) against adults of *Aphis gossypii*

Toxin name	LC50 µg/g of diet on 4th day	95 % Fiducial limit		Slope ± Standard error	Chi square value	Degrees of freedom
		Lower	Upper			
VKK-AC1	96.08*	_	_	0.21 ± 0.15	0.215	3
VKK-AC2	0.075	0.001	0.333	0.41 ± 0.15	0.588	3
VKK-BB1	0.122	0.002	0.4011	0.48 ± 0.15	2.21	3
VKK-BB2	3.72	1.02	435.02	0.38 ± 0.15	0.89	3
VKK-PX1	0.21	0.01	0.56	0.54 ± 0.15	0.90	3
Btk HD-1	16.3	3.73	393	0.40 ± 0.16	3.76	3

* Unable to attain 50% mortality with highest concentration (10 µg/g of diet) used.

Thus in all the three forms, three native *Bt* strains were found to be better than the reference *Bt* strain *Btk* HD-1. The comparative analysis of LC_{50} values showed that VKK-AC2 and VKK-BB1 were the most effective strains followed by VKK-PX1 and VKK-BB2. Whereas, reference *Bt* strain as well as VKK-AC1 were found to be inconsistent as regards efficacy.

Characterization of *Bt* toxin protein by SDS-PAGE: Protein level characterization showed the banding patterns ranged from 20-135 kDa (Fig. 2A). To certain extent there was variation in the protein composition among isolates. Protein profile of pre-solubilized form of HD-1 and HD-73 showed 11 and 7 bands, respectively. Of these six bands were common *viz.,* 135, 105, 92, 65, 55, 48 kDa (Fig.2A). On the other hand *Bt* var. *tolworthi* and *Bt* var. *israelensis* showed only five bands each in pre-solubilized form ranging from 42-95 kDa.

The number of bands varied from 6-9 in pre-solubilized form ranging from 39-108 kDa. In pre-solubilized form the *Bt* toxins are in spore and crystal form (Fig. 2A). In solubilized form the molecular weight of reference strain varies from 20-106 kDa with maximum eight bands in HD-1 and HD-73 followed by five bands in *Bt* var. *tolworthi* (21-70 kDa) and four bands in *Bt* var. *israelensis* (22-72 kDa); and in solubilized form of native *Bt* strains, the number of bands varied from 7-10 and molecular weight ranging from 21-106 kDa (Fig. 2B). In case of trypsinized form, all the five native *Bt* strains showed 2 bands each just in the range of 60-66 kDa (Fig. 2C). Whereas *Bt* var *kurstaki* HD-1 and HD-73 strain showed five and four bands respectively in somewhat wider range of 39-62 as compared to native *Bt* strains. However, only 59 kDa protein was observed in trypsinized form of reference strains *Bt* var. *tolworthi* and *Bt* var. *israelensis.*

Analysis of presence of *cry* genes by PCR: The *cry* gene content of thirty native *Bt* strains along with four reference *Bt* strains were determined by PCR analysis of *cry1, cry2, cry3, cry4, cry7, cry8, cry9,cry11,cry12* and *cry15* (Table 4). Three strains viz., *Bt* var. *kurstaki* HD-1, HD-73 and VKK-BB2, out of seven strains showed the expected amplicon size of 276 bp of *cry1* gene whereas, VKK-AC2 amplified novel band of 100 bp. Similarly for *cry2* gene, only one *Bt* strain VKK-BB2 amplified expected amplicon size of 689-701 bp (Table 4).

Except *Btt*, no other *Bt* strain had amplified the PCR product for *cry3* gene. Similarly expected PCR product of 797 bp of *cry4* gene was amplified in *Bt* var. *isralensis* alone. However all the shortlisted *Bt* strains *viz.,* VKK-AC1, VKK-AC2, VKK-BB1, VKK-BB2 and VKK-PX1 amplified novel band of 275-292 bp with *cry4* gene specific primers. *Cry3, cry7, cry8, cry11* and *cry12* genes were found to be absent. Although with *cry9* gene specific primers *Bt* strains VKK-BB1 amplified novel band ranging from 200-

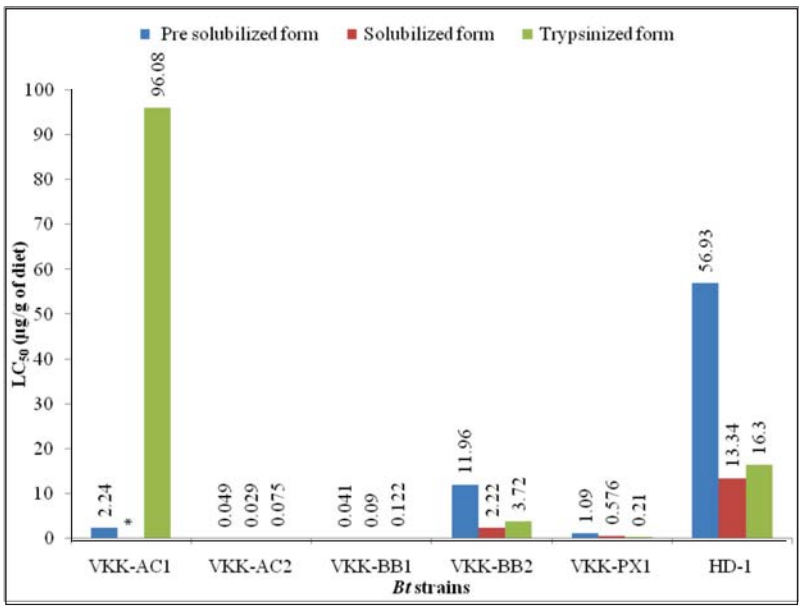

Fig. 1. Comparative toxicity of five selected *Bt* strains along with reference strain *Btk* HD-1 in the pre-solubilized, solubilized and trypsinized form against adults of *Aphis gossypii* *Unable to attain 50% mortality with highest concentration (10 µg/g of diet) used

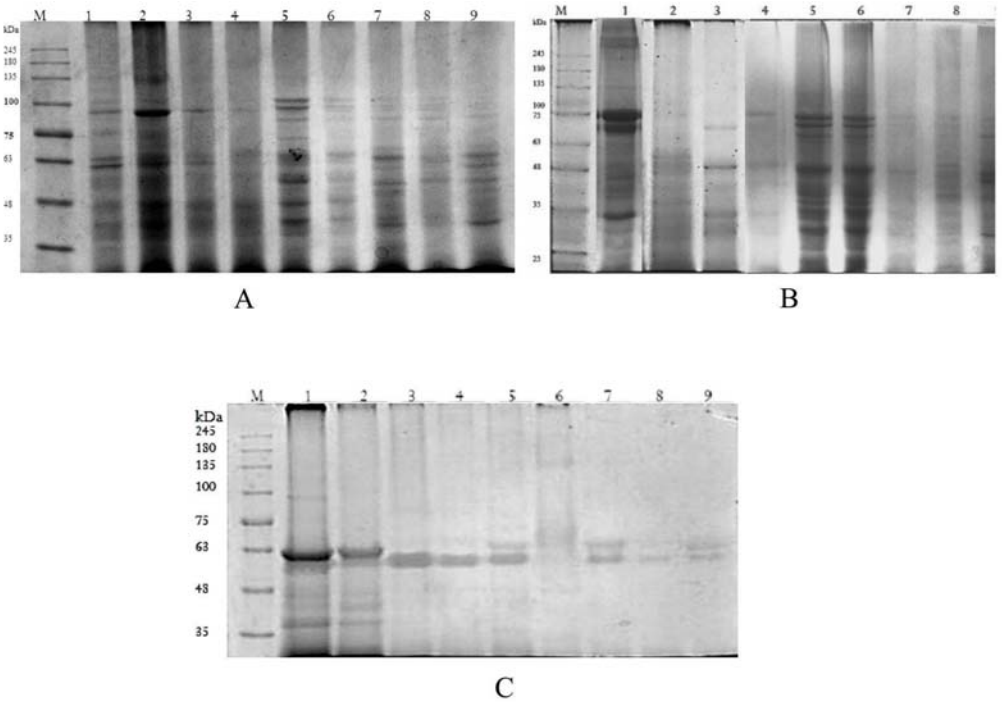

Fig. 2. SDS-PAGE profile of reference strains and selected *B. thuringiensis* isolates

A.Pre-solubilized form, B. Solubilized form C. Trypsinized form; Lanes : M. Marker; 1. *Bt kurastaki* HD-1; 2. *Bt kurastaki* HD-73; 3. *Bt tolwarthi*; 4. *Bt isralensis*; 5.VKK-AC1; 6.VKK-AC2; 7. VKK-BB1; 8. VKK-BB2; 9. VKK-PX1

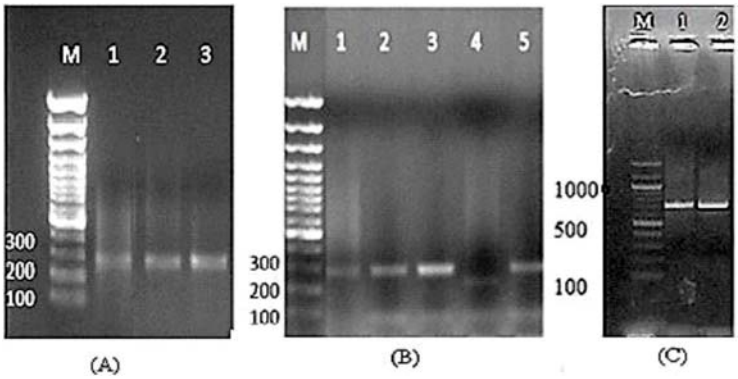

Fig. 3. Agarose gel electrophoresis of PCR products amplified A. *Cry* 1 primers. M: Molecular Marker (1000bp), Lane1- HD-1, Lane2- HD-73, and Lane3- VKK-BB2; **B.** C*ry*4 primers. M: Molecular Marker (1000bp), 1-5 isolates Lane1- VKK-AC1, Lane2- VKK-AC2, Lane3- VKK-BB1, Lane4- VKK-BB2, Lane5- VKK-PX1; C. *Cry* 2 primers. M: Molecular Marker (1000bp), Lane1- HD-1, Lane2- VKK-BB2

270 bp. Similarly with *cry15* gene specific primer none of the *Bt* strains amplified expected PCR product of 430 bp instead VKK-BB-1 showed unexpected band of 200 bp.

Studies on *Bt* toxicity against hemipterans are rare, perhaps due to the lack of rearing protocols. Merely a few *cry* proteins are weakly to moderately active against hemipterans in artificial diet feeding assays- against potato aphid (Walters and English, 1995) and pea aphid (Porcar *et al*., 2009). The inadequate toxicity was related to the use of non soluble *Bt* crystals on feeding assays which has to be solubilized in a alkaline condition as against the acidic pH present in their stomach (Cristofoletti *et al.*, 2003).

Recently, Mandla (2015) screened native *Bt* strains for the insecticidal activity in pre-solubilized, solubilized as well as trypsinized form to overcome the acidic pH of the aphids. Interestingly, variable toxicity was observed in the *Bt* strains isolated from soil, warehouses and insects. Strains isolated from soil

Table 4. Characteristics of the primer sets used to identify *cry* genes and distribution of *cry* genes in the strains of *Bacillus thuringiensis*

S.No.	*cry* gene	Primer sequence	Amplicon size(bp)	Annealing temperature (°C)	*Bt* strain ID
1	*cry 1*	FP: CATGATTCATGCGGCAGATAAAC RP :TTGTGACACTTCTGCTTCCCATT	276	50	HD-1, HD-73, VKK-AC2*, VKK-BB2
2	*cry 2*	FP: GTTATTCTTAATGCAGATGAATGGG RP:CGGATAAAATAATCTGGGAAATAGT	689-701	47.5	HD-1, VKK-BB2
3	*cry 3*	FP: CGTTATCGCAGAGAGATGACATTAAC RP:CATCTGTTGTTTCTGGAGGCAAT	589	50	Negative
4	*cry 4*	FP: CAAGCCGCAAATCTTGTGGA RP:ATGGCTTGTTTCGCTACATC	797	45.5	*Bt* var. *israelensis*, VKK-AC1*, VKK-AC2*, VKK-BB1*, VKK-BB2
5	*cry 7*	FP: AGTGGAGAGTTTACGGTAGCC RP: CAATCCCAGTGTTTACTTGGAC	211	50	Negative
6	*cry 8*	FP: ATGAGTCCAAATAATCTAAATG RP: TTTGATTAATGAGTTCTTCCACTCG	373-376	48.5	Negative
7	*cry 9*	FP: CGGTGTTACTATTAGCGAGGGCGG RP: GTTTGAGCCGCTTCACAGCAATCC	351-354	55	VKK-BB1*
8	*cry 11*	FP: TTTGCACCAGATAATACTAAGGAC RP: AACAACTGCGATAAATACCACTCT	485	50	Negative
9	*cry 12*	FP: CTCCCCCAACATTCCATCC RP: AATTACTTACACGTGCCATACCTG	363	49	Negative
10	cry 15	FP: ATCTGGGGTTACCGTTTCTGC RP: CGTCGTTGCTGTTCCTCTCC	430	55	VKK-BB1

* denote the non-specific and novel amplicons of PCR products

showed least toxicity (20-50%), while those from warehouses showed moderate to high toxicity (50-80%) with solubilized as well as trypsinized form. Toxicity of strains isolated from insects ranged from negligible (<20%) to highly toxic (100%) against cotton aphid. Maximum of 13 *Bt* strains were highly toxic (70-100% mortality) in trypsinized form followed by pre-solubilized form, whereas nine strains were highly toxic- the least was in solubilized form with only two strains being highly toxic against *A. gossypii*. These results agrees with Cristotoletti *et al.* (2003; Li *et al.*, 2011) to certain extent but the lowest efficacy of solubilized form of protein is yet to be elucidated.

In the present study, two strains viz., VKK-AC2 and VKK-BB1 (LC_{50} 0.041-0.1µg/g of diet) were found to be the most effective against adults of *A. gossypii* in pre-solubilized, solubilized as well as trypsinized form followed by VKK-PX1 and VKK-BB2 (LC_{50} 0.21-11.96 µg/g of diet). Also, findings on the reserves of *B.thuringiensis* in insect cadavers agrees with Ishiwata (1901), who isolated *Bt* for the first time from diseased larvae of silkworm followed by Berliner (1911) from the Mediterranean flour moth.

Protein profile characterization based on the SDS-PAGE gel showed the banding patterns from 20-135 kDa. Protein bands of 62-68 kDa were present in most of these isolates. Haggag and Yousef (2010) had distinguished protein profiles of *Bt* strains into three main protein groups *viz*., group I (28-58 KDa), group II (60-80 KDa) and group III (125-150 KDa). In the present study, all three groups were present.

Protein profiling of solubilized form showed that molecular weight varied from 20-106 kDa with

Table 5. Characterization of *Bt* strains by PCR, showing specific and non-specific (novel) band

S.No.	*Bt* strain ID	*cry* gene specific product size (bp)					
		cry1 (276)	*cry2* (680-700)	*cry3* (589)	*cry4* (797)	*cry9* (354)	*cry15* (430)
		Reference strains					
1	HD-1	+	+	-	-	-	-
2	HD-73	+		-	-	-	-
3	*Btt*	-	-	+	-	+	-
4	*Bti*	-	-	-	+	-	-
5	VKK–PXI	-	-	-	276	-	-
6	VKK–AC1	-	-	-	275	-	-
7	VKK–AC2	100	-	-	283	-	-
8	VKK–BB1	-	-	-	292	200	200
9	VKK–BB2	+	+	-	292	-	-

-Not present; + Present; Numeral depicts Novel bands.

maximum of eight bands in HD-1 and HD-73 followed by five in *Bt* var. *tolworthi* (21-70 kDa) and four in *Bt* var. *isralensis* (22-49 kDa). Whereas in the solubilized form, maximum eight bands were obtained in VKK-AC1(22-94 kDa) followed by six in VKK-AC2 (23-69 kDa) and four in VKK-BB1(24-70 kDa). Both VKK-BB2 and VKK-PX1 showed four bands ranging from 24-92 kDa. In case of trypsinized form, there were 2 bands each in the range of 60-66 kDa, whereas *Bt* var. *kurstaki* HD-1 and HD-73 strain showed five and four bands, respectively, in somewhat wider range of 39-62 kDa. However, only 59 kDa protein band was observed with trypsinized form of *Bt* var. *tolworthi* and *Bt* var. *israelensis.*

Cry toxins are present in the form of protoxin in the crystal of *Bt*, upon activation of the protoxin, an insecticidal *cry* toxin is generated (Bulla *et al*., 1979; 1981). However, the processing of protoxin to toxin is different among the respective toxin groups, depending on host specificity, *i.e.,* toxins that kill lepidopterans, coleopterans or dipterans. 65 kDa protein in *cry1A* and *cry4* toxins primarily kill lepidopteran and dipteran larvae, respectively, and it is the product of protoxins in the molecular weight range of 125-135 kDa. Similarly, 68 kDa protein in *cry3* toxin that kill coleopteran larvae are products of 72 kDa protoxins. The protein profile of these strains ranged from 133-150 kDa which corresponds to the *cry* proteins, and 18 to 27 kDa proteins which correspond to the Cyt proteins. Similar findings had been reported by Bukhari and Shakoori (2010), Azizoglu *et al*. (2011) and Assaeedi *et al*. (2011). Similarly, the 60-65 kDa protein which was found to be lethal against adults of cotton aphid is presumed to be toxin form of some *cry* protein. Even the protein ranging from 22 to 108 kDa in pre-solubilized and solubilized form were found to have toxicity against hemipterans and needs further investigation.

The parasporal crystal of *Bt* var. *kurstaki* HD-73 comprises *cry1Ac* protein only, whereas HD1 strain, of the same subspecies, contains five different *cry* toxins *i.e., cry1Aa*, *cry1Ab*, *cry1Ac*, *cry2Aa* and *cry2Ab*. However, *Bt* var. *tolworthi* and *Bt* var. *isralensis* comprises *cry3* and *cry4* toxins, respectively. The expected product size of 276 bp of *cry1* was found to be present in *Bt* var. *kurstaki* HD-1, HD-73 and VKK-BB2. VKK-AC-2 strain showed unexpected PCR product with *cry1* primer that could correspond to a new gene. Céron *et al*. (1995) reported that an unexpected amplified fragment might correspond to a new *cry* gene, using a multiplex PCR with specific primers. Porcar and Juarez-Parez (2003) also supplemented this explanation.

Similarly, for *cry2* gene only VKK-BB2 showed expected amplicon size of 689-701 bp. Except for *Bt* var. *tolworthi,* no other *Bt* strain had amplified the PCR product for *cry3* gene. Although expected PCR product of 797 bp of *cry4* gene was amplified in *Bt* var. *isralensis*. However, all the potential *Bt* strains viz., VKK-AC1, VKK-AC2, VKK-BB1, VKK-BB2 and VKK-PX1 amplified novel band of 275-292 bp with *cry4* gene specific primers. Further investigation will be required to characterize these novel amplified fragments to correlate with insecticidal activity against hemipterans.

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INCIDENCE OF APHID *MACROSIPHUM EUPHORBIAE* THOMAS ON POTATO IN NORTHERN KASHMIR

MOHAMMAD MUNIB*, ABDUL ROUF WANI AND ARSHAD ABASS**

Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus, Srinagar 190025
***Current address: Sector 6, Hyderia Colony, Khumani Chowk, Bemina, Srinagar 190018*
**Email: mohmmadmunib@yahoo.in*

ABSTRACT

The investigations on the incidence and severity of foliage aphid *Macrosiphum euphorbiae* Thomas on potato (*Solanum tuberosum* L.) in northern Kashmir Valley were undertaken at Baramulla, Kupwara and Bandipora districts in the two cropping seasons 2011 and 2012. Observations revealed that it appeared in the 2nd week of April to 1st week of May and attained peak in June in plains and mid hills; while at the high hills, it appeared by the end of May to 1st week of June with peak being at the end of June to 1st week of July. Maximum incidence of 16.00±4.98% was at Ajas Bandipora followed by 15.55±5.56% at Pattan Baramulla; and the least incidence of 8.00±3.12% was observed at Gurez, Bandipora in 2011. Similarly, during 2012, the maximum incidence of 16.00±5.24% was observed at Pattan Baramulla, and the least of 8.88±2.88% at Gurez. Based on pooled data, a maximum incidence of 15.77±0.21% was observed at Pattan Baramulla and the least of 8.44±0.43% was again at Gurez.

Key words: Potato, aphid, North Kashmir, seasonal incidence, peak, Baramulla, Kupwara, plains, hills, Bandipora

Potato, *Solanum tuberosum* L. is attacked by several insect pests in the field as well as in storage, of which the damage is mainly caused by aphids, jassids, cut worms, termites, white grubs, leaf eating caterpillars, epilachna and other beetles (Singh, 1990). Different stages of crop and its emerging leaves had definite role on landing, settling and population buildup of aphids (Trivedi and Verma, 1990). Several species of aphids infest potato crop such as *Aphis craccivora* Koch, *A. gossypii*, *A. fabae*, *Myzus persicae* Sulz., *Rhopalosiphum nymphaeae* L., *R. rufiabdominalis* and *Tetraneura nigriabdominalis* Sasaki (Kashyap and Verma, 1982). More damage occurs through the transmission of viral diseases (Bacon *et al*., 1978). Among these *M. persicae* is the most important transmitting potato virus Y and PLRV (Bhatnagar *et al*., 2012). The present study is on the foliage aphid *Macrosiphum euphorbiae* Thomas, which occurs in Kashmir, in particular in the few districts of northern Kashmir to evaluate its seasonal incidence.

MATERIALS AND METHODS

Observations on the incidence were recorded at all the locations ranging from plains to higher altitudes of districts Baramulla, Kupwara, and Bandipora, during the cropping season of 2011 and 2012. The localities covered include Yarikhah, Kunzer and Pattan (district Baramulla, 2481, 1761 and 1556 msl, respectively); Budnambal, Handwara and Yonus (district Kupwara, 3120, 1592 and 1551 msl, respectively); and Gurez, Ajas and Sumbal (district Bandipora, 2468, 1593 and 1578.2 msl, respectively). Five plants were randomly selected and from each plant, five leaves were examined for ascertaining the aphid population, from which % incidence was calculated. The severity of the aphid was graded under 1-4 Scale (Nagrare *et al*., 2009)- Grade: 1-Scattered appearance of few aphids; 2- Moderate infestation any one branch; 3- Severe infestation on more than one branch or half portion of the plant; 4- Very severe infestation, in the whole plant. Severity index (SI) was calculated with randomly selected five infested plants at fortnightly interval and graded on the basis of appearance of pest. The plants were considered infested even if a single pest was observed.

$$\text{Severity index (SI)} = \frac{\text{Sum of total grade points (1-4 infestation grade G-I to G-IV, respectively) of the infested plants}}{\text{Total number of infested plants observed}}$$

RESULTS AND DISCUSSION

Observations on the incidence revealed that the aphid appeared on 2nd April to 1st week of May and

Table 1. Incidence of foliage aphid *Macrosiphum euphorbiae* Thomas on potato- northern Kashmir (2011, 2012)

Year	Pattan		Baramulla Kunzer		Yarikhah		Yonus		Kupwara Handwara		Budnambal		Sumbal		Bandipora Ajas		Gurez	
	Obsr.date	Aphid	Obsr. date	Aphid	Obsr. date	Aphid	Obsr. date	Aphid	Obsr. date	Aphid	Obsr. date	Aphid	Obsr. date	Aphid	Obsr. date	Aphid	Obsr. date	Aphid
2011	1st April	0.00	3rd April	0.00	30th May	12.00	5th April	0.00	6th April	0.00	28th May	0.00	2nd April	0.00	4th April	0.00	10th June	0.00
	16th April	0.00	18th April	0.00	14th June	28.00	20th April	4.00	21st April	0.00	12th June	12.00	17th April	4.00	19th April	4.00	25th June	8.00
	1st May	8.00	3rd May	8.00	29th June	40.00	5th May	12.00	6th May	8.00	27th June	20.00	2nd May	12.00	4th May	20.00	10th July	16.00
	16th May	20.00	18th May	20.00	14th July	16.00	20th May	20.00	21st May	16.00	12th July	32.00	17th May	16.00	19th May	28.00	25th July	28.00
	31st May	36.00	2nd June	32.00	29th July	8.00	4th June	24.00	5th June	28.00	27th July	16.00	1st June	28.00	3rd June	40.00	9th Aug.	12.00
	15th June	48.00	17th June	36.00	13th Aug.	8.00	19th June	36.00	20th June	40.00	11th Aug.	8.00	16th June	36.00	18th June	32.00	24th Aug.	4.00
	30th June	24.00	2nd July	16.00	28th Aug.	0.00	4th July	20.00	5th July	24.00	26th Aug.	4.00	1st July	20.00	3rd July	16.00	8th Sept.	4.00
	15th July	4.00	17th July	4.00	12th Sept.	0.00	19th July	8.00	20th July	8.00	10th Sept.	0.00	16th July	8.00	18th July	4.00	23rd Sept.	0.00
	30th July	0.00	1st Aug.	0.00	27th Sept.	0.00	3rd Aug.	0.00	4th Aug.	0.00	25th Sept.	0.00	31st July	0.00	2nd Aug.	0.00	8th October	0.00
2012	2nd April	0.00	1st April	0.00	28th May	8.00	3rd April	0.00	5th April	0.00	30th May	0.00	4th April	0.00	6th April	0.00	8th June	0.00
	17th April	0.00	16th April	0.00	12th June	32.00	18th April	4.00	20th April	0.00	14th June	12.00	19th April	8.00	21st April	8.00	23th June	12.00
	2nd May	12.00	1st May	4.00	27th June	44.00	3rd May	8.00	5th May	4.00	29th June	24.00	4th May	12.00	6th May	24.00	8th July	16.00
	17th May	28.00	16th May	16.00	12th July	20.00	18th May	28.00	20th May	16.00	14th July	36.00	19th May	20.00	21st May	28.00	23rd July	24.00
	1st June	36.00	31st May	28.00	27th July	12.00	2nd June	28.00	4th June	32.00	29th July	20.00	3rd June	28.00	5th June	36.00	7th Aug.	16.00
	16th June	40.00	15th June	32.00	11th Aug.	4.00	17th June	40.00	19th June	44.00	13th Aug.	12.00	18th June	32.00	20th June	24.00	22nd Aug.	8.00
	1st July	20.00	30th June	24.00	26th Aug.	0.00	2nd July	24.00	4th July	24.00	28th Aug.	8.00	3rd July	16.00	5th July	8.00	6th Sept.	4.00
	16th July	8.00	15th July	8.00	10th Sept.	0.00	17th July	8.00	19th July	8.00	12th Sept.	0.00	18th July	4.00	20th July	0.00	21st Sept.	0.00
	31st July	0.00	30th July	0.00	25th Sept.	0.00	1st Aug.	0.00	3rd Aug.	0.00	27th Sept.	0.00	2nd Aug.	0.00	4th Aug.	0.00	6th October	0.00

Data based on 5 random plants with 25 leaves; Obsr. Date- observation date

attained peak in June in plains and mid hills; at high hills it appeared by the end of May to 1st week of June with peak being by the end of June to 1st week of July (Table 1). Table 2 reveals that 16% (maximum) incidence was observed at Ajas (Bandipora) and the least 8% at Gurez (Bandipora) in 2011. In 2012 too it was similar with 16% incidence at Pattan (Baramulla) and 8.88% at Gurez (Bandipora). These results suggest that although aphids occur but their incidence remains low- this is supported by Verma *et al.* (1998) who reported that aphids appear approximately 35 days after planting in potato.

The results presented in Table 3 and 4 with pooled data reveal that aphids start their feeding activity in May and attained peak towards June at Pattan (plain), Kunzer (mid hill) and Yarikhah (high hill) attaining 0.89, 0.82 and 1.02%, respectively in Baramulla district. However, in Kupwara, the pest started feeding in April at Yonus (plain) and in May at Handwara (mid hills)

Table 2. Incidence of foliage aphid *M. euphorbiae* on potato - at Baramulla, Kupwara and Bandipora

Year	Baramulla	Kupwara	Bandipora						
	Pattan	Kunzer	Yarikhah	Yonus	Handwara	Budnambal	Sumbal	Ajas	Gurez
2011	15.55±5.56	12.88±4.65	12.44±4.59	13.77±4.06	13.77±4.76	10.22±3.65	13.77±4.16	16.00±4.98	8.00±3.12
2012	16.00±5.24	12.44±4.29	13.33±5.24	15.55±4.87	14.22±5.34	12.44±4.13	13.33±3.88	14.22±4.62	8.88±2.88
Pooled	15.77±0.21	12.66±0.21	12.88±0.43	14.66±0.88	13.99±0.21	11.33±1.10	13.55±0.21	15.11±0.88	8.44±0.43

*Data based on 5 random plants with 25 leaves; No. of observations in a year 9; Data expressed as Mean ± SE

Table 3. Severity of foliage aphid *M. euphorbiae* infestation on potato at Baramulla, Kupwara and Bandipora (pooled data-2011, 2012)

District	Location	Severity of infestation *(Severity Index)					
		April	May	June	July	August	September
Baramulla	Pattan	0.00	1.23±0.17	1.70±0.10	0.65±0.14	-	-
	Kunzer	0.00	1.13±0.13	1.40±0.00	0.75±0.25	-	-
	Yarikhah	-	1.00±0.00	1.40±0.19	1.20±0.00	0.50±0.00	-
Kupwara	Yonus	0.50±0.00	1.15±0.5	1.95±0.14	1.00±0.00	-	-
	Handwara	0.00	1.00±0.00	2.15±0.14	1.00±0.00	-	-
	Budnambal	-	0.00	1.00±0.00	2.05±0.14	1.00±0.00	-
Bandipora	Sumbal	0.50±0.00	1.05±0.05	1.95±0.14	0.83±0.17	-	-
	Ajas	0.50±0.00	1.20±0.10	1.70±0.19	0.75±0.25	-	-
	Gurez	-	-	0.50±0.00	1.60±0.10	1.00±0.00	0.50±0.00

Data based on five infested plants; * Severity Index-1=Scattered appearance of few aphids; 2=Moderate infestation on any one branch; 3=Severe infestation on more than one branch or half portion of the plant; and 4=Very severe infestation in the whole plant; Data expressed as Mean ± SE

Table 4. Severity of foliage aphid *M. euphorbiae* infestation on potato at Baramulla, Kupwara and Bandipora

Year	*Severity Index								
	Baramulla				Kupwara	Bandipora			
	Pattan	Kunzer	Yarikhah	Yonus	Handwara	Budnambal	Sumbal	Ajas	Gurez
2011	0.79	0.85	0.97	1.12	1.00	0.97	1.09	1.17	0.87
2012	1.00	0.79	1.07	1.17	1.07	1.05	1.07	0.90	0.92
Pooled Mean±SE	0.89±0.09	0.82 ±0.02	1.02 ±0.04	1.14 ±0.02	1.03±0.02	1.01±0.03	1.08 ±0.009	1.03±0.13	0.89 ±0.02

Data based on five infested plants; * Severity Index-1=Scattered appearance of few aphids; 2=Moderate infestation on any one branch; 3=Severe infestation on more than one branch or half portion of the plant; and 4=Very severe infestation in the whole plant; Data expressed as Mean ± SE

with peak severity in both locations being in June; at Budnambal (high hill), the feeding started during June and attained peak in July. Similar trend was observed in Bandipora district as well. At Gurez (high hill) infestation started from June and attained peak towards July (0.89%). Two year data, revealed the highest mean severity of 1.14±0.02% (Scale 1) was at Yonus (district Kupwara) and 0.82±0.02% (Scale-1) as the lowest at Kunzer (Baramulla district). The above findings suggest that severity index of the aphid was low at all nine locations in north Kashmir falling in Scale-1 indicating that aphids do less damage.

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MORPHOMETRICS OF *TRICHOGRAMMA* SPP. COLLECTED FROM HARYANA AND PUNJAB

MOHD. YOUSUF, SALMAN KHAN* AND MOHSIN IKRAM

Forest Entomology Division
Forest Research Institute, P.O. New Forest, Dehra Dun, Uttarakhand 248006
**Email: salman1315@gmail.com (corresponding author)*

ABSTRACT

The genus *Trichogramma* constitutes an important group of egg parasitoids. It has wide range of host insects, covering many pests of agricultural crops as well as some key insect pests of important forest trees. Amongst the biological control agents, species of *Trichogramma* are the most common. The present study, with the *Trichogramma* species collected during the four years' survey (2012-2015), across different districts of Haryana and Punjab, has led to study of nine species: *T. achaeae, T. agriae, T. breviciliata, T. chilonis, T. chilotraeae, T. flandersi, T. japonicum, T. plasseyensis* and *T. poliae*. Descriptions are given for these along with their detailed diagnostic characters, and additional morphometrics. Host range and distribution from Haryana and Punjab are also discussed.

Key words: *Trichogramma*, Hymenoptera, egg parasitoids, Haryana, Punjab, survey, descriptions, diagnostics, morphometrics, hosts, distibution

Genus *Trichogramma* Westwood (Trichogrammatidae) is a group of minute hymenopteran wasps, widely used for biological control of many insect pests of agricultural as well as forestry importance. Its species are distributed throughout the world, in all the six zoogeographical regions (Ahmad et al., 2008). Its species parasitize wide range of insects across the globe, belonging to Lepidoptera, Coleoptera, Hymenoptera, Diptera and Hemiptera (Debach and Rosen, 1991). Species of *Trichogramma* are most commonly explored in applied biocontrol of many important pests. These parasitic wasps are very small, measuring 0.38 to 0.54 mm in length. The major diagnostic characters of the genus include: the females with antennae having 2-segmented funicle and single segmented club; presence of RS1 vein track, sigmoid venation in forewings; while in males funicle segments and club segment are fused to form a single flagellum bearing long setae. Important contribution on the taxonomy, survey and field biocontrol of Indian *Trichogramma* includes: Nagaraja and Nagarkatti (1969); Nagarkatti (1972); Nagaraja (1973; 1996); Nagarkatti and Nagaraja (1977); Yousuf and Shafee (1988); Ahmad et al. (2002); Yousuf et al. (2004); Nagaraja and Gupta (2007); Nagaraja et al. (2007); Yousuf and Hassan (2007, 2008a,b,c); Ahmad et al. (2008); Nagaraja and Mohanraj (2010) and Yousuf et al. (2015).

MATERIALS AND METHODS

Present survey on *Trichogramma* spp. was carried out from 2012 to 2015, and forestry and agroforestry areas of districts- Amritsar, Barnala, Bathinda, Faridkot, Fatehgarh Sahib, Ferozepur, Gurdaspur, Hoshiarpur, Jalandhar, Ludhiana, Moga, Nawanshahr, Patiala, Ropar, Sangrur and Taran Taran in Punjab covered. Similarly, districts of Haryana namely, Bhiwani, Fatehabad, Hisar, Jhajjar, Jind, Kaithal, Karnal, Kurukshetra, Mahendragarh, Panipat, Rewari, Rohtak, Sirsa, Sonipat and Yamuna Nagar were surveyed. Collections were carried out by sweeping method using fine cotton cloth sweeping net. Green land areas with grasses and small plants were swept the collected material preserved in 70% ethyl alcohol.

Out of these specimens belonging to *Trichogramma* were sorted out, and after following the normal procedure of dehydration, specimens were dissected in clove oil under stereozoom microscope. The important morphological parts were mounted in Canada balsam, oriented in required position and permanent slides prepared with cover slips. Slides were examined under the research microscope for taxonomic characters. Identification at species level was done following the keys and descriptions given by: Ashmead, (1904); Ishii, (1941); Nagaraja and Nagarkatti (1969); Nagaraja (1973); Yousuf and Shafee (1988) and Yousuf and Hassan (2007).

RESULTS AND DISCUSSION

Nine species of *Trichogramma* were collected and studied and these include: *T. achaeae, T. agriae, T. breviciliata, T. chilonis, T. chilotraeae, T. flandersi, T. japonicum, T. plasseyensis* and *T. poliae.* Table. 1 lists the important morphometrics of these and Fig. 1 shows some important morphometrics. The descriptions are as below:

1. *Trichogramma achaeae* Nagaraja & Nagarkatti

Trichogramma achaeae Nagaraja and Nagarkatti, 1969: 396.

Diagnosis: Body about 0.5 mm long, yellow to dark yellow. Male antennae with long hairs, longest hair about 2.5x maximum width of flagellum. Male genitalia having DEG triangular and with blunt apex, reaching nearly tips of gonoforceps; MVP very minute;

Table 1. Morphometrics of *Trichogramma* spp.

	T. achaeae (mm)	*T. agriae* (mm)	*T. breviciliata* (mm)	*T. chilonis* (mm)	*T. chilotraeae* (mm)	*T. flandersi* (mm)	*T. japonicum* (mm)	*T. plasseyensis* (mm)	*T. poliae* (mm)
Flagellum length (♂)	0.176	0.169	0.158	0.172	0.139	0.143	0.147	0.150	0.165
Max. length of flagellar hairs (♂)	0.088	0.102	0.060	0.178	0.084	0.066	0.099	0.076	0.073
RS1 (♂)	5	3	6	4	3	5	7	4	5
RS2(♂)	14	12	15	11	9	10	10	10	10
r-m (♂)	28	21	24	16	20	21	18	20	20
Between RS2 & r-m (♂)	51	52	55	35	32	36	49	25	40
Genitalia length (♂)	0.129	0.145	0.152	0.110	0.136	0.126	0.149	0.110	0.117
Length of aedeagus with apodemes (♂)	0.119	0.120	0.108	0.106	0.106	0.108	0.142	0.081	0.113
Antennal club length (♀)	0.092	0.055	0.088	0.092	0.081	0.077	0.077	0.084	0.092
Ovipositor length (♀)	0.177	0.207	0.195	0.195	0.138	0.138	0.246	0.147	0.189
Hind tibia length (♀)	0.179	0.169	0.185	0.180	0.120	0.139	0.165	0.146	0.180

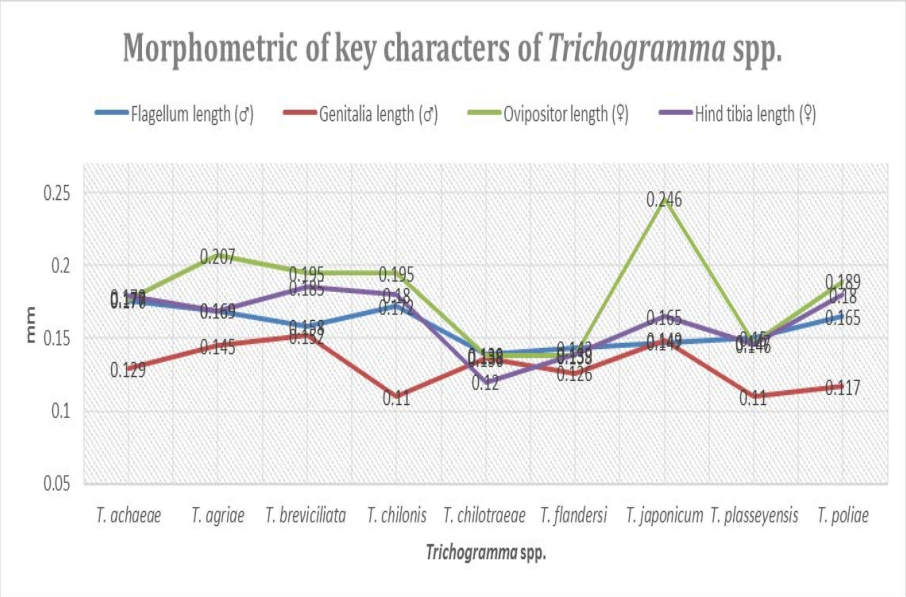

Fig. 1. Morphometrics of *Trichogramma* spp.

apodemes about two-third of aedeagus; both combinedly about as long as complete male genital capsule; about two–third the length of hind tibia. Female with ovipositor about as long as hind tibia.

Morphometrics: Male: Head in facial view wider than long, about 0.183 x 0.213 mm. flagellum 0.176 x 0.0367 mm; maximum length of flagellar hair 0.088 mm with total of 32 to 47 flagellar hairs. Fore wings 0.539 x 0.269 mm; marginal fringe 0.033 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 5, 14, 28 and 51 respectively; hind tibia 0.158 mm long. Genitalia 0.129 x 0.055 mm. Aedeagus with apodemes 0.119 mm long, distance from CS to GF 0.012 mm. Female: Head in facial view 0.198 x 0.249 mm. Fore wings 0.623 x 0.325 mm, maximum length of marginal fringe is 0.040 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 6, 16, 32 and 61 respectively. Antennal club 0.092 x 0.033 mm. Hind tibia 0.179 mm long; ovipositor 0.177 mm long.

Hosts: *Achaea janata, Agrius convolvuli, Catopsila pyranthe, Clostera cupreata, Corcyra cephalonica, Earias insulana, E. vitella, Ergolis merione, Helicoverpa armigera, Pectinophora gossypiella, Spodoptera litura* and *Tiracola plagiata*.

Distribution: India (Gujarat, Haryana, Karnataka, Punjab and West Bengal) and China (Fujian).

Material examined: Punjab; Faridkot, Tippi praiya, 2♂1♀, 28.viii.2012; Moga, Rajiana, ♂1, 13.xi.2012; Faridkot, Sandma penda, 1♀, 29.vii.2013; Taran Taran, Muradnagar, 1♀1♂, 11.ix.2013, sweeping, M. Yousuf; Haryana; Panipat, Naultha, 1♀, 29.ix.2014, Sweeping, Salman Khan.

2. *Trichogramma agriae* Nagaraja

Trichogramma agriae Nagaraja, 1973: 277.

Diagnosis: Body about 0.50 mm long; dark yellow; maximum length of flagellar hair about 3.5x as long as maximum flagellar width. Fore wings with marginal fringe on tornus about 1/7th of wing width. Male genitalia with DEG triangular and highly sclerotized; slightly constricted at base, reaching below the level of MVP also MVP is small and distinct. CR reaching nearly 2/3rd the entire length of genitalia; length of apodemes and aedeagus together less than the length of hind tibia. DEG short not reaching up to CS. Ovipositor about 1.5x as long as hind tibia.

Morphometrics: Male: Head in facial view wider than long, about 0.161 x 0.205 mm. flagellum 0.169 x 0.033 mm. Maximum length of flagellar hair 0.102 mm with total of 41 flagellar hairs. Fore wings 0.474 x 0.242 mm; marginal fringe 0.033 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 3, 12, 21 and 52 respectively. Hind tibia 0.165 mm long. Genitalia 0.145 x 0.055 mm. Aedeagus with apodemes 0.120 mm long, distance from CS to GF is 0.010 mm. Female: Head in facial view wider than long, 0.169 x 0.202 mm. Fore wings 0.484 x 0.195 mm; maximum length of marginal fringe 0.029 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 5, 13, 20 and 45 respectively. Antennal club 0.055 x 0.015 mm. Hind tibia 0.169 mm long; ovipositor 0.207 mm long.

Hosts: *Agrius convolvuli* and *Corcyra cephalonica.*

Distribution: India (Haryana, Karnataka, Punjab and Uttar Pradesh) and China.

Material examined: Punjab; Nawanshahr, Rahon, 1♀, 10.ix.2013; Jalandhar, Kartarpur, 1♀, 11.ix.2013; Doaba, 1♀, 24.xi.2013, sweeping, M. Yousuf; Haryana; Karnal, Madhuban, 1♂, 29.ix.2014, sweeping, Salman Khan.

3. *Trichogramma breviciliata* Yousuf & Hassan

Trichogramma breviciliata Yousuf and Hassan, 2007: 8.

Diagnosis: Body about 0.45mm long, yellowish brown; male antennae with flagellum slightly more than 4x as long as wide having about 55 short, stout and blunt flagellar setae, also longest seta is slightly more than the maximum width of flagellum; fore wings with vein track RS1 having 4 setae, RS2 with 12 setae, r-m with 21 setae, between RS2 and r-m 36 setae; genitalia with prominent DEG, holding posterior extremity with an spatulate shaped terminal lobe; Chelate structure just behind the tip of gonoforceps; aedeagus longer than apodemes, together shorter than entire genitalia and also shorter than hind tibia. female antennae with club about 2.5x as long as wide. Ovipositor about as long as hind tibia.

Morphometrics: Male: Head in facial view wider than long, about 0.202x0.246 mm. flagellum 0.158 x 0.0367 mm, maximum length of flagellar hair 0.060 mm with total of 35 to 42 flagellar hairs. Fore wings 0.558 x 0.251 mm; marginal fringe 0.035 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 6, 15, 24 and 55 respectively; hind tibia 0.180 mm long. Genitalia 0.152 x 0.074 mm. Aedeagus with apodemes

0.108 mm long, distance from CS to GF is 0.014 mm. Female: Head in facial view about 0.182x0.198 mm. Fore wings 0.493 x 0.242 mm, maximum length of marginal fringe 0.0367 mm; setae in RS1, RS2, r-m and between RS2 & r-m are 4, 11, 24 and 36 respectively. Antennal club 0.088 x 0.040 mm. Hind tibia 0.185 mm long; ovipositor 0.195 mm long.

Hosts: *Corcyra cephalonica, Eutectona machaeralis, Hasora alexis* and *Hyblaea puera.*

Distribution: India (Haryana, Madhya Pradesh, Maharashtra, Punjab and Orissa).

Material examined: Punjab; Faridkot, Mudki, 1♀, 13.xi.2012; Moga, Lande, 3♂, 13.xi.2012; Barnala, Kuns, 1♀, 12.ix,2013, sweeping, M. Yousuf; Haryana; Hisar, 1♂, 30.ix.2014; sweeping, Salman Khan; Fatehabad, Agroha, 1♂, 20.viii.2015, sweeping, R.B.Singh.

4. *Trichogramma chilonis* Ishii

Trichogramma chilonis Ishii, 1941: 173.

Diagnosis: Body about 0.45-0.51 mm long, yellowish, male antennae with long and tapering flagellar hairs, longest hair about 2.5x as long as maximum width of flagellum; fore wings with fringe on tornus about one-sixth the wing width; genitalia having DEG triangular with prominent lateral lobes; Chelate structure clearly below the level of gonoforceps; MVP broad at base; aedeagus as long as apodemes; both together slightly shorter than hind tibia; female with ovipositor as long as or slightly longer than hind tibia; body yellowish.

Morphometrics: Male: Head in facial view wider than long, about 0.166 x 0.202 mm. flagellum 0.172 x 0.033 mm, maximum length of flagellar hair 0.178 mm with total of 32 to 45 flagellar hairs. Fore wings 0.381 x 0.186 mm, marginal fringe 0.0367 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 4, 11, 16 and 35 respectively. Hind tibia 0.125 mm long. Genitalia 0.110 x 0.048 mm. Aedeagus with apodemes 0.106 mm long, distance from CS to GF is 0.012 mm. Female: Head in facial view 0.161 x 0.168 mm. Fore wings 0.486 x 0.260 mm, maximum length of marginal fringe 0.044 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 4, 13, 24 and 44 respectively; Antennal club 0.092 x 0.040 mm. Hind tibia 0.180 mm long; ovipositor 0.195 mm long.

Hosts: *Achaea janata, Acherontia styx, Acigona steniellus, Acrobasis caryae, A. juglandis, Aglossa dimidiata, Agraulis vanillae, Agrius cingulata, Agrius convolvuli, Ampillia dioscoridea, Anomis flava, Arctia coerulea, Argyroploce schistaceana, Ascotis selenaria dianerla, Atherigona soccata, Bactra sp., Barathra brassicae, Cerura vinula, Chilo indicus, Chilo infuscatellus, Chilo partellus, Chilo sacchariphagus, Chilo suppressalis, Chilo venosatus, Clanis bilineata, Clostera anachoreta, Cnaphalocrocis medinalis, Cocytodes coerulea, Corcyra cephalonica, Creatonotus transiens, Crocidolomia binotalis, Danaus plexippus, Deilephila nerii, Diatraea saccharalis, Earias insulana, Earias vitella, Emmalocera depressella, Ephestia cautella, Ergolis merione, Etiella zinckenella, Eucosma schistaceana, Euproctis flavinata, Eutectona machaeralis, Gastropacha populifolia, Grapholitha glycinivorella, Helicoverpa armigera, Heliothis assulta, Heliothis zea, Hemerophila atrilieneata, Herse convolvuli, Homona coffearia, Hyblaea puera, Hymenia recurvalis, Jaspida distinguenda, Laspeyresia caryana, Macroglossum pyrrhosticum, Mycalesis gotama, Naranga aenescens, Oebia undalis, Olethreutes schistaceana, Ostrinia furnalis, Ostrinia nubilalis, Papilio xuthus, Parasa consocia, Parnara guttata, Pelopidas mathias, Philosamia cynthia ricini, Pieris rapae, Plutella xylostella, Procera sacchariphagus, Procera venosatus, Prodenia litura, Prodesaia kurosawai, Psara spp., Samia cynthia, Scirpophaga excerptalis, Scirpophaga incertulas, Scirpophaga innotata, Scirpophaga nivella, Scirpophaga sp., Sesamia inferens, Sitotroga cerealella, Spilarctis obliqua, Spodoptera litura, Spodoptera mauritiana, Tiracola plagiata, Trichoplusia ni,* and unidentified lycaenid, noctuid, pyralid and sphingid eggs.

Distribution: India (Andhra Pradesh, Bihar, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand and West Bengal); Pakistan; Japan; Philippines; Thailand; Vietnam and China.

Material examined: Punjab; Moga, Lande, 1♀1♂, 13.xi.2012; Faridkot, Tena penda, 1♂, 13.xi.2012; Jalandhar, Merah, 2♀, 11.ix.2013; Barnala, Khuddi, 1♀2♂, 12.ix.2013, sweeping, M. Ikram; Barnala, Kuns, 4♀4♂, 12.ix.2013; Hoshiarpur, Satyal, 1♀, 24.xi.2013; Ferozepur, Sikhwa, 2♂, 25.xi.2013; Hoshiarpur, Bijwada, 2♂, 04.iii.2014; sweeping, M. Yousuf; Haryana; Panipat, Naultha, 1♂, 29.ix.2014; Jind, Dakhal, 1♀, 30.ix.2014; Kurukshetra, Thanesar, 1♀,

01.x.2014; Bhiwani, Paitas Khurd, 1♂, 07.xii.2014; Rohtak, Makroli, 1♀, 17.ii.2015; Sonipat, Murthar, 1♀, 18.viii.2015; Jind, Barodi, 1♂, 30.ix.2015; Rewari, Khol, 1♂, 29.ix.2015, sweeping, Salman Khan.

5. *Trichogramma chilotraeae* Nagaraja & Nagarkatti

Trichogramma chilotraeae Nagaraja and Nagarkatti, 1969:394.

Diagnosis: Male, adult small 0.51 mm long, antennae with flagellar hairs more than three times the maximum width of flagellum; genitalia with more or less triangular DEG having a tapering apex which does not project beyond gonoforceps, but extended only up to the level of CS; aedeagus prominent and long, 1.2x as long as apodemes, projecting beyond gonoforceps. MVP very distinct and long; aedeagus together with apodemes slightly shorter than hind tibia. In female, antennae typically clubbed with few short hairs. Ovipositor slightly longer than hind tibia.

Morphometrics: Male: Head in facial view distinctly wider than long, about 0.165 x 0.202 mm; flagellum 0.139 x 0.025 mm, maximum length of flagellar hair 0.084 mm with total of 29 flagellar hairs. Fore wings 0.437 x 0.204 mm; marginal fringe 0.033 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 3, 9, 20 and 32 respectively; hind tibia 0.138 mm long; genitalia 0.136 x 0.046 mm; aedeagus with apodemes 0.106 mm long, distance from CS to GF is 0.021 mm. Female: Head in facial view slightly wider than long, about 0.143 x 0.172 mm. Fore wings 0.446 x 0.186 mm; maximum length of marginal fringe is 0.033 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 4, 11, 17 and 31 respectively; antennal club 0.081 x 0.026 mm; hind tibia 0.120 mm long; ovipositor is 0.138 mm long.

Hosts: *Agrius convolvuli, Bactra sp., Chilo infuscatellus, C. partellus, C. suppressalis, Corcyra cephalonica, Helicoverpa armigera, Pelopidas mathias, Ostrinia furnacalis* and *Trichoplusia ni.*

Distribution: India (Karnataka, Punjab and West Bengal) and Thailand.

Material examined: Punjab; Hoshiarpur, Unchi Bassi, 1B&, 10.ix.2013; Jalandhar, Merah, 1♀, 11.ix.2013, sweeping, M. Yousuf; Haryana; Hisar, Durjanpur, 1♀, 25.xii.2014; Yamuna Nagar, Rador, 1♀, 16.ii.2015, sweeping, Salman Khan.

6. *Trichogramma flandersi* Nagaraja & Nagarkatti

Trichogramma flandersi Nagaraja and Nagarkatti, 1969:394.

Diagnosis: Males extremely small 0.45 mm long; antennae with flagellar hairs long about 3x of maximum width of flagellum; genitalia with prominent DEG, the posterior extremity ending in a characteristic rounded terminal lobe which projects far beyond the GF; MVP chitinized ridge extends from the anterior margin of gonobase up to almost half the total length of genitalia; apodemes about two thirds as long as aedeagus; CS located close to tips of GF; markedly hook like in appearance; MVP inconspicuous, but a pair of minute sclerotized protuberances present at base of CS, close to median ventral ridge. Females with antennae having few short hairs. Ovipositor almost as long as hind tibia.

Morphometrics: Male: Head in facial view wider than long, about 0.161 x 0.202 mm. Flagellum 0.143 x 0.023 mm, maximum length of flagellar hair 0.066 mm with total of 23 flagellar hairs; fore wings 0.474 x 0.223 mm; marginal fringe 0.046 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 5, 10, 21 and 36 respectively; hind tibia 0.154 mm long; genitalia 0.126 x 0.055 mm; aedeagus with apodemes 0.108 mm long, distance from CS to GF is 0.0092 mm. Female: Head in facial view wider than long, about 0.165 x 0.213 mm. Fore wings 0.484 x 0.214 mm, maximum length of marginal fringe 0.044 mm; setae in RS1, RS2, r-m and between RS2 & r-m are 6, 10, 19 and 38 respectively; antennal club 0.077 x 0.022 mm; hind tibia 0.139 mm; ovipositor 0.138 mm long.

Hosts: *Agrius convolvuli, Chilo infuscatellus* and *Corcyra cephalonica*.

Distribution: India (Karnataka and Punjab).

Material examined: Punjab; Jalandhar, Kartarpur, 1♂, 24.xi.2013; sweeping, M. Yousuf; Haryana; Hisar, 1♀, 30.ix.2014; sweeping, Salman Khan.

7. *Trichogramma japonicum* Ashmead

Trichogramma japonicum Ashmead, 1904: 165.

Diagnosis: Male about 0.5 mm long; male antennae having flagellum with tapering hairs, longest hair about 3.5x maximum width of flagellum; fore wings with marginal fringe on tornus about 1/5th of wing width; male genitalia, having DEG horse shoe shaped, extending slightly beyond the sides of genitalia; CS far below the level of GF; MVP inconspicuous; aedeagus distinctly longer than apodemes both together as long

as entire genital capsule and hind tibia separately. Female yellow with ovipositor distinctly longer than hind tibia.

Morphometrics: Male: Head in facial view wider than long, about 0.156 x 0.163 mm. Flagellum 0.147 x 0.029 mm, maximum length of flagellar hair 0.099 mm with total of 26 to 35 flagellar hairs. Fore wings 0.493 x 0.223 mm, marginal fringe 0.046 mm; setae in RS1, RS2, r-m and between RS2 & r-m are 7, 10, 18 and 49 respectively. Hind tibia 0.139 mm long. Genitalia 0.149 x 0.053 mm. Aedeagus with apodemes 0.142 mm long, distance from CS to GF is 0.025 mm.

Female: Head in facial view wider than long, about 0.162 x 0.189 mm. Fore wings 0.502 x 0.223, maximum length of marginal fringe 0.037 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 7, 13, 20 and 42 respectively. Antennal club 0.077 x 0.037 mm; Hind tibia 0.165 mm long; ovipositor 0.246 mm long.

Hosts: *Aglossa dimidiata, Agrotis ypsilon, Anchonoma xeraula, Anomis flava, Aphomia gullaris, Ascotis dianeria, Ascotis selenaria, Biston margina, Cataoela adjurella, Chilo suppressalis, Chilo spp., Chilotraea auricilia, Chilotraea polychrysa, Cnaphalocrocis medinalis, Corcyra cephalonica, Cocytodes coerulea, Creatonotus transiens, Dendrolimus punctatus, Dendrolimus spectibilis, Ephestia cautella, Ephestia kuehniella, Eutectona machaeralis, Hyblaea puera, Jaspida ditinguenda, Lampides boeticus, Leucania separata, Melanitis leda, Naranga aenescens, Notiphila dorsopunctata, Notiphila similis, Notiphila spinosa, Ostrinia furnalis, Ostrinia nubilalis, Pelopidas mathias, Parnara guttata, Plutella xylostella, Prodenia litura, Pyralis farinalis, Scirpophaga excerptalis, Scirpophaga incertulas, Scirpophaga nivella, Semia cynthia, Sesamia inferens, Sepedon plumbellus, Sepedon sauteri, Sepedon sphegens, Sepedon violaceua, Sitotroga cerealella, Spodoptera mauritiana, Spilarctia obliqua, Susumia exigua, Trichoplusia ni, Tryporyza incertulas, Tryporyza innotata* and *Tryporyza nivella.*

Distribution: India (Andhra Pradesh, Haryana, Karnataka, Jammu & Kashmir, Maharashtra, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal); Japan; China; Korea; Malaysia; Philippines; Thailand; Vietnam; Indonesia; France and USA.

Material examined: Haryana; Hisar, 1♂, 06.ix.2014; Yamuna Nagar, Tippi Majra, 1♀, 23.xii.2014; Kurukshetra, Ladwa, 1♀, 23.xii.2014; Panipat, Manglaura, 1♂, 17.iii.2015; Jhajjar, 1♀, 28.ix.2015; Karnal, Madhuban, 1♀, 30.ix.2015; sweeping, Salman Khan.

8. *Trichogramma plasseyensis* Nagaraja

Trichogramma plasseyensis Nagaraja, 1973: 278.

Diagnosis: Body about 0.5 mm long, brownish yellow; male antennae having flagellum with 30-35 blunt and short flagellar hairs, longest hair about 2x maximum width of flagellum; fore wings with marginal fringe on tornus about one-fifth the wing width; male genitalia having short DEG which does not reach the chelate structures, highly sclerotized with slight constrictions, with moderate bulging sides at base and sharp apex extending slightly beyond MVP. The MVP is minute; CS below the level of GF; aedeagus equal or slightly longer than apodemes, both together slightly shorter than hind tibia. Female with ovipositor almost equal or slightly longer than hind tibia.

Morphometrics: Male: Head in facial view wider than long, about 0.156x0.238 mm; flagellum 0.150 x 0.031 mm, maximum length of flagellar hair 0.076 mm with total of 26 to35 flagellar hairs. Fore wings 0.502 x 0.232 mm; marginal fringe 0.0391 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 4, 10, 20 and 25 respectively; hind tibia 0.103 mm long; genitalia 0.110 x 0.039 mm; aedeagus with apodemes 0.081 mm long; distance from CS to GF is 0.012 mm. Female: Head in facial view wider than long, about 0.165 x 0.205 mm. Fore wings 0.437 x 0.214 mm; maximum length of marginal fringe 0.041 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 4, 15, 20 and 28 respectively; antennal club 0.084 x 0.033 mm; hind tibia 0.146 mm; ovipositor 0.147 mm long.

Hosts: *Chilo auricilius, C. infuscatellus, C. terrenellus, C. tumidicostalis, Corcyra cephalonica, Eutectona machaeralis* and *Hyblaea puera.*

Distribution: India (Andhra Pradesh, West Bengal, Karnataka, Chhattisgarh, Madhya Pradesh, Maharashtra, Orissa and Punjab) and New Guinea.

Material examined: Punjab; Moga, Lande, 1♀2♂, 13.xi.2012; Faridkot, Narayangarh, 1♂, 13.xi.2012; Faridkot, Tibbi praiya, 1♀, 13.xi.2012; sweeping, M. Yousuf; Haryana; Rohtak, Makroli, 1♀, 29.ix.2014; Kalanaur, 1♀, 14.iii.2015; Karnal, Nangla, 1♀, 17.iii.2015; Karnal, Baldi, 1♀, 29.ix.2014; Jhajjar, 1♀, 28.ix.2015; Jind, 2♀, 30.ix.2015; Karnal, Madhuban, 1♂, 30.ix.2015; sweeping, Salman Khan.

9. *Trichogramma poliae* Nagaraja

Trichogramma poliae Nagaraja, 1973: 279.

Diagnosis: Body slightly more than 0.5 mm long, light brownish yellow; male antennae having flagellum with 30-35 long tapering hairs, longest hair about 3x maximum width of flagellum; fore wings with marginal fringe on tornus about one-sixth the wing width; male genitalia having DEG with prominent lateral lobes; CS below the level of GF; MVP large and broad at base; apodemes shorter than aedeagus, both together slightly shorter than hind tibia. Female with ovipositor about as long as hind tibia.

Morphometrics: Male: Head in facial view wider than long, about 0.152 x 0.249 mm. Flagellum 0.165 x 0.029 mm, maximum length of flagellar hair 0.073 mm with total of 40 flagellar hairs. Fore wings 0.465 x 0.223 mm; marginal fringe 0.037 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 5, 10, 20 and 40 respectively. Hind tibia 0.154 mm long. Genitalia 0.117 x 0.055 mm. Aedeagus with apodemes about 0.113 mm long, distance from CS to GF is 0.011 mm. Female: Head in facial view wider than long, about 0.191 x 0.246 mm. Fore wings 0.511 x 0.260 mm; maximum length of marginal fringe 0.040 mm, setae in RS1, RS2, r-m and between RS2 & r-m are 3, 15, 23 and 51 respectively. Antennal club 0.092 x 0.0367 mm. Hind tibia 0.180 mm long; ovipositor 0.189 mm long.

Hosts: *Chilo auricilius, C. infuscatellus, C. tumidicostalis, Clostera cupreata, C. fulgurita* and *Corcyra cephalonica.*

Distribution: India (West Bengal, Punjab, Uttarakhand and Uttar Pradesh).

Material examined: Punjab, Jalandhar, Merah, 1♀, 11.ix.2013; sweeping, M. Yousuf; Haryana; Hisar, Nawagaon, 1♂1♀. 16.iii.2015; sweeping, Salman Khan.

Trichogramma spp., are being utilized for biological control of insect pests of agriculture as well as forestry importance worldwide. In forestry, potential of its species against poplar defoliators *Clostera cupreata* and *C. fulgurita* and teak defoliator *Hyblaea puera* and *Eutectona machaeralis* had been evaluated (Ahmad, 1990,1992; Yousuf, 2005). Additional morphometrics for identifications have been made now which might be helpful for the correct identification of species from Haryana and Punjab.

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BIOEFFICACY OF ETHIPROLE 40 + IMIDACLOPRID 40 (GLAMORE 80WG) AGAINST BIHAR HAIRY CATERPILLAR, *SPILARCTIA OBLIQUA* (WALKER)

N.I. DEVI* AND R.P. SRIVASTAVA

Insecticide Toxicology Laboratory, Department of Entomology, College of Agriculture
GB Pant University of Agriculture and Technology, Pantnagar 263145
**Email: nidevi933@gmail.com*

ABSTRACT

Bioefficacy of ethiprole 40+ imidacloprid 40 (Glamore 80WG) against 14d old larvae of *Spilosoma obliqua* (Walker) by leaf dip method revealed a feeding inhibition of 87.60 and 81.86% @0.833 and 0.666% at 24HAF (hours after feeding) as compared to control, respectively. The LC_{50} values against 9d old larvae at 2.5, 3.0, 3.5, 4.0 and 5.0 days after feeding (DAF) were 1.018, 0.802, 0.606, 0.464 and 0.334%; and against 14d old larvae at 4.0 and 5.0 DAF were 0.628 and 0.563%, respectively. The LT_{50} values against 9d old larvae were 51.08, 81.90 and 96.85 hr @0.833, 0.666 and 0.499%, respectively. The LC_{50} values against 9d old larvae in atomization method at 3, 4 and 5 DAE (days after exposure) were 0.466, 0.369 and 0.324%, respectively; and against 5d old larvae it was observed to be 0.293 and 0.130% at 3 and 4 DAE, respectively. With the topical exposure method, it neither showed morbidity nor mortality up to 4 DAE to the five doses (4.15 to 20.82µg/larva) against 14d old larvae.

Key words: *Spilarctia obliqua*, Glamore 80WG, bioassay, leaf dip method, atomization method, topical application, feeding inhibition

The Bihar hairy caterpillar, *Spilarctia* (=*Spilosoma* =*Diacrisia*) *obliqua* (Walker) (Arctiidae: Lepidoptera), is a widely distributed, serious polyphagous pest (Gupta and Bhattacharya, 2008). Bioefficacy studies with various insecticides had been carried out earlier with synthetic pyrethroids and non pyrethroids (Singh and Singh, 2000a,b; Gupta *et al*., 2004; Chilana, 2009); combination insecticides (Dhingra *et al*., 2007); monocrotophos, malathion, endosulfan, cartap (Kundu, 1991); imidacloprid, cypermethrin, emamectin benzoate, neem and flubendiamide (Muthusamy *et al*., 2011); alphamethrin, deltamethrin, cypermethrin, endosulfan, profenofos, indoxacarb, monocrotophos, chlorpyrifos, emamectin benzoate, triazophos (Vaitheeswaran, 2009; Bhatt, 2013; Thodsare, 2014; Chand, 2012); on ascorbic acid, acetic acid, methyl parathion, monocrotophos, azadirachtin, endosulfan, triazophos, thiamethoxam, lambda-cyhalothrin, indoxacarb and imidacloprid (Mandal and Senapati, 1989; Mandal *et al*., 2013); seven metal dialkyl dithiocarbamates (Arora *et al*., 2003); methomyl, endosulfan and fenvalerate (Peerajade *et al*., 1999); quinalphos, fenvalerate, methyl parathion and malathion (Kumar *et al*., 1996); and monocrotophos, quinalphos, endosulfan, phenthoate, phosalone (Sidhu and Dhawan, 1980; Singh *et al*., 1982). Thus bioefficacy data on ethiprole, imidacloprid and its combination is lacking, and hence the present study with ethiprole+ imidacloprid against *S.obliqua*.

MATERIALS AND METHODS

First instar larvae of *S.obliqua* were collected from Norman E. Borlaug Crop Research Centre (NEBCRC), G.B.Pant University of Agriculture and Technology, Pantnagar, and kept in plastic tubs (dia. 36cm, ht. 14cm) containing fresh and soft castor leaves. The petiole was wrapped with a wet piece of cotton swab to protect it from drying, maintained with periodical fresh food supply and proper hygienic conditions. These larvae were used as and when required.

Leaf dip method bioassay to evaluate the contact and stomach toxicity of ethiprole 40 + imidacloprid 40 (Glamore 80WG, Bayer CropScience Limited) was done with 5d (mean weight= 0.0217g/larva), 9d (mean weight= 0.0792g/larva) and 14 days (mean weight= 0.358g/larva) old larvae at 22±2°C, RH 79±5%, following Kodandaram and Dhingra (2007). The concentrations were 0.499, 0.332, 0.166 and 0.002% against 5d old; and 0.833, 0.666, 0.499, 0.332 and 0.166% against 9 and 14d old larvae, prepared in tap water. For this, leaves were cut into pieces ($5\times5cm^{2)}$ and dipped in each concentration for 3 min, air dried and fed to larvae. In control, leaves were dipped in

water only. Each treatment was replicated thrice with each consisting of 5 larvae. Treated leaves were changed every 12 hr. The data on mortality were recorded at 1, 2, 3 and 4 days after feeding (DAF) with 5d old; 1, 2, 3, 4, 5 and 6 DAF with 14d old; and 1, 2, 2.5, 3, 3.5, 4, 5 and 6DAF with 9d old larvae. The data on feeding % were recorded at 12, 24, 36, 48, 60 and 72 hr after feeding (HAF) only in 14d old larvae. Moribund larvae were counted as dead.

Atomization method of bioassay to evaluate the contact toxicity (LC_{50}) was done against 5d (mean weight= 0.0217g/ larva) and 9d (mean weight= 0.0769g/ larva) old larvae (at 24±2°C, RH 72±5%). Five concentrations *viz*., 0.499, 0.332, 0.166, 0.003 and 0.002% against 5d, and 0.833, 0.666, 0.499, 0.332 and 0.166% against 9d old larvae, prepared in tap water were included, replicated thrice with each consisting of 10 larvae. Sprays were given with an atomizer and larvae contained in the same petri dish to give contact exposure for 30 min (Chilana, 2009), with water alone spray in control. Thereafter larvae were transferred to rearing boxes (24x15x8 cm) containing fresh castor leaves. The data on mortality were recorded at 1, 2, 3 and 4 days after exposure (DAE) with 5d and 1, 2, 3, 4, 5, 6 and 7 DAE with 9d old larvae. Moribund larvae were counted as dead.

Topical application method bioassay to evaluate the contact toxicity (LD_{50}) was done at 29±3°C, RH 61±5% against 14d old larvae (mean weight= 0.324g/ larva) following earlier work (Hummelbrunner and Isman, 2001; Pavela, 2005; Bhatt, 2013)). Five concentrations *viz*. 0.833, 0.666, 0.499, 0.332 and 0.166% prepared in tap water were used. A fixed volume of 2.5µl/ larva was topically applied to the thoracic region of cold-immobilised larva individually by Hamilton microapplicator. The doses were 20.82, 16.65, 12.47, 8.30 and 4.15 µg a.i./larva, respectively, with control having water only, and replicated thrice, each consisting of 5 larvae. The larvae were then transferred to petri dishes containing fresh castor leaves. The data on mortality were recorded at 1, 2, 3 and 4 DAE. Moribund larvae were counted as dead.

The mortality data were corrected using Abbott's formula (Abbott, 1925) and subjected to probit analysis following Finney (1971). Feeding % (F.P.) was calculated following Purwar and Srivastava (2003) and feeding inhibition % (F.I.) following Isman *et al.* (1990) and Pande and Srivastava (2003) as given below:

$$\text{F.P.} = \frac{(\text{Initial leaf area provided for feeding}) - (\text{Leaf area left after feeding})}{\text{Initial leaf area provided}} \times 100$$

$$\text{F.I.}(\%) = \frac{C - T}{C + T} \times 100,$$

where C=consumption of control disc, and T=consumption of treated disc.

RESULTS AND DISCUSSION

Leaf dip method bioassay

Dosage mortality response: For the contact and stomach toxicity of ethiprole 40+ imidacloprid 40 (Glamore 80WG) against 9 and 14d old larvae of *S.obliqua* indicated no mortality at 0.332 and 0.166% up to 24HAF against 9d old larvae, and until 48HAF against 14d old larvae. Thus 0.166 and 0.332% reduced the feeding, the mean leaf area consumed (MLAC) being 7.33 and 7.83 cm^2 compared to 19.08 cm^2 in control, amounting to a feeding inhibition of 45.03 and 40.93%, respectively. It is further evident from the Table 1 that the higher concentrations of. 0.833 and 0.666%, although did not cause mortality up to 2DAF, extremely reduced the feeding (MLAC=1.32 and 1.75 cm^2) with inhibition of 87.60 and 81.86% as compared to control, respectively. The reduction in feeding was more (5.49 and 7.00%) at the highest concentrations and less at the lower concentration (29.3 and 31.3%), respectively. The maximum mortality at 24HAE was 26.6% at 0.833%, which increased to 33.3% at 48, 53.3% at 60 and 66.6% at 72HAF with 9d old larvae; and with 14d old larvae, the highest concentration of 0.833% resulted in half of the mortality (33.3%) as compared to 9d old larvae at the end of three days. Thus it is evident that mortality was high with 9d old larvae compared to 14d old larvae at the same concentration and at the same days after feeding.

The LC_{50} values against 9d old larvae at 2.5, 3.0, 3.5, 4.0 and 5.0 DAF were 1.018, 0.802, 0.606, 0.464 and 0.334 %, respectively, and against 14d old larvae at 4.0 and 5.0DAF, these were 0.628 and 0.563%, respectively. A comparison of LC_{50} value against 9 and 14d old larvae at 4 and 5DAF indicated 1.35 and 1.68 times higher values in the 14d old larvae whose mean larval weight was 0.2788g higher than the 9d old larvae. The LC_{30} and LC_{90} values against 9d old larvae at 4DAF were 0.279 and 1.620% and against 14d old larvae were 0.381 and 2.142%, respectively (Table 2).

Table 1. Efficacy of ethiprole 40 + imidacloprid 40 on feeding behaviour of 14d old larvae of *S. oblique*- leaf dip method

Conc.	MLAC (cm^2)						Feeding %						Feeding Inhibition (%)					
(%)	12HAE	24HAE	36HAE	48HAE	60HAE	72HAE	12HAE	24HAE	36HAE	48HAE	60HAE	72HAE	12HAE	24HAE	36HAE	48HAE	60HAE	72HAE
0.833	3.91	1.37	1.08	1.33	2.83	3.25	15.66	5.49	4.33	2.66	5.66	6.50	75.60	87.60	91.80	94.80	89.26	88.06
0.666	4.41	1.75	1.83	3.16	4.50	4.41	17.66	7.00	7.33	6.33	9.00	8.83	73.83	81.86	86.30	88.20	83.70	84.06
0.499	5.25	4.66	6.83	12.16	10.91	5.75	21.00	18.66	27.33	24.33	21.83	11.50	67.30	58.26	61.03	64.20	65.06	79.39
0.332	5.33	7.83	24.08	26.75	48.58	15.33	21.33	31.33	96.33	53.50	97.16	30.66	65.00	40.93	1.83	30.26	1.40	53.09
0.166	21.66	7.33	24.41	32.50	50.00	19.66	86.66	29.33	97.66	65.00	100.0	39.33	8.33	45.03	1.16	21.23	0	43.53
Control	25.00	19.08	25.00	50.00	50.00	50.00	100.0	76.33	100.0	100.0	100.0	100.0	–	–	–	–	–	–
SEM	2.548**	1.663**	1.463**	2.716**	1.398**	1.271**	10.193**	6.653**	5.853**	5.433**	2.797**	2.543**	13.63*	8.29*	7.195**	7.344**	4.067**	4.399**
CD at 5%	8.027	5.239	4.610	8.557	4.406	4.006	32.110	20.958	18.440	17.115	8.812	8.013	44.44	27.04	23.45	23.92	13.25	14.33

mean wt. = 0.358 g/larva; MLAC= Mean Leaf Area Consumed; significant*; highly significant**; HAE- hours after exposure

Table 2. Dosage-mortality response of ethiprole 40 + imidacloprid 40 against *S. obliqua* - leaf dip method

Age and Mean Weight of insect	Duration of exposure	LC values in % LC_{30}	LC_{50}	LC_{90}	Chi Square	Regression Equation Y= a+bx	Fiducial Limits at LC_{50} Lower	Upper
14d old larvae	4 DAF	0.3817	0.6283	2.1427	2.4081	Y = 3.408 + 0.408x	0.4689	1.0944
(0.358 g/larva)	5 DAF	0.3338	0.5636	2.0457	4.9562	Y = 3.558 + 0.402x	0.4125	0.9276
	2.5 DAF(60HAF)	0.5886	1.0181	3.9225	1.5357	Y = 3.117 + 0.363x	0.6830	6.2402
9d old larvae	3 DAF (72HAF)	0.4358	0.8022	3.6023	2.9241	Y = 3.459 + 0.343x	0.5535	3.0757
(0.0792 g/larva)	3.5 DAF (84HAF)	0.3674	0.6066	2.0828	1.6933	Y = 3.43 + 0.412x	0.4515	1.0285
	4 DAF (96HAF)	0.2798	0.4647	1.6207	1.4938	Y = 3.694 + 0.416x	0.3299	0.6675
	5 DAF (120HAF)	0.2091	0.3341	1.0581	0.8414	Y = 3.942 + 0.452x	0.2151	0.4420

DAF = Days After Feeding, HAF = Hours After Feeding

Against 5d old larvae, there was no toxicity up to 2 DAF, with mortality ranging from 0 to 40% at 3DAF, with maximum mortality (63.3%) being at 4 DAF with 0.499%; and at the two successive lower concentrations, the mortality was 50% (0.332% conc.) and 40% (0.166% conc.), and there was no mortality at 0.002% up to 4 DAF. Thus it can be concluded that Glamore 80WG did not possess good contact and stomach insecticidal activity, as reflected in the leaf dip method.

Duration- mortality response: Ethiprole 40 + imidacloprid 40 at a concentration of 0.833% caused 30, 50 and 90% mortality with 9d old larvae in 32.25, 51.08 and 158.44 h; at a lower concentration (0.666%), the same level of mortality required more time i.e. 54.90, 81.90 and 219.26 h; at a still lower concentration (0.499%) the time required for the same response was still higher i.e. 67.05, 96.85 and 239.42 h, respectively. It is clear that the median lethal time (LT) values decreased with increase in concentration of toxicant. Thus the present study revealed that *S.obliqua* larvae require higher concentration and the toxicant takes relatively more time to effect the mortality (Table 3).

The contact and stomach toxicity data reveal that a higher concentration is required for control of *S. obliqua* (higher LC value), and also an extremely longer duration to cause 50% mortality (higher LT value). Nevertheless, it is quite effective in reducing the feeding (>75%) beyond a concentration of 0.33% within 12 h and with a reduction in mean larval weight. Thus ethiprole 40+ imidacloprid 40 appears to possess only a lower level of contact and stomach toxicity against the grown up (14d old) larvae of *S. obliqua* as revealed through leaf dip method bioassay.

Atomization method bioassay

Dosage-mortality response: The results reveal that ethiprole 40+ imidacloprid 40 did not appear to posses high contact toxicity against second and third instar larvae (Table 4, 5). However, a low level of contact toxicity was observed as seen in figure, where the lowest concentration (0.166%) caused a maximum of 43.3% mortality at 7DAE [the surviving larvae had a little lower mean larval weight (0.526g) than control (0.651g)], and the highest concentration (0.833%) resulted in 100% mortality at 7DAE. Against 5d old larvae also same pattern was observed (3.3% mortality at 0.002% and 73.3 % mortality at 0.499% at 4DAE). The LC_{50} values against 9d old larvae at 3, 4 and 5DAE were 0.466, 0.369 and 0.324%, respectively; and against 5d old larvae were 0.293 and 0.130% at 3 and 4DAE, respectively. Thus 3.5x increase in mean larval weight (0.021 to 0.076 g) resulted in 1.5x increase in LC_{50} value at 3DAE and a 2.8x increase in LC_{50} value at 4DAE. At LC_{30}, 3DAE, the

Table 3. Duration-mortality response of ethiprole 40+ imidachloprid against (9 day old larvae) of *S.obliqua*-leaf dip method

Conc. % (ppm)	LT values in hr LT_{30}	LT_{50}	LT_{90}	Chi square	Regression equation Y=a+bx	Fiducial limit at LT_{50} Lower	Upper
0.833 (8330)	32.2549	51.0854	158.4415	1.9984	Y = 4.2136 + 0.2614x	35.7061	63.6147
0.666 (6660)	54.9043	81.9094	219.2659	3.6489	Y = 3.5807 + 0.2851x	67.5636	101.7471
0.499 (4990)	67.0565	96.8541	239.4249	1.7195	Y =3.2736 + 0.2973x	81.4565	123.6789

Mean wt. 0.0792 g/larva

Table 4. Dosage-mortality response of ethiprole 40+ imidachloprid against *S.obliqua*- atomization method

Age and mean weight of insect	DAE	LC values in %		Chi square	Regression equation Y=a+bx	Fiducial limit at LC_{50}	
		LC_{30}	LC_{50}			Lower	Upper
9d old larvae	3	0.2649	0.4660	0.6196	Y = 3.832 + 0.368x	0.3644	0.6041
(0.0769 g/larva)	4	0.2076	0.3698	1.2543	Y = 4.039 + 0.369x	0.2721	0.4686
	5	0.1808	0.3242	1.3148	Y = 4.152 + 0.37x	0.2264	0.4118
5d old larvae	3	0.0672	0.2932	0.6443	Y = 2.665 + 0.637x	0.1414	0.6079
(0.0217 g/larva)	4	0.0336	0.1302	0.9863	Y = 2.665 + 0.637x	0.0703	0.2409

DAE- days after exposure

Table 5. Duration-mortality response of ethiprole 40+ imidachloprid (9 day old larvae) of *S.obliqua*- atomization method

Conc. % (ppm)	LT values in days			Chi square	Regression equation	Fiducial limit at LT_{50}	
	LT_{30}	LT_{50}	LT_{90}		Y=a+bx	Lower	Upper
0.499 (4990)	2.0001	3.5164	14.1014	1.2556	Y = 3.8243 + 0.2843x	2.8516	4.3154
0.332 (3320)	2.6398	4.6947	19.3677	0.3975	Y = 3.6014 + 0.2757x	3.8443	6.1181

Mean wt. = 0.0769 g/larva

increase in LC value from 5d old to 9d old larvae was 3.94x and at 4DAE it was 6.17x. These indicated that with increase in larval weight and days after exposure, there is increase in LC value.

Duration-mortality response: The duration-mortality response observed against 9d old larvae at 0.499 and 0.332% revealed the following- at 0.499%, 2.0 days were required to cause 30% mortality, which increased to 3.51 days for 50% mortality and 14.10 days for 90% mortality; at the lower concentration of 0.332%, the respective values were 2.63, 4.69 and 19.36 days. The LT values, further proved that ethiprole 40+ imidacloprid 40 has only a low level of contact toxicity.

Topical method bioassay

The *S.obliqua* larvae neither showed morbidity nor mortality upto 4DAE with the five doses evaluated (4.15 -20.82µg/larva). There was not enough contact toxicity, and the larvae were however robust (mean wt.=0.324g/larva). The very high doses evaluated indicates that either there exists development of tolerance or there is lack of contact toxicity.

There is no previous literature on the bioassays for evaluation of toxicity of ethiprole+ imidacloprid against *S.obliqua.* However, Sharma and Srivastava (2009) observed it to be effective against rice whorl maggot and leaf folder in Himachal Pradesh. Lakshmi *et al.* (2010) observed that ethiprole+ imidacloprid exhibited initial and persistent toxicity against BPH (*Nilaparvata lugens*), WBPH (*Sogatella furcifera*) and GLH (*Nephotettix virescens*) but was also highly toxic to natural enemies in Godavari delta of Andhra Pradesh. Its higher dose @125g a.i./ha) revealed 41.20 and 58.13% reduction in predatory spiders and 35.74 and 56.21% reduction in mirid bugs by Kumar *et al.* (2010) at Coimbatore. Prasad and Gupta (2011) observed that at 100g a.i./ha it was superior against rice yellow stem borer (*Scirpophaga incertulas*) in deep water rice in Uttar Pradesh.

Efficacy of imidacloprid40+ethiprole40, when evaluated by Bhanu and Reddy (2012) against BPH and WBPH @50, 75 and 100g a.i./ha revealed that all the dosages recorded more than 98% reduction in population of both BPH and WBPH over control. The present findings with LC_{50} value of 0.464 and 0.628% at 4DAF against 9 and 14d old larvae of *S.obliqua*, and feeding inhibition of 84.0 and 43.5% at the concentration of 0.666 and 0.166% in comparison of control at 74HAE reveal the efficacy of sublethal concentrations on the feeding.

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EFFECT OF SILICA ON YELLOW STEM BORER IN RICE

SEEMA TRIPATHY* AND L. K. RATH

Department of Entomology, College of Agriculture
Orissa University of Agriculture and Technology, Bhubaneswar 751003
**Email: seematripathy2@gmail.com (corresponding author)*

ABSTRACT

The study on influence of Si applied in forms of fertilizer formulations against yellow stem borer, *Scirpophaga incertulas* Walker infesting rice through field experiment was carried out at Central Research Farm, Department of Entomology, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar during *kharif*, 2014. It was observed that foliar application of orthosilicic acid @4 ml/ l applied at 20, 35, 50 and 65 days after transplanting (DAT) was the best treatment in reducing deadheart and white ear head incidence and increased the grain yield. Higher uptake of silica established a negative correlation with stem borer incidence, whereas, the same produced a significant and positive correlation with grain yield.

Key words: Yellow stem borer, dead heart, white ear head, grain yield, orthosilicic acid, fertiliser formulation, foliar spray

Rice is attacked by 20 major pests in India (Pathak and Khan, 1994) and yellow stem borer is one of the key pests that cause nearly 40-60% yield loss (Jayaraj and Muthukrishnan, 2013). Even though a lot of chemicals are available to combat this pest, yet, satisfactory control has not yet been achieved, and rather indiscriminate use of pesticides resulted in erosion in environmental quality. Induction of plant resistance through application of certain macro and micro nutrients in rice ecosystem has proved to be effective for management of stem borers. Silicon in particular has been studied to impart a fair degree of resistance in rice against stem borers. Panda et al. (1977) and Ranganathan et al. (2006) studied the effect of silicon in controlling yellow stem borer in rice. Therefore, an attempt was made to evaluate the field efficacy of certain silicon fertilizers in rice against yellow stem borer.

MATERIALS AND METHODS

A rice variety Swarna (135 days) was transplanted in the field of Central Research Farm, Department of Entomology, Orissa University of Agriculture and Technology, during 2014, with all recommended agronomic practices. Different formulations of silicon fertilizers were applied both as basal and foliar sprays on different dates on rice. A total of nine treatments including a control were taken in a R.B.D. with three replications each (Table 1). Silicon was applied as foliar spray in the form of orthosilicic acid four times at 20, 35, 50 and 65 days after transplanting (DAT) and calcium silicate, fly ash and steel slag each were applied as basal soil application.

Observations on yellow stem borer in terms of deadheart were recorded at weekly interval starting from 15 DAT and white ear head at 7 days before harvesting. The plant sample at maximum deadheart and white ear head stages were collected and analysis of silica uptake by the plant was determined in the laboratory of ICAR-National Rice Research Institute, Cuttack as per the method suggested by Wei-min et al. (2005). The grain yield was computed from each subplot and converted to q/ha. All the data were subjected to statistical analysis as per the method suggested by Gomez and Gomez (1984) with necessary transformation wherever required. The correlation between silica uptake at maximum dead heart stage, white earhead stage and grain yield were also worked out as suggested by Gomez and Gomez (1984).

RESULTS AND DISSUSSION

Effect of silicon on yellow stem borer

Incidence (deadheart): The data in Table 1 reveal that there was no significant difference between the treatments up to 29 DAT, as far as the incidence was concerned. However, significant differences between

Table 1. Effect of silicon on the incidence of yellow stem borer in rice

Treatments	Incidence of deadheart (%) at							Mean dead heart (%)	Mean white earhead (%)
	15 DAT	22 DAT	29 DAT	36 DAT	43 DAT	50 DAT	57 DAT		
T_1: Orthosilicic acid @ 2ml/l	0.00(0.71)	0.33(0.88)	0.41(0.91)	1.92(1.54)	4.07(2.13)	3.61(2.03)	2.31(1.68)	1.81(1.41)	4.05(2.13)
T_2: Orthosilicic acid @ 4ml/l	0.00(0.71)	0.75(1.09)	0.83(1.12)	1.47(1.39)	3.05(1.87)	2.88(1.84)	1.60(1.44)	1.51(1.35)	3.33(1.95)
T_3: Calcium silicate @ 0.5t/ha	0.00(0.71)	0.38(0.90)	0.37(0.90)	2.11(1.62)	4.58(2.25)	3.26(1.93)	2.41(1.70)	1.87(1.43)	4.52(2.24)
T_4: Calcium silicate @ 1t/ha	0.00(0.71)	0.78(1.10)	1.10(1.27)	1.91(1.54)	4.43(2.21)	2.83(1.82)	2.12(1.61)	1.88(1.46)	4.21(2.15)
T_5: Fly ash @ 250kg/ha	0.00(0.71)	1.05(1.24)	1.12(1.27)	2.70(1.78)	3.95(2.10)	3.06(1.88)	2.39(1.70)	2.04(1.52)	5.82(2.49)
T_6: Fly ash @ 500kg/ha	0.00(0.71)	1.03(1.23)	0.75(1.09)	2.55(1.74)	3.69(2.04)	3.33(1.92)	2.00(1.57)	1.91(1.47)	4.82(2.28)
T_7: Steel slag @ 250kg/ha	0.00(0.71)	0.33(0.88)	0.74(1.08)	3.15(1.91)	4.43(2.22)	3.79(2.07)	3.32(1.95)	2.25(1.54)	7.46(2.81)
T_8: Steel slag @ 500kg/ha	0.00(0.71)	0.86(1.13)	1.13(1.28)	2.61(1.76)	4.37(2.21)	3.38(1.96)	2.50(1.73)	2.12(1.55)	5.28(2.39)
T_9: Control	0.00(0.71)	1.81(1.52)	2.79(1.76)	7.69(2.89)	10.48(3.3)	7.56(2.83)	4.71(2.27)	5.00(2.18)	11.44(3.45)
SE_m(±)C.D.(0.05)CV(%)	0.00NS-	0.16NS-	0.17NS-	0.100.309.80	0.100.297.48	0.130.3911.11	0.090.289.31	—-	0.180.546.44

Figures in parentheses $\sqrt{x + 0.5}$ transformed values

the treatments with respect to deadhearts were observed from 36 DAT onwards. At 36 DAT, the control treatment showed 7.69% deadhearts while T_2 produced only 1.47 % deadhearts, remaining at par with T_1, T_4 and T_3 treatments, respectively. A similar trend more or less existed for rest of the observation period. As regards to mean performance, it was observed that treatment T_2 was the best with only 1.15% deadhearts as against 5.0% in untreated control.

Incidence (white earhead); The data on white ear head at 113 DAT (Table 1) reveal that the treatment T_2 was the best with the least white earheads (3.3%) which remained at par with most of the other silicon treatments excluding T_7 (7.46% white earhead), whereas, untreated control showed11.44% white ear head.

It was observed that irrespective of the treatments, the mean number of deadhearts and white earheads were even less than half the value of these parameters in untreated control. In various silicon treatments, production of less deadhearts and white earheads might be attributed to failure of neonate larvae to penetrate the leaf sheath and stem due to higher silica deposition. Bandong and Litsinger (2005) also studied excessive stem hardening in rice due to silica mediated lignin and cellulose deposition on leaf sheath cell, which caused less penetration. Chandramani et al. (2010) also suggested that reduction in stem borer incidence in rice was caused due to wearing of mandibles of early larval instars which might have prevented further penetration to cause deadhearts and white earheads. The present findings derive supported from these.

Silicon uptake and grain yield

The data on amount of silicon taken by rice plants in various treatments at maximum deadheart (43 DAT) and white ear head stage (113 DAT) are presented in Table 2. These observations reveal that the plants in T_2 contained 15.30 % silica followed by T_4 (15.10%) and T_1 and T_3, each with 15% silicon content. At this stage a corresponding value for untreated control was also 11.20%. Silicon content at white ear head stage (113 DAT) was found to be maximum in T_2 (15.50 %) which was significantly different from rest of the treatments. The treatment T_1 and T_4 retained each of 13.50% silica, whereas, control treatment had least amount of silicon (10.20%).

These indicate that when silica was applied, the plants absorbed silicon. Orthosilicic acid being a source of well available silicon to rice plants might have caused higher mobility into plant system as compared to other form of fertilizers. Ma and Takahashi (2002) stated that rice was a good silicon accumulator and responded to available form of silicon and when silica level in paddy straw was below 11% the plants could accumulate more silica. Thus, treated rice plants accumulated more silica than the untreated plants in the present findings.

Table 2. Silica uptake in rice infested by yellow stem borer vs. grain yield

Treatments	Silica uptake (%)		
	Maximum deadheart – 43DAT	Maximum White earhead- 113 DAT	Grain yield (q/ha)
T_1: Orthosilicic acid @ 2ml/l	15.00 (3.94)	13.50 (3.74)	39.37
T_2: Orthosilicic acid @ 4ml/l	15.30 (3.97)	15.50 (4.00)	45.08
T_3: Calcium silicate @ 0.5t/ha	15.00 (3.94)	12.20 (3.56)	32.54
T_4: Calcium silicate @ 1t/ha	15.10 (3.95)	13.50 (3.74)	37.78
T_5: Fly ash @ 250kg/ha	12.30 (3.58)	10.50 (3.32)	28.89
T_6: Fly ash @ 500kg/ha	13.60 (3.75)	10.60 (3.33)	31.43
T_7: Steel slag @ 250kg/ha	14.00 (3.81)	10.70 (3.35)	31.43
T_8: Steel slag @ 500kg/ha	14.00 (3.81)	11.90 (3.52)	32.06
T_9: Control	11.20 (3.42)	10.20 (3.27)	23.97
SE_m(±)CD(0.05)CV(%)	0.050.162.46	0.040.121.92	3.219.6116.53

Figures in parentheses $\sqrt{x + 0.5}$ transformed values

Effect of silica on rice grain yield

The data on grain yield (Table 2) revealed that highest yield of 45.08 q/ha was obtained with treatment T_2 which was statistically at par with T_1 (39.37 q/ha) and T_4 (37.78 q/ha). The treatment T_3 (32.54 q/ha) was at par with T_8 (32.06 q/ha) and T_6 (31.43 q/ha) and rest of the treatments. However, the control treatment (T_9) registered the lowest grain yield of 23.97 q/ ha. Kornodorfer and Lepsch (2001) also observed higher grain yield in rice due to silicon application. Higher grain yield in rice due to silica fertilization also has been observed by Fallah et al. (2014) and Kasturi Thilagam et al. (2014), and the present findings are also in line with these.

Correlation between silicon content and other parameters

The data on correlation studies between silicon content *vs* deadheart and white earhead is presented in Table 3. The silicon content in plants was found to be negatively and significantly correlated to deadheart (r = -0.72*) and white earhead (r = -0.69*), whereas, it was found to be significantly and positively correlated to grain yield (r = -0.95**).

Table 3. Correlation coefficients - silica content, infestation parameters and grain yield

S. No.	Silica content (%) vs	Correlation coefficient (r)
1	Deadheart (maximum DH stage)	-0.72*
2	White ear head (maximum WEH stage)	-0.69*
3	Grain yield	0.95**

* Significant at p=0.05; ** Significant at p=0.01

It is highlighted in the present findings that the increase in silicon level was positively correlated with grain yield, and as discussed it was negatively correlated with deadhearts and white earheads.

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POPULATION DYNAMICS OF INSECT PESTS OF PIGEONPEA IN SOUTH GUJARAT

R. M. JALONDHARA AND D. R. PATEL*

Department of Entomology, N.M. College of Agriculture,
Navsari Agricultural University, Navsari 396450
**Email: Patel.devendra2829@yahoo.com*

ABSTRACT

The field experiment on the population dynamics of pigeonpea pests carried out at the College Farm, N. M. College of Agriculture, N.A.U., Navsari during *kharif* 2014-15 brought out the correlation between various weather parameters and insect pests. These indicated that maximum temperature exhibited significant positive influence on the incidence of cow bug, pod bug, blue butterfly, plume moth and pod borer. Minimum temperature exhibited significant negative impact on plume moth and pod fly and significant positive impact on mite and blister beetle. Average temperature exhibited significant positive influence on cow bug, blister beetle, blue butterfly and pod borer and negative influence on pod fly population. Morning, evening and average relative humidity exhibited positive relationship with mite and leaf folder population, while, it was significantly negative with plume moth, pod borer and pod fly populations.

Key words: Pigeonpea, aphid, cow bug, pod bug, blue butterfly, plume moth, pod borer, pod fly, mite, leaf folder, blister beetle, correlation coefficients, weather factors

Pigeonpea [*Cajanus cajan* (L.) Millsp.] also known as red gram or tur is grown all over the country, but extensively cultivated in Maharashtra, Karnataka, Madhya Pradesh, Uttar Pradesh, Andhra Pradesh, Odisha, Bihar, Tamil Nadu, and Gujarat. Among the factors responsible for low yield, the damage caused by insect pests is one of the major factors in pigeonpea. The weather factors prevailing in a region play an important role in the occurrence and subsequent buildup of pest population. The present study evaluates these through correlations between pest population and weather factors.

MATERIALS AND METHODS

The field experiment was carried out at the College Farm, N. M. College of Agriculture, N. A. U., Navsari during *Kharif* 2014-15. Pigeonpea cultivar, Vaishali was sown on 17th July, 2014 with spacing 90 x 20cm. For recording pest populations, the crop area was divided in to 10 quadrats and 5 plants were randomly selected from each quadrat. Observations were recorded at weekly interval starting from second week after sowing till harvesting. Observations on sucking pests *viz.* cow bug, pod bug, aphid nymph and adults were made by counting on whole plant basis by visual search method on five plants/ spot. The mite population was recorded from three trifoliate leaves/ plant, one from top, middle and bottom position. For recording leaf folder, number of larvae was counted by opening the webbed leaves on the plant on five plants/spot. For *Helicoverpa armigera*, and blue butterfly number of larvae were counted by visual search method (on whole plant basis) on five plants/per spot. Fifty pods were randomly collected from the field (not more than 5 pods/plant) and examined for damage due to tur plume moth and pod fly. Number of pods damaged due to plume moth larva was ascertained by small dirty hole between two grain on pod indicated damage due to plume moth larvae and pod fly damage could be detected by presence of maggot or pupa tunneled grain by splitting the pods. Blister beetles were counted as number of adults on five plants. Data obtained on the incidence of insect pests and weather factors were statistically analyzed and simple correlation coefficients computed.

RESULTS AND DISCUSSION

The population of aphid, *Aphis craccivora* was observed on pigeonpea from 33rd meteorological week (MW) to 37th meteorological week (MW). The population ranged from 0.06 to 1.06 aphids/ plant with peak incidence being 1.06 aphids/ plant at 34th MW. The incidence of mite, *Tetranynchus urticae* was noticed between 34th MW to 46th MW, with population ranging between 0.62 to 5.58 mites/ leaf, with peak activity being at 40th MW. The cow bug, *Oxyrachis tarandus* was observed from 42nd MW to 47th MW

and it was 0.86 to 2.18 bugs/ plant with peak incidence during 45th MW. The pod bug, *Clavigralla gibbosa* was observed between 43rd MW to 49th MW, with population being between 1.12 and 6.54 pod bugs/plant with peak incidence at 47th MW.

The leaf folder, *Anticarsia irrorata* was observed between 34th MW to 42th MW and its population remained between 0.14 to 5.44 larvae/plant with peak incidence at 37th MW (5.44 larvae/plant). The blister beetle, *Mylabris pustulata* occurred from 39th MW to 46th MW, and its population was between 1.24 and 3.88 beetles/plant with peak observed during 43th MW. The lepidopteran pest, blue butterfly, *Lampides boeticus* was observed between 43rd MW to 48th MW with peak incidence being at 47th MW (1.34 larvae/plant). The % pod damage by plume moth, *Exelastis atomosa* ranged between 4.38 to 10.74% from 43rd MW to 6th MW with peak being on 48th MW (10.74%). The population of *Helicoverpa* appeared from 43rd MW to 6th MW, with its larval population being 0.80 to 15.38 larvae/ plant. The damage by pod fly, *Melanagromyza obtusa* appeared in 43rd MW and then gradually increased and maximum infestation (80.82%) found during 6th MW.

Correlation coefficients between weather factors and incidence of insect pests given in Table 1 and 2 reveal that the aphid population was significantly positively correlated with evening relative humidity (r= 0.434), wind velocity (r= 0.608) and rainfall (r= 0.673); while, it was significantly negative with sunshine hours (r=-0.474). This is in contrast with Pandey and Das (2014), who observed significant negative impact of evening relative humidity and wind speed on population. The multiple regression equation predicted for aphid was Y= -0.3058 -6.5842 ERH +0.0357 WV + 0.0273 SSH + 0.0016 RF (R^2= 0.4731).

Results revealed that the population of mite was significantly positively correlated with minimum temperature (r=0.636) morning relative humidity (r= 0.709), evening (r= 0.761) and average relative humidity (r=0.784), wind velocity (r= 0.401); whereas, sunshine hour had significant negative correlation (r= -0.660). The multiple regression equation obtained was Y= -4.4919 – 0.0070 Min TEMP.+ -6.6641MRH – 6.5927 ERH + 13.3563 ARH–0.1777 WV – 0.1103 SSH (R^2= 0.5807).

The correlation between cow bug incidence and maximum (r= 0.538) and average temperature (r= 0.482) were positive and significant. The multiple regression equation predicted was Y= -3.7148 + 0.0820 Max Temp. +0.0526 Avg Temp. (R^2= 0.2686). Significant positive correlation was observed between pod bug population and maximum temperature (r= 0.512). Veda (1993) reported that the rainfall and temperature played a key role in multiplication of the pod bug. The multiple regression equation predicted for pod bug was Y= -8.9890 + 0.3074 Max TEMP. (R^2= 0.2613).

The correlation between leaf folder population and evening (r=0.488), average relative humidity (r= 0.474) and wind velocity(r=0.494) were positive and

Table 1. Correlation coefficients of pigeonpea insect pests vs. weather parameters

Insect	Maximum Temperature	Minimum Temperature	Average Temperature	Morning RH	Evening RH	Average RH	Wind velocity (Km/Hr.)	Sunshine hours	Rainfall
Aphid	-0.281	0.286	0.081	0.158	0.434*	0.376	0.608**	-0.474*	0.673**
Mite	-0.337	0.636**	0.332	0.709**	0.761**	0.784**	0.401*	-0.660**	0.355
Cow bug	0.538**	0.253	0.482*	0.023	-0.160	-0.115	-0.198	0.269	-0.283
Pod bug	0.512**	0.058	0.313	-0.092	-0.301	-0.256	-0.240	0.326	-0.280
Leaf folder	-0.326	0.389	0.141	0.354	0.488*	0.474*	0.494*	-0.446*	0.178
Blister beetle	0.173	0.417*	0.423*	0.386	0.268	0.315	-0.073	-0.099	0.030
Blue butterfly	0.591**	0.178	0.450*	-0.030	-0.257	-0.205	-0.244	0.302	-0.301
Plume moth	0.693**	-0.478*	-0.020	-0.571	-0.837**	-0.802**	-0.672**	0.830**	-0.646**
Pod borer	0.825**	-0.029	0.407*	-0.234	-0.565**	-0.498**	-0.528**	0.624**	-0.482*
Pod fly	-0.079	-0.965**	-0.811**	-0.774**	-0.751**	-0.795**	-0.447*	0.606**	-0.480*

*Significance at p=0.05; **Significance at p=0.01

Table 2. Correlation coefficients of pigeonpea insect pests vs. weather factors

Insect pests	A value	Temperature ^{0}c			Humidity%			Wind velocity	Sunshine hours	Rainfall	R^2 value
		Maximum	Minimum	Average	Morning	Evening	Average				
Aphid	-0.3058	-	-	-	-	-6.5842		0.0357	0.0273	0.0016	0.4731
Mite	-4.4919	-	-0.0070	-	-6.6641	-6.5927	13.3563	-0.1777	-0.1103	-	0.5807
Cow bug	-3.7148	0.0820	-	0.0526	-	-	-	-	-	-	0.2686
Pod bug	-8.9880	0.3074	-	-	-	-	-	-	-	-	0.2613
Leaf folder	-2.9025		0.0213		-	-0.0032	0.0293	0.1665	0.0617	-	0.1155
Blister beetle	-2.7728	-	0.0509	0.0899	-	-	-	-	-	-	0.1199
Blue butterfly	-2.9113	0.0791	-	0.0233	-	-	-	-	-	-	0.3072
Plume moth	-20.5103	1.2412	-0.5619	-	6.0893	5.9534	-12.0757	0.3471	-0.6812	-0.0047	0.7434
Pod borer	-41.8695	2.0755	-	-0.4960	-	-0.2280	0.1535	0.5250	-1.1692	-0.0094	0.6461
Pod fly	180.1699	-	-1.1369	-5.1174	-29.2486	-29.4883	58.5429	-0.6341	2.3275	-0.0178	0.9167

significant, while for sunshine hours (r= -0.446) it was negative and significant. Similar observations had been reported by Akhilesh Kumar and Paras Nath (2005), who observed that relative humidity had significant positive impact on leaf folder. The multiple regression equation was predicted for leaf folder was Y= - 2.9025 -0.0213 Min TEMP. – 0.0032 ERH + 0.0293 ARH+ 0.1665 WV +0.0617 SSH (R^2= 0.1155).]

The results revealed that minimum (r= 0.417) and average temperature (r= 0.423) showed significant positive correlation with blister beetle population; according to Akhilesh Kumar and Paras Nath (2005) temperature and sunshine hours had non-significant negative impact. The multiple regression equation was predicted for blister beetle was Y= -2.7728 +0.0509 Min Temp. + 0.0899 Avg Temp (R^2= 0.1199).

A positive and significant correlation was observed between blue butterfly population and maximum temperature (r= 0.591) and average temperature (r=0.450). The multiple regression equation was predicted for blue butterfly was Y= -2.9113 + 0.0791 Max TEMP. + 0.0233 Avg Temp. (R^2= 0.3072). As regards plume moth population, with maximum temperature (r= 0.693) and sunshine hours (r= 0.830) relationships were significant and positive; it was significant negative correlation with minimum temperature, evening and average relative humidity, wind velocity and rainfall. Jha (2003) observed that maximum, minimum and mean temperature and wind speed had a negative correlation with *E. atomosa*. The multiple regression equation fitted for plume moth was Y= -20.5103 + 1.2412 Max TEMP. – 0.5619 Min TEMP. + 6.0893 MRH+ 5.9534 ERH– 12.0757 ARH + 0.3471 WV – 0.6812 SSH -0.0047 RF (R^2= 0.7434).

There existed a correlation between pod borer population and maximum (r= 0.825), average temperature (r= 0.407) and sunshine hours (r= 0.624), and these were positive and significant; with evening (r= -0.565) and average relative humidity (r= -0.498), wind velocity (r= -0.528) and rainfall (r= -0.482), these were found negative and significant. Patel and Koshiya (1999) observed a negative correlation of *Helicoverpa* population with maximum and minimum temperature. Jha (2003) showed that correlation between mean relative humidity was significantly negative with larval abundance. Bisane et al. (2013) observed that larval incidence of *Helicoverpa* was significantly negatively correlated with minimum temperature and evening relative humidity. The multiple regression equation was predicted for pod borer was Y= -41.8695 + 2.0755 Max TEMP.– 0.4960 Avg TEMP. – 0.2280ERH + 0.1535 ARH +0.5250 WV – 1.1692 SSH – 0.0094 RF (R^2= 0.6461).

As regards pod fly, relation with minimum (r= -0.965), average temperature (r= -0.811), morning (r= -0.774), evening (r= -0.751) and average relative humidity (r= -0.795), wind velocity (r= -0.447) and rainfall (r= -0.480) were negative and significant; but positive correlation was observed with sunshine hours (r= 0.606). Subharani and Singh (2009) observed a significant negative correlation between pod fly and morning and evening relative humidity, and it is in agreement with current observations. The multiple regression equation was predicted for pod fly was Y= 180.1699 – 1.1369 Min TEMP. – 5.1154 Avg Temp. - 29.2486 MRH – 29.4883 ERH + 58.5429 ARH– 0.6341 WV + 2.3275 SSH - 0.0178 RF (R^2= 0.9167)

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MORPHOMETRIC ANALYSIS OF OXYOPID SPIDERS (ARANEAE: OXYOPIDAE) FROM KARNATAKA

RAMAKRISHNAIAH, T. N., SREERAMULU ARUNKUMAR, S. RAMAKRISHNA AND JAYAPRAKASH

Centre for Applied Genetics, Department of Zoology
Bangalore University, Bengaluru 560056
**Email: ramakrishnaiahtn@gmail.com (corresponding author)*

ABSTRACT

The current study highlights the morphometry of Oxyopidae (Lynx spiders) viz., *Oxyopes lineatipes, Oxyopes javanus, Oxyopes shweta, Oxyopes sunandae* and *Peucelia viridana,* collected from different geographical locations of Karnataka. The morphometry of prosoma, opisthosoma, chelicerae, palp, spinnerets and legs were carried out. Principal Component Analysis (PCA) was performed for eight variables using a correlation matrix and varimax rotation, single principal components with eigen values (11.84) were extracted. Principal Component Analysis was found to have variation among the variables. The first Principal component accounts for 99% of the total variance followed by the second PCA.

Key words: Karnataka, Spiders, Oxyopidae, Morphomtery, PCA, prosoma, opisthosoma, chelicerae, palp, spinnerets, legs

Arachnids constitute the second largest class representing 7% of known arthropods and it is estimated that 8.3% of arthropods are arachnids (Coddington and Levi, 1991). Spiders are the most diverse and abundant invertebrate predators in the terrestrial ecosystems (Specht and Dondale, 1960). Order Araneae is subdivided into the ancient Mesothelae (segmented abdomen) and the derived Opisthothelae (unsegmented body). Opisthothelae can be subdivided into two lines, the paraphyletic Mygalomorphae and all the "true" spiders, the Araneomorphae. About 46,000 species of spiders belonging to 114 families and 3935 genera are described as of now (World Spider Catalog, 2016), of which from India, about 1520 species under 377 genera and 60 families are known (Sebastian and Peter, 2009). Tikader (1982; 1987) published an inclusive list of Indian spiders with nearly 1067 species under 249 genera and 43 families. Siliwal et al. (2005) studied the families covering many species distributed in the Indian subcontinent.

Oxyopidae (Lynx spider) is represented by 9 genera 455 species, of which about 70 species under 4 genera viz., *Hamadruas* Deeleman-Reinhold, 2009; *Hamataliwa* Keyserling, 1887; *Oxyopes* Latreille, 1804; and *Peucetia* Thorell, 1869 had been reported from India (World Spider Catalog, 2016). In India, 46 species are known so far (Biswas and Roy, 2005; Gajbe, 2008; Bodkhe and Vankhede, 2012; World Spider Catalog, 2016).

Spiders are the important predators in most terrestrial habitats (Wise, 1993), and are the potential biological indicators and help in the natural control of harmful insects (Kremen et al. 1993). Generally the classification of spiders is based on morphometric characters which are mainly dependent on the structure of spinnerets, eye arrangements, chelicerae, tarsal claws and the labium. However, the reproductive organs are considered mainly for species identification (Heinemann and Uhl, 2000).

Morphometrics generally reveal the interrelationship between the various features such as total length of the body, legs spinnerets, and other body parts. It is a reliable technique for recognizing the degree of reproductive maturity without sacrificing the animals (Anandan, 1982). The morphometrics are especially used for differentiation of sex (Suthaharan, 1986). It is a technique that has been effectively applied and has been proven useful for delineating major clades and for potentially diagnosing species.

In the present study, an attempt has been made on the morphometrics of oxyopid spiders from Karnataka, focused on five species.

MATERIALS AND METHODS

Spiders were collected using ground/aerial hand collecting methods as given in Coddington et al. (1996) from few selected locations in Karnataka (Table 1).

Table 1. Habitat and distribution of five oxyopid spiders studied

Scientific name	Common name	Distribution	Location/ Coordinates	Habitat
Oxyopes lineatipes CL Koch 1847	Lined lynx spider	India, China, Philippines, Java and Sumatra	Antharagange, Kolar (13.1770° N, 78.2020° E)	Grass and low shrubs
Oxyopes javanus Thorell 1887	Striped lynx spider	India, China and Philippines	Athani, Belgaum (16.7269° N, 75.0641° E)	Grass and low shrubs
Oxyopes shweta Tikader 1970	White lynx spider	India and China	Davanagere (14.4663° N, 75.9238° E)	Grass and low shrubs
Oxyopes sunandae Tikader 1970	Orange lynx spider	India (endemic)	Dubare, Coorg (12.3375° N, 75.8069° E)	Grass and low shrubs
Peucetia viridana Stolickza 1869	Green lynx spider	India, Srilanka and Myanmar	Thuppadahalli, Bangalore (12.9716° N, 77.5946° E)	Grass and low shrubs

The web-building and free-living spiders on the foliage and stems of living or dead shrubs, tall herbs, tree trunks, etc were collected. The specimens were collected in perforated bottles and carried to the laboratory (Centre for Applied Genetics, Bangalore University, Bengaluru) photographed using Sony 12 megapixel digital camera. These were fixed in 40% ethyl alcohol and after some hours, transferred to flasks with 70% alcohol. Identification of species was accomplished based on morphological characters given in Sebastian and Peter (2009) and Tikader (1987). The morphometric measurements were carried out using the electronic digital Vernier calipers in mm scale and the data analyzed for mean ± standard deviation (n=10). Principal Component Analysis (PCA) analysis was performed using SPSS for Windows 08, Version 15.0.

RESULTS AND DISCUSSION

Five species viz., *Oxyopes lineatipes* (Fig. 1a), *Oxyopes javanus* (Fig. 1b), *Oxyopes shweta* (Fig. 1c), *Oxyopes sunandae* (Fig. 1d), *Peucetia viridana* (Fig. 1e) were collected from locations in Karnataka viz., Bangalore, Athani, Davanagere, Dubare and Chikkamagaluru. Seasonal variations in species and richness observed revealed that there is noteworthy increase in the species richness during September-December (2016) (Fig. 2). Measurements (all are in mm) and description of the morphometrics of the five species studied is given in Table 2.

Oxyopes lineatipes: The body length of female ranges from 14.14± 0.03, and have large and broad abdomen than males. The first and second pairs are more or less equal in length. The mean length and width of head is 5.4±0.02 and 4.2± 0.01, respectively, and that of abdomen is 8.2± 0.04 and 4.1± 0.02, respectively. First pair of legs is the largest (27.3± 0.01) and third pair the smallest (20.37±0.03) (Table 3).

O. javanus: The female body size ranges from 13.63± 0.05 mm. The first and second pairs are subequal in length. The mean length and width of prosoma is 5.2± 0.05 and 4.1±0.03, and that of abdomen 7.9±0.03 and 3.8±0.01, respectively. First pair of legs is the largest (25.8± 0.04) and the third pair is the smallest (18.2±0.05) (Table 3).

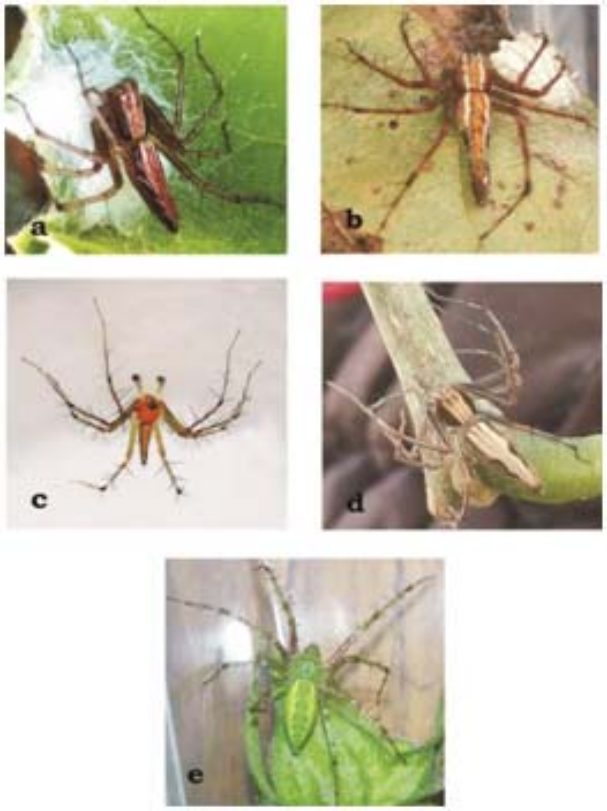

Fig 1. Species studied: a.*Oxyopes lineatipes*; b. *Oxyopes javanus*; c. *Oxyopes shweta* d.*Oxyopes sunandae*; and e. *Peucetia viridana*.

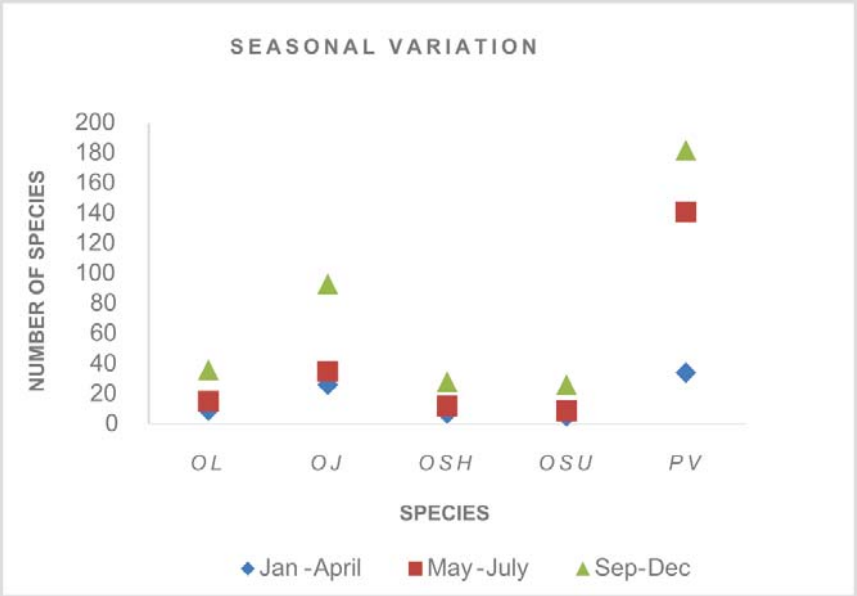

Fig. 2. Seasonal variations in species richness of oxyopids studied

Table 2. Morphological characteristics of oxyopid spiders studied

Parameters	*Oxyopes lineatipes*	*Oxyopes javanus*	*Oxyopes shweta*	*Oxyopes sunandae*	*Peucetia viridana*
Prosoma	Cephalothorax wide and reddish brown, thoracic region somewhat circular in outline.	longer than wide, middle regions whitish, lateral sides dark brown, posterior end with a median dark patch ventrum pale with a median broad dark brown patches	longer than wide, circular in outline. covered with white pubescence,	Wide, yellowish brown dorsum with two pairs of orange lines.	longer than wide, moderately high, with brown spots clothed with few spines, posterior row slightly procurved and situated in equal distance,
Palp	Tarsal region slightly blackish	Tarsal region black	Tarsal region of palp slightly blackish, anterior tip pointed.	Palpal tibia and tarsum with dorsal blackline	Tarsal region black and tapering
Opisthosoma	Larger than wide, mid dorsal area brownish, bordered on either side by a lateral white longitudinal band.	longer than wide, middle regions whitish, lateral sides dark brown, posterior end with a median dark patch ventrum pale with a median broad dark brown patches,	Longer than wide, tapering the posterior end, mid dorsal area brownish, bordered on eitherside by lateral white longitudinal band, lateral sides also with a narrow white line.	Longer than wide, tapering to posterior end, cardiac area reddish orange, bordered by yellowish bands each bearing the black spots, posterior end blackish	Abdomen long, narrowing behind, clothed with fine hairs, mid dorsally with a longitudinal deep brown line with lateral branches, ventrum with a broad conspicuous longitudinal chalk white band
Legs	Greenish brown, spiny,	ventral side of the legs with blackish row	Greenish-brown, spiny, retrolateral surface of the femora I-IV with a black line.	Greenish-brown, spiny retrolateral surface of femora I-IV with a blackish line.	Long and strong, clothed with conspicuous black spots and black long spines.
Epigynum	Complex	Complex	Complex	Complex	Complex

O. shweta: The female body length measures from 13.71± 0.01 mm, and males have large and broad abdomen than females. The first and second pairs are more or less equal in length. The mean length and width of head is 5.3± 0.02 and 5.2± 0.01 respectively, and that of abdomen 7.9± 0.03 and 3.8± 0.02, respectively. First pair of legs is the largest (26.3± 0.04) and the third pair is the smallest (19.37± 0.06) (Table 3).

O. sunandae: The body length measures 12.24± 0.05, with males having large and broad abdomen than females. The first and second pairs are more or less equal in length. The mean length and width of head is 4.5± .02 and 3.4± 0.02, and that of abdomen is 7.3± 0.04 and 3.2± 0.03, respectively. First pair of legs is the largest (23.8± 0.02) and the third pair is the smallest (15.39± 0.01) (Table 3).

Peucetia viridana: The body length of female ranges from 49.9± 0.01, and males have large and broad abdomen. The first and second pairs are more or less equal in length. The mean length and width of head is 11.8± 0.02 and 8.7± 0.01, and that of abdomen 37.1± 0.03 and 18.9± 0.01, respectively. First pair of legs is the largest (66.97± 0.03) and the third pair is the smallest (29.47± 0.05) (Table 3).

The data were tested for normal distribution: prosomal length, prosomal width, opisthosoma length and width. Principal Component Analysis using a correlation matrix and varimax rotation, single principal components with which eigen values were extracted (Table 4) [Kaiser-Meyer-Olkin measure of sampling Adequacy and Bartlett's test of sphericity (X^2=31.8, df=7, sig=0.00). Shannon Index and evenness ranges obtained are given in Fig. 3. A clear separation of the two morphs was possible along PC1 which explains 98% of the variance (Fig. 4).

Thus categorize the present study characterizes the phenotypes based on metric properties and typify

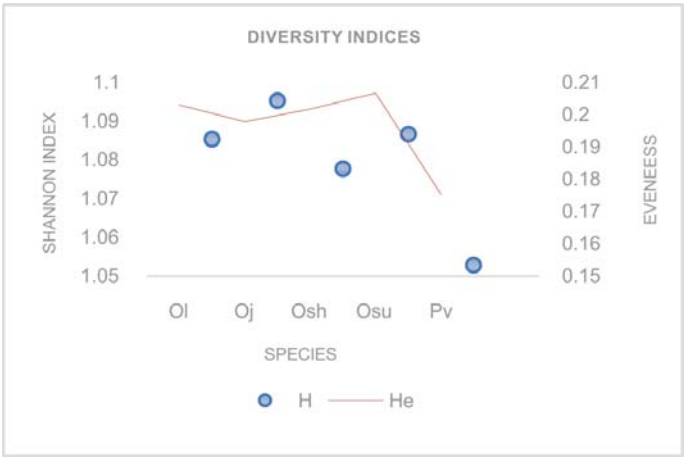

Fig. 3. Shannon index-H and Evenness-E_H for oxyopids studied

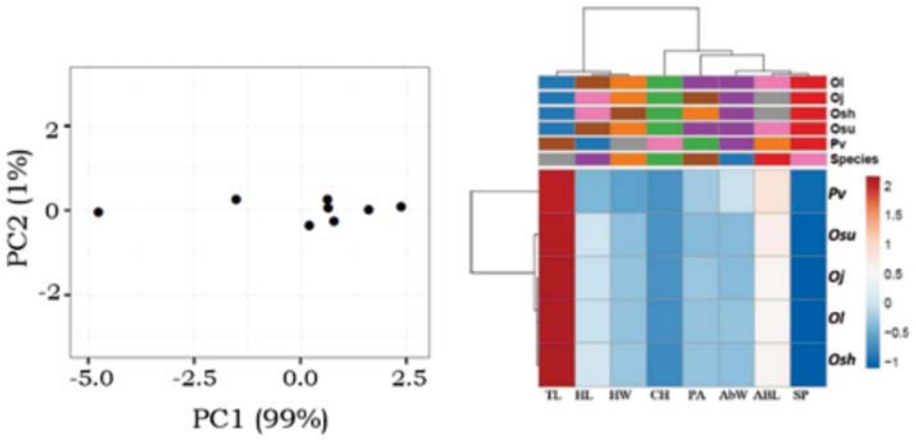

Fig. 4. Principal component analysis- morphological characters

Table 3. Morphometrics of oxyopid spiders studied (Mean ± Standard deviation)

Morphological characters	Character code	*Oxyopes lineatipes*	*Oxyopes javanus*	*Oxyopes shweta*	*Oxyopes sunandae*	*Peucetia viridana*
Prosoma Length	P L	5.4±0.02	5.2±0.05	5.3±0.02	4.5±0.02	11.8±0.02
Prosoma Width	PW	4.2±0.01	4.1±0.03	5.2±0.01	3.4±0.02	8.7±0.01
Chelicera	CH	2.2±0.02	2.3±0.01	2.1±0.01	1.9±0.01	6.3±0.02
Palp	PLP	4.1±0.03	4.3±0.02	4.1±0.03	3.2±0.03	16±0.03
Opisthoma Length	OL	8.2±0.04	7.9±0.03	7.9±0.03	7.3±0.04	37.1±0.03
Opisthoma Width	OW	4.1±0.02	3.8±0.01	3.8±0.02	3.2±0.03	18.9±0.01
Spinnerets	SPN	0.59±0.01	0.53±0.02	0.56±0.02	0.44±0.01	1.09±0.02
Total length	TL	14.14±0.03	13.63±0.05	13.71±0.01	12.24±0.05	49.9±0.01
Leg1	L1	27.3±0.01	25.8±.0.04	26.3±0.04	23.8±0.02	66.97±0.03
Leg2	L2	25.81±0.02	22.9±0.01	23.1±0.05	21.01±0.02	63.11±0.04
Leg3	L3	20.37±0.03	18.2±0.05	19.37±0.06	15.39±0.01	29.47±0.05
Leg4	L4	26.36±0.01	24.51±0.03	25.36±0.02	22.12±0.03	58.11±0.06

Table 4. Principal components-morphological characters through correlation matrix

Morphological characters	Character code	Components	
		PC1	PC2
Prosoma Length	PL	0.749	0.662
Prosoma Width	PW	0.629	0.770
Chelicera	CH	0.799	0.599
Palp	PLP	0.781	0.623
Opisthoma Length	OL	0.804	0.594
Opisthoma Width	OW	0.792	0.611
Spinnerets	SPN	0.636	0.768
Total length	TL	0.782	0.623
Leg1	L1	0.774	0.631
Leg2	L2	0.776	0.630
Leg3	L3	0.585	0.802
Leg4	L4	0.758	0.653
Eigen values	EV	11.84	0.122
% of variance	% Var	98.66	1.013
Cumulative %	% Cum	98.61	99.67

differences through measurement of the body and leg parts emphasizing on the size assessment. The major phenotypic variations observed in length of the total body, head, abdomen, chelicera, palp and spinnerets between the fives species studied brought out. In the perspective of understanding the mechanisms of evolution, its cause and consequences on the phenotypic variation is important (Miner et al. 2005).

Principal component analysis (PCA) method adopted herein is used as a dimension reducing technique (Foottit and Mackauer, 1990) for investigating the morphological variations (Manly, 1994). PCA is specifically designed to analyze a set of correlated variables without prior assumption of multiple groups and helps in minimum selection of the parameters for correct groupings (Humphries et al. 1981). Clustering is one of the foremost technique between the multivariate analyses (Kettenring, 2006). Cluster analysis method was used for the morphological characters obtained through standardized measurements. In addition to the cluster analysis, overall morphological characters were represented in the form of scatter plot based on PCA analysis to have view of general information between the processed samples as an initial analysis thorough ClustVis R version 3.2.2. (Metsalu and Vilo, 2015).

Morphometrics from five species presented show their importance in characterizing the spider species. The present study shows that, it is important to use interspecific variation during descriptions.

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FIELD EFFICACY, NON-TARGET TOXICITY AND ECONOMICS OF NOVEL SYSTEMIC MOLECULES AGAINST *LIPAPHIS ERYSIMI* AND ITS SEASONAL INCIDENCE IN MUSTARD

DEBASHIS ROY*, P. K. SARKAR AND SUKAMAL SARKAR**

*Department of Agricultural Entomology; **Department of Agronomy*
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, 741252, West Bengal
**Email: debashisroy915@gmail.com (corresponding author)*

ABSTRACT

Population of mustard aphid *Lipaphis erysimi* Kalt., was observed to buildup from mid December and attained peak after mid January irrespective of plant parts of rapeseed variety *Subinoy* during 2013-2014 and 2014-2015 at Instructional Farm, Jaguli, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal. Minimum temperature, relative humidity and dew point were observed to be positively correlated with population buildup; while, maximum temperature and rainfall showed a negative relationship. The field efficacy of azadirachtin 5% w/w, pyriproxyfen 10 EC, flonicamid 50 WG, acephate 75 SP, dimethoate 30 EC, chlorpyrifos 20 EC, imidacloprid 17.8 SL, thiamethoxam 25 WG, thiacloprid 21.7 SC and acetamiprid 20 SP revealed that flonicamid (84.9 to 94.7% mortality) and pyriproxyfen (81.7 to 93.00%) effectively managed this pest up to 15-18 days followed by imidacloprid (77.5 to 89.00%) and thiacloprid (71.9 to 85.8%) for first 10 days. Azadirachtin and organophosphates showed significant results for first 5-6 days with 44.1 to 56.3% and 52.7 to 74.1% mean population reduction during first and second season, respectively. Flonicamid and pyriproxyfen were found to be comparatively safe to the predators viz. *Coccinella septempunctata* and *Episyrphus balteatus* in contrast to others. Highest mean seed yield (16.3 q/ha) was obtained with flonicamid along with 1: 10.06 cost: benefit ratio followed by thiacloprid (1: 8.24), imidacloprid (1: 7.72) and pyriproxyfen (1: 7.55).

Key words: *Lipaphis erysimi*, flonicamid, pyriproxyfen, conventional insecticides, organophosphates, neonicotinoids, field efficacy, economics, safety, predators, seasonal incidence, population dynamics

In Indian mustard (*Brassica campestris* var. yellow sarsoon) (Cruciferae), the second most important edible oilseed crop, mustard aphid *Lipaphis erysimi* Kalt. (Homoptera: Aphididae) is regarded as a national pest (Rao et al., 2014). It is considered to be a major limiting factor (Nagar et al., 2012), reducing yield to the tune of 35.4-91.3% (Patel et al., 2004) and the oil content by 5-15% (Shylesha et al., 2006). Its management relies heavily on insecticides (Chattopadhyay et al., 2005).

Pyridine carboxamide compound flonicamid is a novel systemic insecticide, developed in 2000 (Rouhani et al., 2013) as a modulator of chordotonal organ (IRAC, 2016) which causes acute toxicity to aphid nymphs and adults (Morita, et al., 2007). Another biorational molecule pyriproxyfen, is a pyridine based juvenile hormone agonist (Sullivan and Goh, 2008) with relatively low mammalian toxicity, and being used for managing a variety of insect pests including mustard aphid (Liu and Chen, 2001). Application timing is very important for mustard aphid management, and for conserving aphidophagous natural enemies like *Episyrphus baltiatus* (Diptera: Syrphidae) (Devi et al., 2011) and ladybird beetle *Coccinella septempunctata* (Coleoptera: Coccinellidae) (Singh et al., 2012).

Keeping these in view, the present study evaluates the incidence and population dynamics of *L. erysimi* on rapeseed in its different phenological stages in relation to weather factors. Also, field efficacy of some novel biorational insecticides like flonicamid and pyriproxyfen is evaluated through comparison with azadirachtin, neonicotinoids and organophosphates. Incidentally the cost economics and safety towards few predators have also been analysed and interpreted.

MATERIALS AND METHODS

Field experiments were conducted at the Instructional Farm Jaguli, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Kalyani, Nadia, West Bengal during November to February, 2013-2014 and 2014-2015. There were eleven treatments: azadirachtin 5% (w/w) @ 300 g a.i./ ha (1000 ml/ ha); imidacloprid 17.8% SL @ 25 g a.i./ ha (140 ml/ ha); thiamethoxam 25% WG @ 25 g a.i./ ha (100 g/ ha); thiacloprid 21.7%

SC @ 30 g a.i./ ha (140 ml/ ha); acetamiprid 20% SP @ 20 g a.i./ ha (100 g/ ha); flonicamid 50% WG @ 30 g a.i./ ha (60 g/ ha); pyriproxyfen 10% EC @ 50 g a.i./ ha (500 ml/ ha); acephate 75% SP @ 500 g a.i./ ha (670 g/ ha); dimethoate 30% EC @ 200 g a.i./ ha (660 ml/ ha); chlorpyrifos 20% EC @ 100 g a.i./ ha (500 ml/ ha); and untreated control, replicated thrice. A popular mustard cultivar "*Subinoy (YSB-19-7-C)*" was used with sowing in second week of November with 5 × 4 m^2 plot size and 30 cm (row to row) × 15 cm (plant to plant) spacing, in a completely randomized block design. All the recommended agronomic practices were followed.

Incidence and population buildup of aphid was recorded at weekly intervals from 30 randomly selected (tagged) plants (ten plants from each of 3 replications of untreated control). The apical 10 cm length of tagged plants were demarcated into three parts namely vegetative (shoots and leaves), inflorescence (buds and flowers) and fruiting (siliqua) (Kaher and Ratul, 1992). Observations on total number of adults and nymphs were recorded under magnifying lens (10x). For the whole period, data on weather factors like temperature, rainfall, dew point, sunshine and wind speed were obtained from Automated Weather Station, Department of Agrometeorology and Physics, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur. For evaluating the field efficacy of insecticides, a battery operated sprayer fitted with hollow cone nozzle (V-Dyut Delux, Code: VBD09/TPHB4/SS/WOB, ASPEE Sprayers and Farm Mechanised Equipment, Mumbai) with 16 l capacity. Foliar applications were made at recommended rate of 600 l/ ha spray fluid. Two sprays were done at 20 days interval during each season. Observations with counting the number of aphids (nymphs and adults) from 10 cm portion of the terminal shoot of ten randomly selected and tagged plants from each replication were made (Kumar, et al., 2007). Efficacy was assessed based on the number of living aphids on treated plants in comparison to control. Pre-imposition data were recorded 24 hr before treatment followed by post-imposition data at 3rd, 7th, 10th, 14th and 19th day of insecticide application, and % mortality of aphids enumerated according to Salahuddin et al. (2015) as follows:

$$\% \text{ mortality} = \frac{(\text{pre spray data}) - (\text{post spray data})}{\text{pre spray data}} \times 100$$

Observations on important predators- *C. septempunctata* and *E. baltiatus* were made with counting of these on thirty randomly selected and tagged plants from each treatment (10 plants from each replication). % reduction/ increase (+) was calculated based on their number of motile stages (mean of three replications) at 15th day of spray application by modified Abbott's formula, as given in Flemming and Retnakaran (1985). Mean seed yield from plots were recorded and computed into q/ ha. These observations were subjected to statistical analysis after necessary transformations. Cost (Rs./ ha) of treatments along with extra yield over untreated control was recorded and estimation of cost: benefit ratio done from the monetary values (Rs./ quintal). Field efficacy data were subjected to one way ANOVA with SPSS (version 18.0: Inc., Chicago, IL, USA) software. Mean values were separated by Duncan's Multiple Range Test (DMRT) as per Gomez and Gomez (1984) at $p < 0.05$ for interpretation of the results.

RESULTS AND DISCUSSION

Incidence of *L. erysimi*

The population of aphids varied from 0.00 to 99.0 (Fig. 1) and 0.00 to 99.9 (Fig. 2)/ 10 cm apical portion (vegetative, floral and fruiting parts together) during 2013-2014 and 2014-2015, respectively. The population differed significantly (p=0.01) among different growing parts. In the first season, infestation initiated in 4th week itself (Fig. 1) and the population attained peak (68.8/ 10 cm apical vegetative portion) in 8th WAS, whereas during 9th and 11th weeks after sowing (WAS), inflorescence and fruiting parts showed highest aphid density (36.8 and 35.2/ 10 cm apical inflorescence and fruiting portion, respectively). Gradually, the population started to decline from 12th week onwards. Similar results were also encountered during 2014-2015, where 9th standard week registered highest number of aphids both at vegetative (63.6 aphids/ 10 cm shoot length) and inflorescence (30.4 aphids/ 10 cm apical inflorescence portion) stages (Fig. 2). Aphid nymphs and adults appeared after first fortnight of December when temperature started to fall down; attained peak in middle of January and then started to decline from second fortnight of January till first fortnight of February, with higher temperature and reduced relative humidity. The population became highest in vegetative growth stage followed by floral stage but, after the fruit set a part of the population shifted to siliqua at the later stage. These findings are in conformity with those of Jena et al. (1997).

Interaction between the population buildup and weather factors evaluated and depicted as shown in Table 1, reveal that minimum temperature, relative

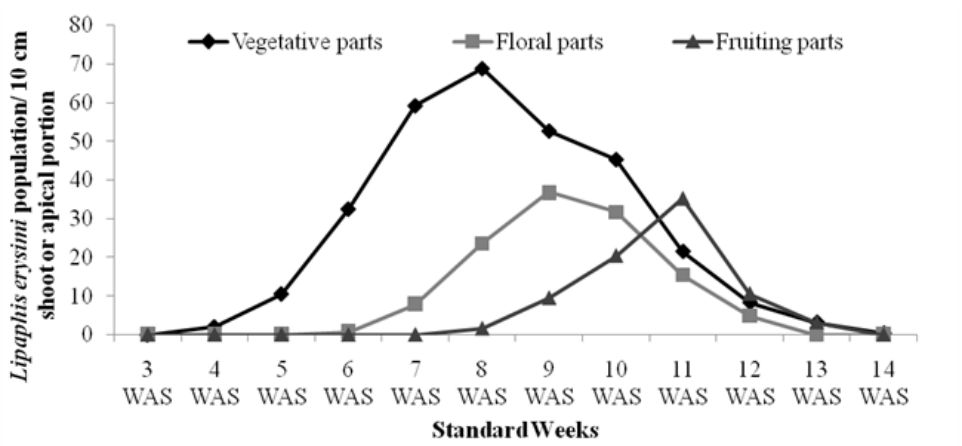

Fig. 1. Incidence (±SEM) of mustard aphid on plant parts of rapeseed-mustard at various weeks after sowing (WAS)- 2013-2014

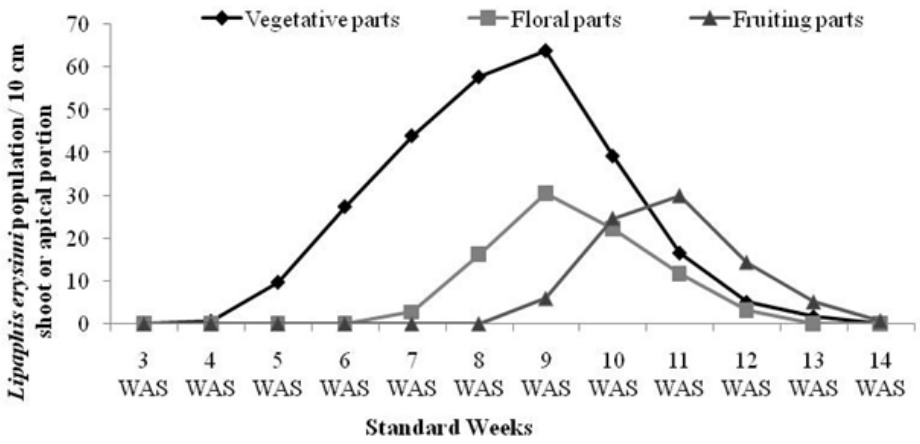

Fig. 2. Incidence (±SEM) of mustard aphid on plant parts of rapeseed-mustard at various weeks after sowing (WAS) (2014-2015)

Table 1. Correlation coefficients-aphid population vs. weather factors

Period	Temperature (°C)		Relative Humidity (%)	Rainfall (mm)	Wind speed (km per hour)	Air pressure	Sunshine hours	Dew Point
	Maximum	Minimum						
2013-2014	-0.815**	0.211*	0.543**	-0.235	-0.195*	0.260	0.852*	0.221*
2014-2015	-0.792**	0.240*	0.518**	-0.212	-0.169*	0.231	0.827*	0.196*

*Significant at $p < 0.01$; ** Significant at $p < 0.05$

humidity and dew point were positively correlated; maximum temperature, rainfall and wind speed showed a negative influence. Kumar et al. (1997) reported that maximum and minimum temperature of 22.81 °C and 13.31 °C, respectively with high relative humidity between 80.71% - 86.50%, provided conducive conditions for aphid incidence. The present observations reveal that overcast sky, relative humidity along with dew point favoured the builup, and slight showers made it to suddenly decline. These findings are in agreement with Bakhetia and Sindhu (1983).

Field efficacy of insecticides

Imidacloprid (91.3%), flonicamid (89.9%), thiacloprid (89.3%), pyriproxyfen (88.8%),

acetamiprid (87.5%) and thiamethoxam (84.6%) were the most effective against all stages of *L. erysimi* at 7th day of first imposition and were significantly superior (p=0.05) over dimethoate (78.1%), acephate (77.7%), azadirachtin (74.5%) and chlorpyriphos (69.9%) during 2013-2014 (Table 2). Flonicamid, imidacloprid and pyriproxyfen were the most effective 19th day after application. During 2014-2015, all the treatments were found superior over the untreated control; thiacloprid and pyriproxyfen showed maximum reduction in population at 7th day and 10th day after first imposition (Table 3).

After second spray application, imidacloprid and pyriproxyfen were found superior up to 7th and 10th day of spray. Flonicamid was effective from day 3 (> 70% mortality after first and second spray). Its effect persisted up to day 19 when more than 80% (after first imposition) and 95% (after second imposition) mortality was achieved. However, conventional molecules had quick knockdown effect against all stages of aphid within first 7 days; and after that no increase in mortality was noticed.

Thus results revealed that flonicamid, pyriproxyfen, imidacloprid and thiacloprid were very effective against *L. erysimi* followed by thiamethoxam and acetamiprid. Dimethoate, acephate and chlorpyriphos had a quick knockdown effect but with reduced residual efficacy. These findings are in conformity with those of Rouhani et al. (2013) which confirmed the superiority of flonicamid and imidacloprid over thiamethoxam. Flonicamid restricted the population below economic threshold level even after 19th day of each imposition as observed by Wrzodak and Woszczyk (2011) against cabbage aphids. Azadirachtin was found quite effective up to 7 days of spray application as shown by Sultana et al. (2009).

Safety to predators

Results given in Table 4 indicate that during the first season, dimethoate showed highest reduction (43.1% and 47.4%) in *C. septempunctata* after 15th day of first and second imposition, respectively; flonicamid with 9.5% and 11.0%, and pyriproxyfen with 11.4% and 14.3% reduction after first and second spray, proved less toxic than thiamethoxam (21.9% and 25.2%), thiacloprid (18.0% and 23.8%), acetamiprid (19.2% and 20.1%), acephate (32.7% and 34.0%) and chlorpyriphos (32.3% and 45.7%).

Flonicamid and pyriproxyfen also exhibited less than 10% mortality of *E. baltiatus* and thus negligible toxicity in 2013-2014. Similar results on the negligible non-target toxicity of flonicamid and pyriproxyfen against *C. septempunctata* and *E. balteatus* were observed during 2014-2015. But, among all the evaluated insecticides, azadirachtin was found the least harmful against during both the years. Findings thus indicated that flonicamid and pyriproxyfen were the least toxic to predators of mustard aphid. Though, azadirachtin was not much promising against *L. erysimi*, it was the safest to predators.

Moens et al. (2010) observed such a negligible toxicity of flonicamid against *E. balteatus*, while, Jansen et al. (2011) indicated that it is a promising insecticide for aphid control. Thiamethoxam was found to be more toxic to the grubs and adult of *C. septempunctata* followed by other neonicotinoids. These observations derive support from Scarpellini and Andrade (2010) with the evidence of high mortality of lady bird beetles from thiamethoxam and also acetamiprid and imidacloprid. Conventional insecticide like dimethoate also proved much toxic against *C. septempunctata* and *E. balteatus* as shown by Dhaka et al. (2009).

Yield and economics

Mean seed yield of rapeseed was higher (7.9-16.3 q/ ha) with various insecticides compared to untreated control (4.7 q/ ha) (Table 5). The extra yield over control was promising with flonicamid (11.6 q/ ha) and pyriproxyfen (10.7 q/ ha) followed by thiacloprid and imidacloprid. Highest cost: benefit ratio (1: 10.06) was obtained from flonicamid, which was found superior over thiacloprid (1: 8.24), imidacloprid (1: 7.72) and pyriproxyfen (1: 7.55). Azadirachtin showed the least yield (7.9 q/ ha) and cost: benefit ratio.

Thus, it can be concluded that *L. erysimi* is a very serious pest of rapeseed-mustard and its infestation was observed during December to February. Two predators, *C. septempunctata* and *E. balteatus* play a very effective role in suppressing this pest in rapeseed. However; to keep the aphid population below economic threshold level, two consecutive spray applications either of flonicamid or pyriproxyfen or imidacloprid or thiacloprid at 15-18 days interval is necessary. Amongst these, the former ensured better efficacy coupled with negligible toxicity to predators. Thus flonicamid and/or pyriproxyfen could be recommended as a sustainable management option for *L. erysimi*.

Table 2. Field efficacy of insecticides against mustard aphid (November - February, 2013-2014)

Treatments	PTC	% mortality/ increase (+) of aphid (nymph and adult)/ 10 cm apical twig (First imposition)					Mean % mortality or increase (+)/ 10 cm apical twig after 1st spray	PTC	% mortality/ increase (+) of aphid (nymph and adult)/ 10 cm apical twig (Second imposition)					Mean % mortality or increase (+)/ 10 cm apical twig after 2nd spray
		3 d	7 d	10 d	14 d	19 d			3 d	7 d	10 d	14 d	19 d	
Azadirachtin 5% (w/w)	88.5	66.8 d (54.82)*	74.5 e (59.67)	64.4 g (53.37)	55.1 g (47.93)	45.4 f (42.36)	61.2 (51.47)	53.6	69.3 e (56.35)	75.2 g (60.13)	51.8 i (46.03)	45.9 i (42.65)	39.1 i (38.70)	56.3 (48.62)
Imidacloprid 17.8% SL	96.2	79.7 a (63.22)	91.3 a (72.85)	88.8 b (70.45)	84.4 b (66.74)	67.6 b (55.31)	82.4 (65.20)	35.1	83.8 a (66.27)	94.7 a (76.69)	95.1 c (77.21)	89.7 c (71.28)	80.1 c (63.51)	88.7 (70.36)
Thiamethoxam 25% WG	79.6	73.0 c (58.69)	84.6 c (66.89)	82.5 d (65.27)	72.6 d (58.44)	54.9 e (47.81)	73.5 (59.02)	38.9	76.6 f (61.07)	89.2 c (70.81)	87.4 e (69.21)	85.8 d (67.86)	70.8 e (57.29)	82.0 (64.90)
Thiacloprid 21.7% SC	84.1	75.5 b (60.33)	89.3 ab (70.91)	87.6 c (69.38)	82.3 c (65.12)	64.7 c (53.55)	79.9 (63.36)	31.4	80.5 cd (63.80)	93.1 b (74.77)	90.9 d (72.44)	84.4 d (66.74)	79.9 c (63.36)	85.8 (67.86)
Acetamiprid 20% SP	86.2	76.2 b (60.80)	87.5 b (69.30)	83.1 d (65.73)	73.7 d (59.15)	61.7 d (51.77)	76.4 (60.94)	36.2	81.2 c (64.30)	87.0 d (68.87)	89.0 e (70.63)	82.6 e (65.35)	76.3 d (60.87)	83.2 (65.80)
Flonicamid 50% WG	91.4	78.5 a (62.38)	89.9 ab (71.47)	91.5 a (73.05)	90.0 a (71.57)	77.4 a (61.62)	85.5 (67.62)	22.7	82.5 b (65.27)	94.8 a (76.82)	99.6 a (86.37)	98.4 a (82.73)	98.2 a (82.29)	94.7 (76.69)
Pyriproxyfen 10% EC	96.3	79.0 a (62.73)	88.8 ab (70.45)	88.6 b (70.27)	83.0 c (65.65)	69.1 b (56.23)	81.7 (64.67)	32.0	82.4 b (65.20)	95.8 a (78.17)	97.2 b (80.37)	96.1 b (78.61)	92.0 b (73.57)	92.7 (74.33)
Acephate 75% SP	87.5	72.3 c (58.24)	77.7 d (61.82)	67.2 f (55.06)	59.0 f (50.19)	38.4 h (38.29)	62.9 (52.48)	52.5	79.5 e (63.08)	81.9 e (64.82)	76.7 f (61.14)	69.5 f (56.48)	62.7 f (52.36)	74.1 (59.41)
Dimethoate 30% EC	85.2	72.5 c (58.37)	78.1 d (62.10)	70.7 e (57.23)	60.3 e (50.94)	42.1 j (40.46)	52.7 (46.55)	50.1	80.1 de (63.51)	78.6 f (62.45)	72.2 g (58.18)	67.0 g (54.94)	59.7 g (50.59)	71.5 (57.73)
Chlorpyrifos 20% EC	80.9	72.8 c (58.57)	69.9 c (56.73)	61.6 h (51.71)	49.2 h (44.54)	31.5 i (34.14)	57.0 (49.02)	54.3	81.3 c (64.38)	74.8 g (59.87)	63.6 h (52.89)	55.0 h (47.87)	44.3 h (41.73)	63.8 (53.01)
Untreated control	85.5	+ 2.5 (0.00)	+ 12.9 (0.00)	+ 20.2 (0.00)	+ 33.4 (0.00)	+ 22.5 (0.00)	+ 18.3 (0.00)	63.4 (0.00)	+ 24.1 (0.00)	+ 15.3 (0.00)	+ 14.8 (0.00)	+ 11.2 (0.00)	+ 5.4 (0.00)	+ 14.2 (0.00)
LSD (0.05)	NS	6.0	5.8	5.5	3.9	6.5	NS	NS	9.0	6.8	4.7	5.8	4.8	NS
SEM±	NS	1.7	1.7	1.6	1.1	1.9	NS	NS	2.6	1.6	1.6	1.1	1.3	NS
CV%	NS	14.7	2.8	3.2	11.5	6.3	NS	NS	5.5	3.9	7.5	7.6	3.3	NS

d = days; PTC = Pre Treatment Count; *Data in parentheses Sin^{-1} transformed values; Means followed by different letters significantly different ($p < 0.05$ by DMRT)

Table 3. Field efficacy of insecticides against mustard aphid (November - February, 2014-2015)

Treatments	PTC	% mortality/ increase (+) of aphid (nymph and adult)/ 10 cm apical twig (First imposition)					Mean % mortality or increase (+) / 10 cm apical twig after 1st spray	PTC	% mortality/ increase (+) of aphid (nymph and adult)/ 10 cm apical twig (Second imposition)					Mean % mortality or increase (+)/ 10 cm apical twig after 2nd spray
		3 d	7 d	10 d	14 d	19 d			3 d	7 d	10 d	14 d	19 d	
Azadirachtin 5% (w/w)	68.2	54.1 g (47.35)*	66.7 g (54.76)	42.5 f (40.69)	35.0 h (36.27)	22.4 j (28.25)	44.1 (41.61)	63.7	61.5 f (51.65)	65.8 i (54.21)	51.2 i (45.69)	45.7 i (42.53)	34.8 j (36.15)	51.8 (46.03)
Imidacloprid 17.8% SL	78.5	78.1 b (62.10)	88.3 b (70.00)	87.1 b (68.95)	78.9 c (62.66)	55.2 d (47.99)	77.5 (61.68)	40.6	81.1 a (64.23)	96.3 a (78.91)	97.6 c (81.09)	89.7 c (71.28)	80.2 d (63.58)	89.0 (70.63)
Thiamethoxam 25% WG	65.3	73.8 d (59.21)	83.6 d (66.11)	80.9 c (64.09)	68.0 d (55.55)	43.3 f (41.15)	69.9 (56.73)	42.5	77.3 d (61.55)	85.2 e (67.38)	88.9 e (70.54)	80.6 de (63.87)	69.0 e (56.17)	80.2 (63.58)
Thiacloprid 21.7% SC	84.0	80.8 a (64.01)	89.4 a (71.00)	88.8 ab (70.45)	83.1 b (65.73)	61.1 c (51.41)	80.6 (63.87)	37.5	79.7 c (63.22)	94.9 bc (76.95)	97.2 c (80.37)	90.1 bc (71.66)	83.1 cd (65.73)	89.0 (70.63)
Acetamiprid 20% SP	79.2	72.7 d (58.50)	84.6 cd (66.89)	83.0 c (65.65)	68.3 d (55.74)	50.9 e (45.52)	71.9 (57.99)	43.3	80.5 ab (63.80)	88.9 d (70.54)	90.1 d (71.66)	79.8 e (63.29)	65.6 f (54.09)	81.0 (64.16)
Flonicamid 50% WG	72.4	73.3 d (58.89)	88.1 b (69.82)	91.3 a (72.85)	89.1 a (70.72)	82.7 a (65.42)	84.9 (67.13)	22.8	79.1 c (62.80)	95.4 b (77.62)	99.9 a (88.19)	99.8 a (87.44)	95.5 a (77.75)	93.9 (75.70)
Pyriproxyfen 10% EC	60.2	76.5 c (61.00)	85.3 c (67.46)	90.3 ab (71.85)	87.7 a (69.47)	78.2 b (62.17)	83.6 (66.11)	33.9	80.3 b (63.65)	96.3 a (78.91)	98.5 b (82.97)	99.4 a (85.56)	90.7 b (72.24)	93.0 (74.66)
Acephate 75% SP	71.5	69.1 f (56.23)	76.3 e (60.87)	73.9 d (59.28)	57.8 f (49.49)	34.7 h (36.09)	62.4 (52.18)	51.2	78.6 cd (62.45)	83.8 f (66.27)	81.1 f (64.23)	65.5 g (54.03)	52.8 h (46.61)	72.4 (58.31)
Dimethoate 30% EC	78.9	71.4 e (57.67)	75.3 e (60.20)	75.2 d (60.13)	60.1 e (50.83)	39.7 g (39.06)	64.3 (53.31)	55.0	74.5 e (59.67)	81.2 gh (64.30)	77.6 g (61.75)	67.1 f (55.00)	53.2 gh (46.84)	70.7 (57.23)
Chlorpyrifos 20% EC	74.8	75.8 c (60.53)	70.9 f (57.35)	61.1 e (51.41)	49.6 g (44.77)	31.5 i (34.14)	57.8 (49.49)	60.4	82.1 a (64.97)	80.6 h (63.87)	70.9 h (57.35)	53.1 h (46.78)	44.7 i (41.96)	66.3 (54.51)
Untreated control	75.6	+ 3.1 (0.00)	+ 10.5 (0.00)	+ 22.6 (0.00)	+ 29.5 (0.00)	+ 25.4 (0.00)	+ 18.2 (0.00)	68.7 (0.00)	+ 20.2 (0.00)	+ 23.1 (0.00)	+ 15.5 (0.00)	+ 12.8 (0.00)	+ 3.2 (0.00)	+ 15.0 (0.00)
LSD (0.05)	NS	6.1	5.8	9.5	4.6	3.7	NS	NS	7.6	4.4	3.8	4.2	10.9	NS
SEM±	NS	1.0	1.7	3.1	1.1	2.5	NS	NS	2.7	1.6	1.5	1.3	4.7	NS
CV%	NS	5.1	4.4	5.6	9.8	2.1	NS	NS	6.5	6.8	2.9	2.1	6.5	NS

d = days; PTC = Pre Treatment Count; *Data in parentheses Sin^{-1} transformed values; Means followed by different letters significantly different ($p < 0.05$ by DMRT)

Table 4. Safety of insecticides to predators *C. septempunctata* and *E. balteatus* (November - February, 2013-2014 & 2014-2015)

Treatments	2013-2014								2014-2015							
	Mean number of motile stage/ 10 plants Before 1st imposition		% reduction/ increase (+) at 15th day of imposition 15 days after 1st imposition		Mean number of motile stage/ 10 plants Before 2nd imposition		% reduction/ increase (+) at 15th day of imposition 15 days after 2nd imposition		Mean number of motile stage/ 10 plants Before 1st imposition		% reduction/ increase (+) at 15th day of imposition 15 days after 1st imposition		Mean number of motile stage/ 10 plants Before 2nd imposition		% reduction/ increase (+) at 15th day of imposition 15 days after 2nd imposition	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Azadirachtin	9.8	6.2	8.2 i	6.2 g	10.2	5.9	13.7 h	7.1 h	9.2	7.1	6.4 h	5.8 f	9.5	6.2	8.5 h	5.2 f
5% (w/w)	(3.21)#	(2.59)	(16.64)*	(14.42)	(3.27)	(2.53)	(21.72)	(15.45)	(3.12)	(2.76)	(14.65)	(13.94)	(3.16)	(2.59)	(16.95)	(13.18)
Imidacloprid	11.2	7.1	27.5 c	18.5 e	8.5	6.6	30.5 d	23.5 d	9.6	6.8	25.9 d	19.5 b	7.9	5.6	30.6 d	20.7 c
17.8% SL	(3.42)	(2.76)	(31.63)	(25.48)	(3.00)	(2.67)	(33.52)	(29.00)	(3.18)	(2.70)	(30.59)	(26.21)	(2.90)	(2.47)	(33.59)	(27.06)
Thiamethoxam	10.5	5.9	21.9 d	22.7 b	7.5	5.2	25.2 e	24.8 c	11.0	6.2	29.3 c	16.6 c	7.1	5.8	34.3 c	21.5 c
25% WG	(3.32)	(2.53)	(27.90)	(28.45)	(2.83)	(2.39)	(30.13)	(29.87)	(3.39)	(2.59)	(32.77)	(24.04)	(2.76)	(2.51)	(35.85)	(27.63)
Thiacloprid	10.0	6.5	18.0 f	18.1 e	8.1	6.1	23.8 f	20.7 e	10.5	5.9	16.2 e	15.3 d	7.5	5.6	18.4 f	17.3 d
21.7% SC	(3.24)	(2.65)	(25.10)	(25.18)	(2.93)	(2.57)	(29.20)	(27.06)	(3.32)	(2.53)	(23.73)	(23.03)	(2.83)	(2.47)	(25.40)	(24.58)
Acetamiprid	9.6	6.7	19.2 e	21.3 c	7.9	6.0	20.1 g	21.2 e	9.9	7.2	15.5 e	16.7 c	6.8	6.0	20.9 e	18.4 d
20% SP	(3.18)	(2.68)	(25.99)	(27.49)	(2.90)	(2.55)	(26.64)	(27.42)	(3.23)	(2.78)	(23.19)	(24.12)	(2.70)	(2.55)	(27.20)	(25.40)
Flonicamid	8.9	6.0	9.5 h	7.1 g	9.0	5.7	11.0 i	8.4 g	10.1	7.1	8.7 g	6.2 f	9.7	6.7	9.4 h	7.8 e
50% WG	(3.07)	(2.55)	(17.95)	(15.45)	(3.08)	(2.49)	(19.37)	(16.85)	(3.26)	(2.76)	(17.16)	(14.42)	(3.19)	(2.68)	(17.85)	(16.22)
Pyriproxyfen	9.2	6.2	11.4 g	9.5 f	9.1	5.9	14.3 h	10.0 f	10.7	6.7	10.1 f	7.8 e	9.0	7.0	12.5 g	9.1 e
10% EC	(3.12)	(2.59)	(19.73)	(17.95)	(3.10)	(2.53)	(22.22)	(18.44)	(3.35)	(2.68)	(18.53)	(16.22)	(3.08)	(2.74)	(20.71)	(17.56)
Acephate	10.1	5.8	32.7 b	23.0 b	9.2	5.4	34.0 c	25.1 c	10.4	6.3	29.7 c	20.1 b	8.5	5.3	34.7 c	23.3 b
75% SP	(3.26)	(2.51)	(34.88)	(28.66)	(3.12)	(2.43)	(35.67)	(30.07)	(3.30)	(2.61)	(33.02)	(26.64)	(3.00)	(2.41)	(36.09)	(28.86)
Dimethoate	9.6	6.6	43.1 a	20.2 d	8.3	6.0	47.4 a	27.9 b	10.2	7.2	34.1 a	19.2 b	5.1	5.5	44.5 a	22.9 b
30% EC	(3.18)	(2.67)	(41.03)	(26.71)	(2.97)	(2.55)	(43.51)	(31.88)	(3.27)	(2.78)	(35.73)	(25.99)	(2.37)	(2.45)	(41.84)	(28.59)
Chlorpyrifos	9.5	7.0	32.3 b	25.8 a	9.4	5.6	45.7 b	31.0 a	9.5	5.7	30.8 b	22.6 a	7.5	5.0	39.1 b	28.1 a
20% EC	(3.16)	(2.74)	(34.63)	(30.53)	(3.15)	(2.47)	(42.53)	(33.83)	(3.16)	(2.49)	(33.71)	(28.39)	(2.83)	(2.35)	(38.70)	(32.01)
Untreated	10.2	6.4	+33.5	+24.1	11.2	9.6	+21.2	+13.0	10.9	7.4	+41.6	+31.8	10.7	8.9	+28.4	+17.2
control	(3.27)	(2.63)	(0.00)	(0.00)	(3.42)	(3.18)	(0.00)	(0.00)	(3.38)	(2.81)	(0.00)	(0.00)	(3.35)	(3.07)	(0.00)	(0.00)
LSD (0.05)	NS	NS	3.6	7.2	NS	NS	4.5	3.6	NS	NS	5.1	6.2	NS	NS	5.8	4.6
SEM±	NS	NS	1.2	2.2	NS	NS	1.6	0.9	NS	NS	1.7	1.5	NS	NS	1.9	1.2
CV%	NS	NS	8.5	4.8	NS	NS	4.9	5.6	NS	NS	3.4	2.6	NS	NS	2.6	7.5

A = *Coccinella septempunctata*; B = *Episyrphus balteatus*; *Data in parentheses Sin^{-1} transformed values; #Data in parentheses $\sqrt{n + 0.5}$ transformed values; Means followed by different letters significantly different ($p < 0.05$ by DMRT)

Table 5. Seed yield and economics of insecticidal treatments (November-February, 2013-2014 & 2014-2015)

Treatments	Seed yield (q/ha)		Mean seed yield (q/ha) Season I & II	Extra yield over untreated control (q/ ha)	Cost: Benefit Ratio
	Season I (2013-2014)	Season II (2014-2015)			
Azadirachtin 5% (w/w)	7.4(2.81)*	8.3(2.97)	7.9(2.90)	3.2	1: 1.06
Imidacloprid 17.8% SL	13.5(3.74)	14.4(3.86)	14.0(3.81)	9.3	1: 7.72
Thiamethoxam 25% WG	12.3(3.58)	13.7(3.97)	13.0(3.67)	8.3	1: 5.37
Thiacloprid 21.7% SC	14.0(3.81)	14.5(3.87)	14.3(3.85)	9.6	1: 8.24
Acetamiprid 20% SP	12.2(3.56)	12.9(3.66)	12.6(3.62)	7.9	1: 5.69
Flonicamid 50% WG	15.9(4.05)	16.6(4.14)	16.3(4.10)	11.6	1: 10.06
Pyriproxyfen 10% EC	15.1(3.95)	15.7(4.03)	15.4(3.99)	10.7	1: 7.55
Acephate 75% SP	10.2(3.27)	11.0(3.39)	10.6(3.33)	5.9	1: 3.73
Dimethoate 30% EC	10.5(3.32)	10.8(3.36)	10.7(3.35)	6.0	1: 4.61
Chlorpyrifos 20% EC	8.9(3.07)	9.6(3.18)	9.3(3.13)	4.6	1: 3.10
Untreated control	4.3(2.19)	5.1(2.37)	4.7(2.28)	-	-

Labour charges (skilled): Rs. 250/ day and cost of hiring power operated spray machine @Rs. 200/ hour as per Indian Council of Agricultural Research, Govt. of India, 2015; *Data in parentheses √x+0.5 transformed values

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IMPACT OF DISSEMINATION OF IPM STRATEGIES AGAINST INSECT PESTS OF TRANSGENIC COTTON IN PUNJAB

VIKAS JINDAL* AND VIJAY KUMAR

Department of Entomology, Punjab Agricultural University, Ludhiana 141004
**Email: vikas_ento@pau.edu*

ABSTRACT

Integrated Pest Management (IPM) module for the management of major insect pests of cotton developed by Punjab Agricultural University, Ludhiana was disseminated in 129 villages of four blocks of Bathinda district, Punjab *viz*., Talwandi Sabo, Mour, Bathinda and Sangat. Two non-IPM villages in each block adjoining to IPM villages were selected as check. The dissemination of IPM strategies reduced the incidence of insect pests in IPM villages as compared to non-IPM villages. The mean population of jassid nymphs and whitefly adults/ three leaves was lower in IPM villages (0.75, 0.79) as compared to non-IPM villages (1.61, 2.58). Mealybug population/ 2.5cm central shoot was lower in IPM villages (0.11) over non-IPM villages (0.49). The tobacco caterpillar infestation was also lower in IPM villages (0.13) than in non-IPM villages (0.62). Population of natural enemies including spiders, predatory bugs, ladybird beetle, green lacewing was highest in IPM villages (0.54) while lowest in non-IPM villages (0.23). The adoption of IPM module resulted in 18.82% reduction in number of sprays in IPM villages over non-IPM villages. The reduction in cost of spray in IPM was 15.87% over non-IPM villages. The average cost of cultivation was Rs. 26752/ ha in IPM villages, which was marginally higher than in non-IPM villages (Rs. 26684/ ha). Average seed cotton yield was higher in IPM villages (22.57q/ha) in comparison to non-IPM villages (19.98 q/ha). The average net return in IPM villages was Rs. 43210/ha, which was more than non-IPM villages (Rs. 35263/ha), with an additional profit of Rs 7945/ha.

Key words: Bt cotton, Insect pests, IPM, adoption, Non-IPM, economics, jassid, whitefly, mealy bug, tobacco caterpillar, predators, yield, cost of cultivation

Cotton (*Gossypium* sp.) cultivation is subjected to biotic stresses due to attack of insect pests and diseases, which play a significant role in achieving optimum yield potential. At world level 1326 species of insects harbour cotton (Hargreaves, 1948) and in India, 162 insect species had been reported, of which nine pests are of utmost importance inflicting 30% losses in yield amounting to Rs 15767.69 million (Dhaliwal *et al.*, 2015). Before the introduction of Bt cotton, bollworms and sucking pests were causing serious damage. The excessive and indiscriminate use of insecticides against bollworms led to various environmental problems, development of insecticidal resistance, decline in population of natural enemies and resurgence of the insect pests. After the introduction of Bt cotton in Punjab, there has been a change in pest scenario in the last decade.

The sucking insect pests like whitefly, *Bemisia tabaci* (Gennadiaus), jassid, *Amrasca biguttula biguttula* (Ishida), thrips, *Thrips tabaci* (Lindemann) and foliage feeders like tobacco caterpillar attained the status of major pests. During 2006, mealy bug, *Phenacoccus solenopsis* (Tinsley) appeared in few pockets of Bathinda, Ferozepur and Muktsar districts and caused economic loss **(**Dhawan *et al*., 2007**)**. Later in 2007, this pest established in other parts of the state and became a menace. Looking into the potential of these insect pests to cause economic losses and sustainability of cotton production it becomes necessary to develop and disseminate IPM strategies. Keeping these in view, the IPM module developed by the Punjab Agricultural University, Ludhiana was disseminated in Bathinda district of Punjab and the impact discussed herein.

MATERIALS AND METHODS

A total of 129 villages were adopted for dissemination of IPM strategies against insect pests in four blocks of Bathinda district viz., Talwandi Sabo (34), Mour (26), Bathinda (45) and Sangat (24). Two villages from each block adjoining these IPM villages were selected as check and these constituted the non-IPM villages. Bt cotton crop was grown following all recommended agronomic practices by Punjab

Agricultural University (PAU). All the selected villages were regularly monitored twice a week from time of sowing to harvesting to disseminate the IPM strategies and to up scale the knowledge of farmers. The IPM developed by PAU comprised of use of recommended hybrids, time of sowing, judicious use of fertilizers, clean cultivation, removal of stacks from fields, sowing of barrier crops and use of insecticides based on economic threshold level (ETL). In each adopted village, a scout was trained regarding production and protection technology on *Bt* cotton who regularly visited the farmers to solve their problems.

Farmers trainings were also conducted to create awareness among the farmers about the recommended varieties/ hybrids, identification and surveillance of insect pests and their natural enemies, fertilizer application, and right use of insecticides. Farmers were provided knowledge about spray techniques, judicious use of pesticides, and ill effects of tank mixtures of pesticides. Farmers were guided about the benefits of recommended pesticides and harmful effects of unrecommended pesticides on cotton crop**.** At least 50 farmers from each village were selected as a target group for dissemination of IPM strategies. Incidence of insect pests like jassid nymphs/ 3 leaves, whitefly adults/ 3 leaves, mealybug/ 2.5 cm in infested plants, tobacco caterpillar larvae/ plant, thrips/ 3 leaves and number of predators/ plant was recorded at weekly interval. The data on various agronomic practices, use of fertilization, insecticides etc were also recorded from each village and their economics worked out.

RESULTS AND DISCUSSION

Impact of IPM technology on varietal selection: IPM technology was adopted in 129 villages in which approximately 16,369 ha area was covered under cotton and about 5,952 farmers followed the IPM strategies (Table 1). The impact of dissemination of IPM technology was observed on sowing time and variety selection and all other agronomic practices. The area under timely sown crop (April to 15th May) varied from 88.2 to 93.5% in different blocks of Bathinda district, with an average of 91.23%. The area under recommended varieties varied from 79.90 to 89.80% in different blocks (Table 1). There was about 85.28% area under recommended varieties in adopted villages. Maximum area was under recommended varieties like MRC 7031, MRC 7017, BCHH 6588 and BCHH 6488. Among different blocks maximum area under recommended varieties i.e. 89.80% was observed in Bathinda block.

Incidence of insect pests and natural enemies in IPM and non-IPM villages: The observations on the incidence of jassids, whitefly, thrips, mealybug and foliage feeder like tobacoo caterpillar indicated that their mean population was comparatively lower in all IPM villages than non-IPM villages. The mean population of jassid nymphs/ 3 leaves was lower in IPM villages (0.75) as compared to non-IPM villages (1.61) in Bathinda district (Fig. 1A). Among IPM villages of different blocks, jassids were lowest in Mour (0.43) and highest in Bathinda block (0.99).

Table 1. Agronomic practices adopted in IPM villages of Bathinda district, Punjab

Blocks	Villages (center)	Number of farmers	Area (ha)		Common cultivars (%)		Areas under different dates of sowing (%)	
			Total	Under cotton	Recommended Bt	Undiscript Bt/Non-Bt	Recommended time (April to 15 May)	After May 15
Talwandi Sabo	34 (3)	1360	7467	5371	79.90	20.10	91.80	8.2
Mour	26 (3)	1169	5772	3552	83.10	16.90	91.40	8.6
Bathinda	45 (9)	2415	6534	3822	89.80	10.21	93.50	6.5
Sangat	24 (2)	1008	3967	3624	88.30	11.70	88.20	11.8
Total/Mean	129	5952	23740	16369	85.28	14.73	91.23	8.77

Similarly, the mean whitefly adults/ 3 leaves was lower in IPM villages (0.79) as compared to non-IPM villages (2.58) in Bathinda district (Fig. 1B). Blockwise it was lowest in Mour (0.49) and highest in Bathinda block (1.03) in IPM villages. The mean population of mealybug/ 2.5 central shoot was again lower in IPM villages (0.11) as compared to non-IPM villages (0.49) in Bathinda district (Fig. 1C). Among IPM villages of different blocks, mealybug incidence was lowest in Mour (0.02) and highest in Bathinda block (0.24). The mean incidence of thrips/ 3 leaves was lower in IPM villages (0.06) as compared to non-IPM villages (033) in Bathinda district (Fig. 1D). Blockwise it was lowest in Bathinda block (0.00) and highest in Talwandi Sabo (0.19) among IPM villages. The maximum incidence of tobacco caterpillar/ plant was observed in non-IPM villages (0.62) and it was 0.13 in IPM villages in Bathinda district (Fig. 1E). The mean number of natural enemies including spiders, predatory bugs, ladybird beetles, green lace wings in different IPM villages was 0.54 per plant, which was relatively higher than the non-IPM villages (0.23/plant). The population was maximum (0.67/ plant) in Sangat block and lowest (0.33/plant) in Mour block (Fig. 1F).

Impact of dissemination of IPM strategies on economics: As regards number and cost of sprays, it was observed that insecticidal sprays for sucking insect pests and foliage feeders was higher in non-IPM villages (5.18) than IPM villages (4.2) (Table 2). The % reduction in the number of insecticide application was highest in Bathinda block (20.75) and lowest in Talwandi Sabo and Mour blocks (17.65). Spray cost was also higher in non-IPM villages (Rs. 2688/ ha) as compared to IPM villages (Rs. 2261/ha). The per cent reduction in the insecticide cost was highest in Bathinda block (16.45) and lowest in Mour block (15.46) (Table 2).

As regards the cost of cultivation, the mean cost of inputs was higher in non-IPM villages (Rs. 6525/ ha) as compared to IPM villages (Rs. 6291/ ha). Block wise it was highest (Rs. 6361/ ha) in IPM villages of Sangat block as compared to Rs. 6599/ ha in non-IPM village of Bathinda block (Table 2). However, the mean cost of farm operation was lower in non-IPM villages (Rs. 20158/ ha) as compared to IPM villages (Rs. 20469/ ha). Cost of cultivation was lower in the non-IPM villages (Rs. 26684/ ha) as compared to IPM villages (Rs. 26752/ ha). Among the blocks, the cost of cultivation was higher in Talwandi Sabo block (Rs. 27463/ ha) of IPM villages than non-IPM villages (Rs. 26842/ ha) of the same block (Table 3).

The mean seed cotton yield was higher in IPM villages (22.57q/ ha) than non-IPM villages (19.98 q/ ha) (Table 3). Among the blocks, the mean seed cotton yield was higher in Talwandi Sabo (24.83 q/ ha) of IPM villages than non-IPM villages (21.36 q/ ha) of the same block. The % increase in seed cotton yield was highest in Talwandi Sabo (13.98) and lowest in Sangat block (8.65) under IPM villages.

The mean net profit was higher in IPM villages (Rs. 43210/ ha) than non-IPM villages (Rs. 35263/ ha) (Table 3). Among the blocks, the mean net profit was higher in Talwandi Sabo (Rs. 49520/ ha) of IPM villages and lowest in Sangat block (Rs. 36991/ ha). The % increase in net profit of IPM villages over non-IPM villages was higher in Talwandi Sabo (20.49) and lowest in Sangat block (16.11) under IPM villages. Additional profit over non-IPM villages was highest in Talwandi Sabo block (Rs. 10148/ ha) and it was lowest

Table 2. Insecticide application, its cost and cultivation cost in IPM vs. non IPM cotton in Bathinda district, Punjab

Block	Number of insecticide applications			Insecticide cost (Rs/ha)			Input cost (Rs/ha)		Cost of farm operation (Rs/ha)	
	IPM	Non-IPM	% reduction	IPM	Non-IPM	% reduction	IPM	Non-IPM	IPM	Non-IPM
Talwandi Sabo	4.2	5.1	17.65	2261	2678	15.57	6273	6506	21191	20336
Mour	4.2	5.1	17.65	2264	2678	15.46	6255	6506	20900	20287
Bathinda	4.2	5.3	20.75	2261	2706	16.45	6276	6599	20013	19897
Sangat	4.2	5.2	19.23	2261	2692	16.01	6361	6491	19772	20115
Mean	4.2	5.18	18.82	2261	2688	15.87	6291	6525	20469	20158

Table 3. Economics for IPM technology and non-IPM practices in transgenic cotton in Bathinda district, Punjab

Block	Cultivation cost (Rs/ha)			Seed cotton yield (q/ha)			Goss Income (Rs/ha)		Net profit			Addtional profit (Rs/ha)
	IPM	Non-IPM	% reduction	IPM	Non-IPM	% increase	IPM	Non-IPM	IPM	Non-IPM	% increase	
Talwandi Sabo	27463	26842	2.26	24.83	21.36	13.98	76983	66215	49520	39372	20.49	10148
Mour	27155	26793	1.33	24.51	21.36	12.85	75994	66215	48839	39422	19.28	9417
Bathinda	26289	26496	-0.79	20.57	18.59	9.63	63777	57627	37488	31231	16.69	6257
Sangat	26102	26606	-1.93	20.35	18.59	8.65	63093	57636	36991	31030	16.11	5961
Mean	26752	26684	0.22	22.57	19.98	11.28	69961	61923	43210	35263	18.14	7945

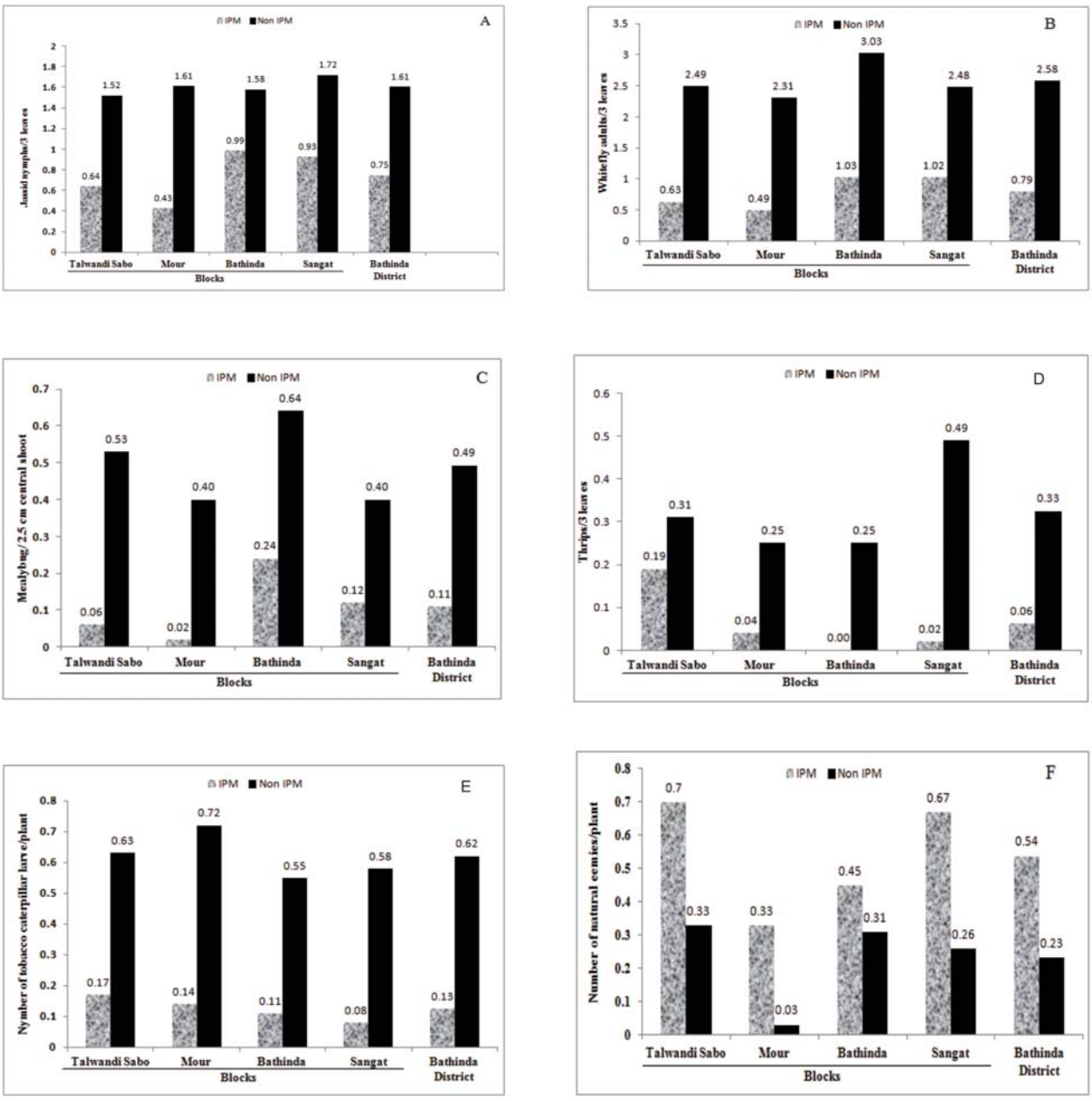

Fig. 1. Incidence of insect pests in IPM and Non-IPM villages in different blocks of Bathinda district

in Sangat block (Rs. 5961/ha). The overall additional profit in district Bathinda due to dissemination of IPM strategies was found to be Rs. 7945/ha.

The present findings corroborate those of of Kranthi *et al.* (2000), who reported that number of sprays for the control of sucking pests and bollworm complex varied from 8-17 in North India and there was 90% reduction in sprays while seed cotton yield increased up to 59%. Plant protection cost reduced by 25-60% due to impact of the IPM strategies. Dhawan *et al.* (2011) reported 38.39% reduction in the number of sprays in IPM villages over non-IPM villages with additional profit of Rs. 140568/ ha. Surulivelu *et al.* (2004) also reported 63% reduction in number of sprays at Coimbatore and Theni districts of Tamil Nadu with the mean of 2.7 in project village as compared to 7.3 in the control villages. With the adoption of IPM strategies, there was less incidence of sucking pests and foliage feeders, higher number of natural enemies in IPM villages as compared to non-IPM villages. There was also reduction in number of sprays, spray cost and cost of cultivation and increase in yield and ultimately the net profit.

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BIOLOGY OF THE INVASIVE MEALYBUG *PHENACOCCUS MADEIRENSIS* GREEN ON COTTON

LEPAKSHI, N. M*., JAGADISH, K. S., SHYLESHA, A. N. AND NARAYANASWAMY, K. C.*****

Department of Entomology, University of Agricultural Sciences (UAS), Bangalore 560065
***National Bureau of Agricultural Insect Resources, Bangalore*
****Department of Sericulture, UAS, Bangalore 560065*
**Email: lepakshileps913@gmail.com*

ABSTRACT

During last decade many invasive mealybugs were reported as major threat to agriculture in India. Among these, the recently introduced mealybug, *Phenacoccus madeirensis* Green (Hemiptera: Pseudococcidae) was observed expanding its horizons to cotton growing areas of South Karnataka and Maharashtra. Since it is necessary to study its lifecycle, so as to identify the vulnerable stage, the present study was undertaken during 2014-15 under laboratory conditions on cotton. The results revealed that its males had a slightly longer nymphal period (22.4± 1.49 days) compared to females (20.96± 1.03 days) due to additional pupal stage. Fecundity of female ranged from 215-398 eggs/ female. The pre-ovipositional, ovipositional and post-ovipositional periods lasted for 9.6± 0.93, 5.56± 0.69 and 4.12± 0.81days, respectively. Adult female lived for 25.04± 1.50 days, while its adult males lived for only 2.48± 0.49 days. The total developmental period of females lasted for 48.28± 2.12 days and in males 24.88± 1.98 days.

Key words: *Phenacoccus madeirensis*, cotton, nymphal period, fecundity, ovipositional period, adult longevity, developmental period

The increase in the worldwide trade of horticultural and ornamental plants has facilitated the introduction and spread of several insect pests. Of late several economically important mealybugs have been introduced into countries in the Mediterranean region of the Palaearctic. One such invasive pest is the Madeira mealybug, *Phenacoccus maderiensis* Green, found infesting ornamentals both in greenhouse and field conditions in Turkey. Although Madeira mealybug was described from Madeira Island by Green in 1923, it is considered to be of neotropical origin (Williams, 1987; 2004; Williams and Granara de Willink, 1992). It is widely distributed in Afrotropical, Australasian, Nearctic, Neotropical and Oriental zoogeographical regions (Ben-Dov *et al.*, 2012). It was also reported from Italy in 1990 by Marotta and Tranfaglia, and more recently in Crete, France and Spain. In India, this mealybug has invaded agroecosystems, including cotton and herbaceous ornamentals, and had been reported from cotton growing tracts of Maharashtra and Karnataka. In Karnataka, it had been reported from the Ramanagara, Chamarajanagar and Kollegala districts (Shylesha and Joshi, 2012). As cotton is prone to the attack of many deadly pests, it is inevitable to study the lifecycle of this new invasive pest, so as to identify and target the most susceptible stage for its management measures.

MATERIALS AND METHODS

The study was conducted during 2014-15 under laboratory conditions at the National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru (12º58'N, 77º38'E, 920ft above MSL). The mealybugs required for culture were collected from the two hosts, *Abutilon indicum* (L.) and *Cestrum nocturnum* L., with its identity confirmed at the NBAIR. These were released onto the potato sprouts, cotton and mesta as host plants for maintaining culture, with the host plants raised repeatedly under glasshouse conditions in plastic pots. For its mass production, amongst the tried methods, culturing on potato sprouts was found to be practically feasible. Hence, two month old potatoes with eye buds were procured from the market washed with water and surface sterilized with common bleach or sodium hypochlorite. A small incision (7 mm depth and 2 cm length) was made on the tubers opposite eye sprouts using a sharp sterilized blade. The potatoes were then treated with 1 ppm gibberellic acid (GA) and left in the solution for one hour to facilitate sprouting and then air dried. After GA treatment, the potatoes were placed on dark humid place in wet cloth and covered with black muslin cloth to promote rapid sprouting. After six to seven days or when sprouts reached 2.5-3.0 cm in length, the potatoes were used for releasing ovisacs.

Each potato sprout was infested with 3 to 5 ovisacs with a camel brush (No. 000) and kept in plastic boxes @ 5 potato sprouts/ box, closed with the dark muslin cloth at 28- 34ºC and 40- 50% RH. After 10 days of release, the crawlers got established. Water was sprayed during morning and evening hours to avoid the moisture loss. In another method, the potato sprouts were placed in a plastic tray (15x25x5 cm) or pot (5 cm dia) containing sterilized sand, and watered daily. When sprouts reached 10 cm height, the ovisacs were released with fine camel hair brush. Similarly, cotton and mesta were raised in plastic pots and ovisacs released to obtain culture continuously. These cultures were protected from contamination of other mealybugs with a formulation of 2% cypermethrin+ methyl parathion 5% dust.

Biology was studied on cotton under glasshouse conditions (27- 35ºC and 39-72% RH) during September, 2014. Sowing was done in plastic pots and labelled replication wise, watered daily, and ten days old seedlings were selected with one egg each placed/ plant with a fine camel hair brush. The release was made once at the beginning of the experiment, with 25 replications maintained. Observations were recorded daily on moulting period (duration of each instar), total number of instars, adult longevity and number of eggs/ female (Figs. 1, 2). The parameters on lifecycle observed were as follows:

Incubation period- freshly laid eggs after oviposition were removed from the host plants and transferred onto fresh cotton seedlings, and time taken for hatching recorded; instar duration- single crawler was released onto each seedling, with date and time of release recorded, and the moulting was identified with exuviae on the host plant. After each moult the cast skin was removed, and the time lapse between two moults divided by 24 hr. gave the instar duration. Summation of individual instar durations gave the total nymphal period. The total number of instars was also observed and recorded; preoviposition period- when nymphs attained adulthood, observations were made twice a day to record the time of first emergence of crawler. The duration between emergence of adult and first oviposition was recorded as the preoviposition period; oviposition period- when matured adults started laying eggs, these were observed enclosed in an ovisac, and the time lapse between the commencement of oviposition and cessation of egg laying recorded; post oviposition period- duration between the time at which the last egg was laid and death of the adult female was observed; adult longevity- number of days the adult survived *i.e.*, the duration from last nymphal moult upto death of the adult was recorded; fecundity- number of eggs laid/ adult female enclosed in ovisac was observed after removing with a fine camel hair brush, number of eggs/ ovisac counted under microscope in a plate containing Whatsman filter paper with bleach; pupal period (males)- after second instar, the male and female were morphologically

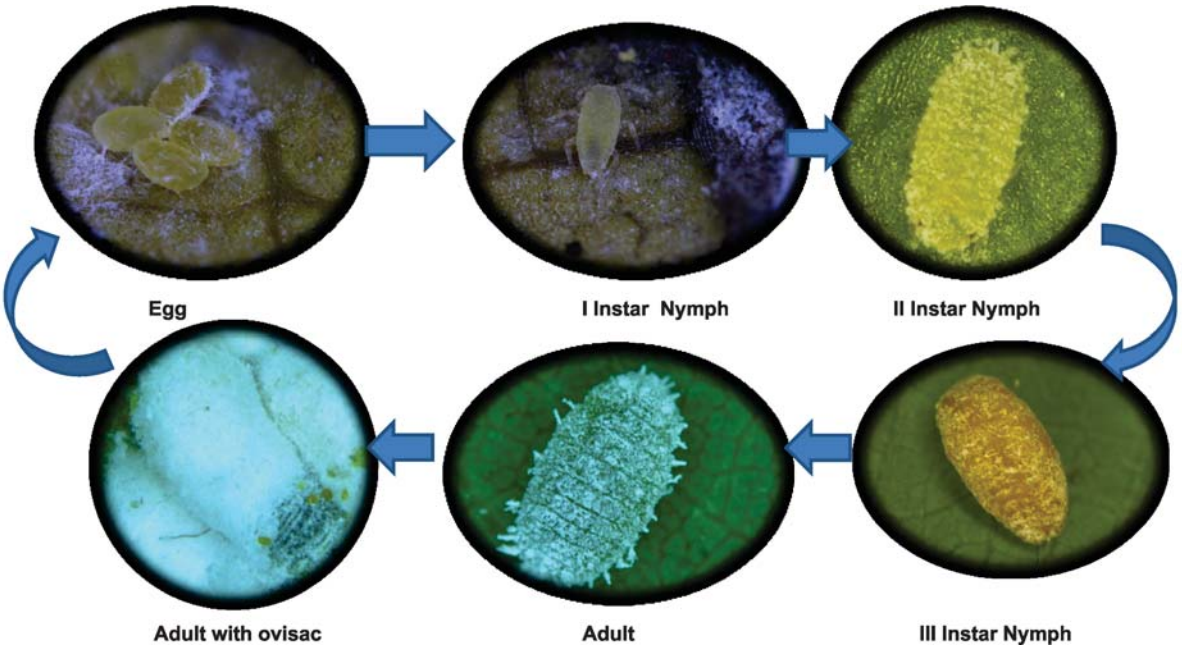

Fig. 1. Life stages of female *P. madeirensis*

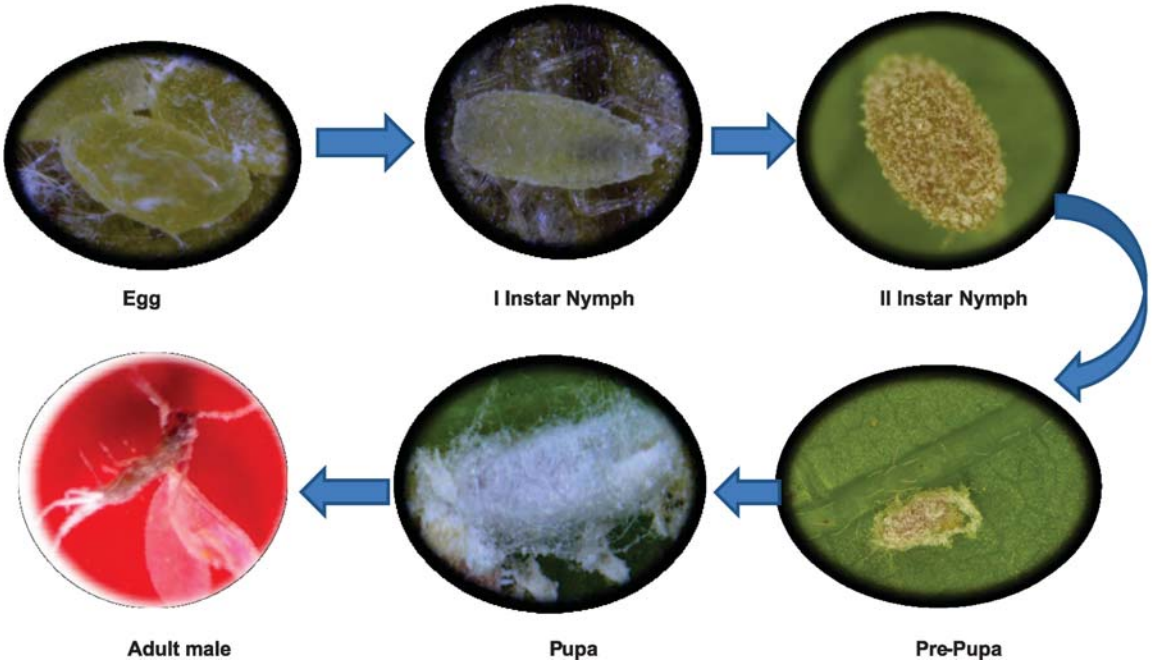

Fig. 2. Life stages of male *P. madeirensis*

distinguishable. Males underwent pupation after second instar, and the time lapse between entering of pupation and emergence of adult observed. All the observations were subjected to computation of range and mean values, and the number observations (n) indicated against each.

RESULTS AND DISCUSSION

The observations on the lifecycle parameters of *P. madeirensis* obtained are presented in Table 1. Adult females laid their eggs on ventral surface of the leaves, petioles, branches and on cracks and crevices of the soil in cottony ovisacs, located in the posterior region of abdomen. The eggs were oval to oblong, lemon yellow or pale orange, hatched in about 6- 9 days (8.04±0.99 days). Nymphs exhibited sexual dimorphism, with females having only three nymphal instars, while the males had four; females were grey to white, while males became pink coloured during their second instar.

The nymphal period was more or less similar irrespective of sex for the first three instars; while in males, the third instar nymph developed into pre-pupa and fourth instar into pupa. The first, second and third instars were 8.64±0.73, 6.52± 0.57 and 5.76±0.70 days, respectively, in female; the males completed first and second instar in 7.92±0.84 and 5.88±0.71 days, respectively. In male, the second instar secreted white silken material, formed a cocoon like structure, in which they underwent moult to form the pre-pupa, and thus the third instar was completed inside the cocoon. The prepupal and pupal duration was observed for 7 to 11 days, with the mean duration of 2.88±0.71 and 5.72±0.44 days, respectively. Thus due to the additional pupal stage, males had longer nymphal developmental period (19-25days; 22.4±1.49 days) compared to females (19-23days; 0.96±1.03 days).

Adult female was oblong, bigger compared to earlier instars, grey or greenish coloured depending on the availability of food, and lacking in spots. The whole body was covered with white dusty waxy secretions. Its longevity was 23- 29 days (25.04±1.50 days). Adult males were delicate bodied, slender, and elongate, with head, thorax, antennae and legs being white. A pair of well developed, metathoracic milky white wings, three pairs of well developed legs, and two pairs of waxy filaments at the anal end of the body were observed. Its longevity ranged from 2 to 3 days (2.48±0.49 days). Parthenogenetic and bisexual mode of reproduction were observed. The preoviposition, oviposition and postoviposition periods ranged from 8 to 11, 4 to 6 and 3 to 5 days (Table 1). Fecundity ranged from 215 to 398 eggs/female (291±72.79), and males were observed in negligible numbers. The total developmental period of females ranged from 45 to 53 days (48.28±2.12 days), and in males from 19 to 25 days (22.40±1.49 days).

Table 1. Lifecycle parameters of *P. madeirensis* on cotton

Stage of life cycle	Duration (in days) / *No. of eggs/female		
	Minimum	Maximum	Mean ±SD (n=25)
Female			
Incubation periodI Instar	6	9	8.04±0.99
I Instar	7	10	8.64±0.73
II Instar	6	8	6.52± 0.57
III Instar	5	7	5.76±0.70
Total nymphal period	19	23	20.96±1.03
Pre-oviposition period	8	11	9.6±0.93
Oviposition period	4	6	5.56±0.69
Post-oviposition period	3	5	4.12±0.81
Adult longevity	23	29	25.04±1.5
*No. of eggs produced/female	215	398	291±72.79
Total life span	45	53	48.28±2.12
Male			
Incubation period	6	9	7.72±0.99
I Instar	6	9	7.92±0.84
II Instar	5	7	5.88±0.71
Pre-pupal period	2	4	2.88±0.71
Pupal period	5	6	5.72±0.44
Total nymphal period	19	25	22.4±1.49
Adult longevity	2	3	2.48±0.49
Total life span	19	25	22.4±1.49

Similar studies on the development and reproduction of *P. madeirensis* on chrysanthemum, under laboratory conditions at different temperature regimes (15, 20, 25, 30, 35 and 40ºC) in Florida, revealed that the female produced 491±38 eggs/ovisac at 20ºC; total development of female took H”30 d at 25 ºC, 46 days at 20ºC and 66 days at 15ºC. Males had longer developmental period of 3 to 9 days than females. The longevity of adult male and female was 3 and 20 days at 25ºC, respectively (Chong *et al.*, 2003).

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MANAGEMENT OF WHITEFLY *BEMISIA TABACI (GENN.)* ON POTATO WITH AZADIRACHTIN AND INSECTICIDE COMBINATIONS

JATIN KUMAR, ANUJ BHATNAGAR*, AJAY KUMAR** AND D.V. SINGH*****

Central Potato Research Institute Campus, Modipuram, Meerut 250110
***Department of Plant Protection, CCS University, Meerut*
****Department of Entomology, S. V. P. University of Agri.& Tech., Meerut 250110*
**Email: dr.anujbhatnagar@gmail.com (corresponding author)*

ABSTRACT

Field trials were conducted on potato (variety Kufri Pukhraj) to evaluate azadirachtin, and its combinations with thiamethoxam, imidacloprid, spinosad, and triazophos against *Bemisia tabaci* at the Central Potato Research Institute Campus Modipuram, Meerut during 2012-13 and 2013-14. The pooled data revealed that neonicotinoids alone and in combination with azadirachtin showed higher efficacy against whitefly in reducing population. Cumulative mean efficacy after third insecticidal spray indicated that thiamethoxam (57.9%) and imidacloprid (55.5%) were highly effective followed by triazophos (54.6%). Combination treatments with azadirachtin showed moderate efficacy and azadirachtin alone was the least effective, followed by spinosad. The highest yield (19.12 t/ha) was obtained with thiamethoxam and it was at par with imidacloprid (18.33 t/ha) and triazophos (18.22 t/ha). Imidacloprid was found to be the most effective and stood second highest among all the treatments with maximum C: B ratio 1: 6.29.

Key words: Potato, whitefly, azadirachtin, combinations, thiamethoxam, imidachloprid, spinosad, triazophos, tuber yield, cost benefit

In potato (*Solanum tuberosum* L.), whitefly *Bemisia tabaci* (Gennadius) is one of the important pests as it not only sucks the sap from tender parts but also vector of potato apical leaf curl disease. It is the main threat to potato causing substantial losses in healthy seed production (Bhatnagar, 2007). Several conventional and synthetic insecticides have been tried against whitefly on various crops in the past (Thakur et al., 1991, Singh and Gupta, 1993). However, these chemicals are expensive and their indiscriminative use is hazardous to human health and the environment. Hence, the present study evaluated the efficacy of combinations of azadirachtin with insecticides like thiamethoxam, imidachloprid, spinosad and triazophos against whitefly and the results presented herein.

MATERIALS AND METHODS

Field experiment was conducted at the Central Potato Research Institute Campus, Modipuram, Meerut during 2012-13 and 2013-14. Potato cv. Kufri Pukhraj was planted following all recommended agronomic practices. Nine insecticides and their combination with azadirachtin viz., T_{1-} azadirachtin 1500 ppm (2ml/l), T_{2-} thiamethoxam 25WG (2g/l), T_3 -imidacloprid 17.5% SL (0.4/l), T_4- spinosad 45 SC (0.5ml/l), T_5- triazophos 40EC (2ml/l), T_6- azadirachtin + thiamethoxam, T_7- azadirachtin + imidacloprid, T_{8-} azadirachtin + spinosad , T_{9-} azadirachtin + triazophos, and T_{10-} untreated control (only water) were evaluated in RBD design, with three replicairons (plot size of 3 x 2 m with gap of 0.75m for reducing drift of sprays).

The insecticides were given in three applications and whitefly incidence recorded one day before spraying as pre-treatment count and one, three and seven days after spraying as post treatment counts. Both nymphs and adults were counted during early morning hours on upper, middle and lower leaves from 5 selected and tagged plants, and % reduction over control expressed % field efficacy calculated using Henderson and Tilton' formula as given below:

$$\% \text{ efficacy} = \frac{1 - (T_a \times C_b)}{(T_b \times C_a)} \times 100$$

where: $T_{a=}$ Population in the treated plot after spray; $T_{b=}$ Population in the treated plot before spray; $C_{a=}$ Population in the control plot after spray; $C_{b=}$ Population in the control plot before spray. The yield data was recorded from net plot after removing halum

in the last week of December, and yield and increase in yield computed along with cost benefits.

RESULTS AND DISCUSSION

The results presented in Table 1 reveal that the incidence of whitefly resulted from residue population on early potato crop, other hosts including weeds in the vicinity of the crop. The incidence reduced with three sprays on 35, 45, and 55 days old crop. The pretreatment population was varying from 8.82 to 9.58, and one day after first spray, efficacy was the highest with thiamethoxam (45.2%) followed by imidacloprid (42.2%); and it was again highest with thiamethoxam (65.2%) and these significantly differed from that of imidacloprid (62.7%) after three sprays (Table 1); after7th day of spray all the treatments were found to be superior over control. Thus thiamethoxam followed by imidacloprid and triazophos were the most effective during both the years. After second spray, thiamethoxam (51.4%) was the best followed by imidacloprid (47.3%) and triazophos (46.2%). Significance of triazophos against this pest had been earlier by Muthukumar and Kalyanasundaram (2003).

Table 1. Field efficacy of insecticidal sprays against *Bemisia tabaci* on potato (pooled data, 2012-13 & 2013-14)

S. No.	Treatments	Mean population/leaf and % field efficacy (in parentheses)					
		Before first spray	After 1st spray	Before second spray	After 2nd spray	Before thirdspray	After 3rd spray
1.	Azadirachtin 1500 ppm	9.12	6.64 (34.3)	9.80	6.63 (35.6)	8.62	5.13 (43.2)
2.	Thiamethoxam 25WG	9.42	4.60 (55.5)	7.42	3.98 (51.4)	6.25	2.80 (57.9)
3.	Imidacloprid 17.5% SL	9.56	4.98 (53.2)	8.56	4.47 (47.3)	6.50	3.08 (55.5)
4.	Spinosad 45 SC	9.20	5.80 (41.8)	8.95	5.66 (40.3)	7.40	4.10 (47.2)
5.	Triazophos 40EC	9.58	5.07 (52.0)	8.58	4.63 (46.2)	6.55	3.16 (54.6)
6.	Azadirachtin + thiamethoxam	9.16	5.21 (48.4)	8.16	4.73 (45.4)	6.70	3.27 (53.1)
7.	Azadirachtin + imidacloprid	9.24	5.40 (47.2)	8.59	5.03 (44.5)	7.05	3.60 (51.4)
8.	Azadirachtin + spinosad	8.98	6.25 (37.1)	9.14	6.11 (36.6)	8.98	4.55 (44.9)
9.	Azadirachtin + triazophos	9.28	5.53 (46.0)	8.70	5.30 (42.8)	10.28	3.71 (50.3)
10.	Untreated control	8.82	10.13	10.9	11.24	11.02	12.13
	SEm ± 1	-	(0.36)	-	(0.36)	-	(0.35)
	CD (p=0.05)	-	(1.07)	-	(1.07)	-	(1.04)

Table 2. Yield and economics of insecticides against *Bemisia tabaci* on potato (pooled data, 2012-13 & 2013-14)

S. No.	Treatments	Mean Tuber yield (t/ha)	Economics of treatments					
			% increase in yield over control	increase in yield over control (t/ha)	*Cost of increased yield potato (Rs.)	**Cost of plant protection (Rs.) (1)	Net profit (Rs.) (2)	Benefit: Cost Ratio (1/2)
1.	Azadirachtin 1500 ppm	15.93	3.60	0.56	4480	3180	1300	1:1.40
2.	Thiamethoxam 25WG	19.12	24.39	3.75	30000	4860	25140	1:6.17
3.	Imidacloprid 17.5% SL	18.33	19.25	2.96	23680	3760	19920	1:6.29
4.	Spinosad 45 SC	16.11	4.81	0.74	5920	7100	-1130	1:0.83
5.	Triazophos 40EC	18.22	18.54	2.85	22800	4420	18380	1:5.15
6.	Azadirachtin + thiamethoxam	17.99	17.04	2.62	20960	4020	16940	1:5.21
7.	Azadirachtin + imidacloprid	17.81	15.87	2.44	19520	3470	16050	1:5.62
8.	Azadirachtin + Spinosad	16.49	7.28	1.12	8960	5140	3820	1:1.74
9.	Azadirachtin + triazophos	17.07	11.06	1.70	13600-	3300	10300	1:4.12
10.	Untreated control	15.37	-	-	-	-	-	-
	SEm ± 1	3.54	-	-	-	-	-	-
	CD (p=0.05)	1.72	-	-	-	-	-	-

* Cost of potato Rs. 800/ q ** (Cost of plant protection- labour+ spray product +machine)

After third spray, again thiamethoxam (47.6%) followed by imidacloprid (45.2%) were the superior treatments (Table 1); seven days after spray, thiamethoxam was the most effective and it was at par with imidacloprid. Overall efficacy indicated that thiamethoxam was best followed by imidacloprid and triazophos during 2012-13 and 2013-14. These observations derive support from Bhatnagar et al. (2016). After three sprays, it was observed that combination treatments have showed only moderate efficacy against *B. tabaci*, and no synergistic effects could be observed. These results corroborate with those of Malik et al. (2005).

In terms of tuber yield there was significant differences amongst the treatments, with highest yield being with thiamethoxam (19.12 t/ha) which was at par with imidacloprid. (18.33 t/ha) and triazophos (18.22 t/ha) (Table 2). The cost benefit ratio was the most optimum with imidacloprid (maximum return Rs. 6.29 per rupee), followed by thiamethoxam, azadirachtin + imidacloprid and triazophos 1:5.15.

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ESSENTIAL OILS AS GRAIN PROTECTANTS AGAINST PULSE BEETLE *CALLOSOBRUCHUS CHINENSIS* (L.) INFESTING PEA SEEDS

LALIT KUMAR, S.C. VERMA*[$], P. L. SHARMA*, BHUPENDER DUTT AND A.K. THAKUR**

Department of Seed Science and Technology
**Department of Entomology; **Department of Forest Products*
Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan 173230
[$]Email: scvermaento@gmail.com (corresponding author)

ABSTRACT

Six plant essential oils *viz.* camphor (*Cinnamomum camphora* L.), wild marigold (*Tegetes minuta* L.), cone-bearing sage (*Meriandra strobilifera* B.), eucalyptus (*Eucalyptus sp.*), lemon grass (*Cymbopogon citratus* L.) and sweet flag (*Acorus calamus* L.) were evaluated against pulse beetle, *Callosobruchus chinensis* (L.) in the Department of Seed Science and Technology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan. All the essential oils were effective against pulse beetle upto two months of treatment. Among them, the treatment with sweetflag recorded the maximum mean mortality (70 %) and found effective against *C. chinensis*. All the tested essential oils at 2.5 ml/ kg inhibited oviposition and progeny development of pulse beetle upto 6 and 8 months after treatment, respectively. Seed damage by pulse beetle was protected with sweet flag upto 8 months of treatment with maximum seed germination (82.67 %), seed vigour index-I(1796.62) and II (1965.90) using 2.5 ml/kg.

Key words: Essential oils, camphor, wild marigold, cone bearing sage, eucalyptus, lemon grass, sweet flag, pea seed, pulse beetle, germination, mortality

Pea (*Pisum sativum* L.) is an important vegetable crop of Himachal Pradesh, and major constraint for its production is the infestation by insect pests in the field as well as in storage. Several bruchids infest pulses in storage and cause loss up to 10-15% with a germination loss from 50-92% (Adugna, 2006). Among the pests that infest the pea seeds in storage, pulse beetle, *Callosobruchus chinensis* L. (Bruchidae: Coleoptera) is important (Alam, 1971; Righi- Assia et al., 2010). It causes weight loss, decreased germination potential and reduction in commercial value of seed (Okunola, 2003). Its damage generally starts in ripened pods in the field from where it is carried over to storage. Insecticides are effective against *C.chinensis*, however, their indiscriminate use led to residual toxicity, insecticide resistance, environmental pollution and adverse effects on food besides side effects on humans (Kumar et al., 2007). There is a need of alternatives to chemical pesticides and fumigants. Plant essential oils and their constituents had been used as an alternative and these possess insecticidal, ovicidal, repellent, and fumigant actions. The present study evaluates few essential oils against *C. chinensis*.

MATERIALS AND METHODS

The pure culture of *C. chinensis* was maintained under laboratory conditions on sterilized pea seeds cv. PB-89, in sterilized jars of half kg capacity. Ten pairs of freshly emerged adults were released in these jars covered with muslin cloth and placed in BOD incubator maintained at 27$\pm$1^{0}C and 70$\pm$5% relative humidity. Six plant essential oils i.e. camphor (*Cinnamomum camphora L.)*, wild marigold (*Tagetes minuta L.*), cone-bearing sage (*Meriandra strobilifera B)*, eucalyptus (*Eucalyptus sp.)*, lemon grass (*Cymbopogon citratus L.*), and sweet flag (*Acorus calamus L.*) were evaluated. These plant materials were collected locally, shade dried and essential oils were extracted with a clevenger apparatus by hydro-distillation. These oils were used @2.5 ml/ kg in plastic container of 250cc capacity containing 200 g of sterilized seeds of pea with three replications. Contents were thoroughly mixed by vigorous shaking. Untreated control was also maintained.

After two months of treatment 25g of seeds was taken out replication wise from each treatment at monthly intervals in a 100 cc container up to 6 months of treatment and five pair of adults released in each.

Data on mortality of adults were recorded after 7 days of release and continued up to 6 months. The data on mortality, adult emergence, seed damage, weight loss and seed germination and seed vigour index were observed after two month of release of beetles. The experiment was carried out at room temperature (minimum and maximum being: 14.5°C and 26.8 °C, respectively). The mortality of adults released on 2,4,6 months old essential oils treated seeds was recorded at 7days of release. Likewise, fecundity was observed on day-7 of release of adults and further progeny development after two months of release. These data were subjected to statistical analysis in Completely Randomized Design after suitable transformation and the significance of treatments calculated as suggested by Cochran and Cox (1964).

RESULTS AND DISCUSSION

The treatment with sweet flag resulted in maximum (91.11%) mortality at two months after treatment. Next best treatment was camphor (42.22%) followed by eucalyptus (35.56%) , lemongrass (33.33%), wild marigold (31.11%) and cone-bearing sage (28.89%). Gradual decrease in mortality was observed in all the treatments at four and six months after treatment (Table 1). Mean maximum mortality (70%) was obtained with sweet flag essential oil which was statistically superior. Pea seeds treated with eucalyptus oil resulted in 27.78% mortality which was at par with other treatments.

The high mortality observed with sweet flag essential oil might be due to the toxicants in its essential oil. This finding is in agreement with Rehman and Schmidt (1999) on its toxic effect due to beta- asarone content in Indian sweet flag. Similarly, El Nahal et al. (1989) reported that essential oil of sweet flag was toxic to *C. chinensis*. Rajendran and Sriranjini (2008) reported that asarone in *A. calamus* is toxic to stored product insect pests.

It is evident from Table 2 that significantly less number of eggs (8 eggs/ 5 females) were observed with sweet flag essential oil at two months after treatment. Similarly after four months, it resulted in minimum oviposition (14.00 eggs/ 5 females); and after month-6 of treatment, minimum egg laying was observed (21 eggs/ 5females). Other treatments also reduced egg laying as given in Table 2.

In the present study, essential oils of sweet flag, lemongrass, camphor, wild marigold, cone-bearing sage and eucalyptus were observed to act as oviposition deterrents, and in decending order after month-6 of treatment. These findings reveal that sweet flag and lemon grass essential oils have high persistence in pea seeds which caused reduced oviposition by pulse beetle. These findings are in conformation with those Rao et al. (1990) who reported ovipositional deterent or ovicidal effect of sweet flag essential oil.

Table 1. Efficacy of essential oils on *C. chinensis*

Treatment	*Mean mortality (%) Month			
	2	4	6	Mean
Camphor	42.22	26.67	13.33	27.40
	(37.31)	(26.69)	(14.47)	(26.16)
Wild marigold	31.11	25.56	16.67	24.44
	(29.74)	(28.09)	(16.67)	(24.83)
Cone-bearing sage	28.89	26.67	15.55	23.70
	(32.52)	(26.12)	(15.77)	(24.80)
Eucalypts	35.56	28.89	18.89	27.78
	(33.86)	(28.33)	(20.50)	(27.56)
Lemongrass	33.33	24.44	14.44	24.07
	(32.85)	(25.14)	(15.12)	(24.37)
Sweet flag	91.11	71.11	47.78	70.00
	(79.90)	(58.07)	(43.72)	(60.56)
Control	15.56	14.44	13.33	14.44
	(17.64)	(16.73)	(16.07)	(16.81)
Mean	39.68	31.11	19.99	30.26
	(37.69)	(29.88)	(20.33)	(29.30)

@2.5 ml/kg; * Mean of three replications; figures in parentheses arc sine transformed values; CD (p=0.05): Treatment- 4.54; Month- 2.97; Month x Treatment- 7.86

Table 2. Effect of essential oils on oviposition, progeny development, seed damage and weight loss in *C. chinensis*

Treatment	*Mean number of eggs /5 pair of beetles			*Mean number of beetles /5 pair of			*Mean seed damage (%)			*Mean weight loss (%)		
	Month			Month			Month			Month		
	2	4	4	4	6	8	6	8	6	8	4	6
Camphor	12.00 (3.59)	4.48 (2.52)	8.59 (3.01)	2.73 (1.89)	4.60 (2.22)	7.46 (2.81)	15.96 (4.05)	29.07 (5.43)	9.67 (3.11)	19.00 (4.42)	23.67 (4.95)	42.67 (6.64)
Wild Marigold	22.67 (4.85)	9.56 (3.17)	8.75 (3.04)	9.63 (3.15)	12.43 (3.54)	15.89 (4.03)	19.44 (4.46)	28.82 (5.41)	14.33 (3.85)	32.00 (5.70)	36.00 (6.08)	43.33 (6.68)
Cone-bearing sage	38.67 (6.27)	15.00 (3.93)	9.83 (3.21)	12.04 (3.54)	15.41 (3.98)	18.44 (4.35)	18.45 (4.35)	25.72 (5.12)	18.00 (4.30)	27.33 (5.28)	45.33 (6.35)	51.67 (7.25)
Eucalypts	44.67 (6.76)	33.00 (5.75)	11.88 (3.52)	14.49 (3.86)	17.60 (4.25)	18.27 (4.33)	24.27 (4.98)	29.65 (5.49)	45.15 (6.76)	49.67 (7.08)	56.33 (8.79)	68.33 (8.91)
Lemongrass	11.33 (3.45)	4.33 (2.19)	4.17 (2.16)	2.12 (1.61)	3.92 (2.08)	5.27 (2.38)	7.55 (2.84)	16.13 (4.08)	9.00 (3.08)	15.27 (3.91)	17.67 (4.32)	27.00 (5.32)
Sweet flag	8.00 (2.99)	1.67 (1.47)	1.92 (1.55)	0.72 (1.10)	1.17 (1.29)	3.14 (1.90)	3.89 (2.09)	6.74 (2.69)	3.33 (1.96)	7.67 (2.86)	14.00 (3.87)	21.00 (4.68)
Control	89.00 (9.48)	47.33 (6.92)	27.10 (5.25)	21.37 (4.67)	21.46 (4.68)	20.56 (4.58)	24.82 (5.03)	29.96 (5.52)	48.00 (6.96)	52.24 (7.26)	92.00 (9.64)	91.33 (9.60)
CD(p =0.05)	(0.68)	(0.35)	0.54	0.46	0.74	0.50	0.32	0.20	(0.45)	(0.34)	(0.48)	(0.99)

* Mean of three replications. Figure in parentheses $\sqrt{x+0.5}$ transformed values

The sweet flag essential oil resulted in reduced emergence (1.67 beetles) after month four of release of beetles. Lemon grass, camphor, wild marigold, cone bearing sage and eucalyptus also resulted in reductions (4.33, 4.48, 9.56, 15.00 and 33.00, respectively). After month-6 of treatment again the least emergence (3.33 beetles) was observed with sweet flag followed by lemon grass (9.00 beetles); after month-8, 7.67 beetles emerged with sweet flag essential oil.

Only oils of sweet flag and lemon grass were effective on inhibition of progeny development up to eight months of treatment (Table 2). The reduction in adult emergence might be due to their high ovicidal, larvicidal and antifeedant action. The toxic and development inhibitory effects of essential oils might be attributed to their composition which may cause suffocation and inhibition of various biosynthetic processes of insects at different developmental stages.

The present study corroborate the findings of Aziz and Abbass (2010) who reported that oils of lemon grass reduced the oviposition of *C. maculatus* on cowpea seeds and also reduced egg hatching and adult emergence.

Table 2 reveals that after month-4 of treatment 1.92% damage was observed with sweet flag oil, while lemon grass resulted in 4.17% damage followed by camphor (8.59%), wild marigold (8.75%), cone-bearing sage (9.83%) and eucalyptus (11.88%). Sweet flag was effective up to 8 months and the rest only up to 4 months. After month-6, pea seeds treated with sweet flag and lemon grass resulted in 3.89 and 7.55% seed damage, respectively; after month-8, seed damage increased to 6.74% with sweet flag essential oil and 16.13% with lemon grass. The reduction in damage with sweet flag and lemon grass essential oils might be due to high antifeedant activity. These results agree with those of Pierce and Schmidt (1993) who reported that sweet flag essential oil spray on maize kernels at 750 mg/ kg restricted damage to only 5%.

The effect of essential oil on weight loss caused by *C. chinensis* revealed that the least weight loss (0.72%) was in sweet flag followed by lemon grass (2.12%), camphor (2.73%), wild marigold (9.63%), cone-bearing sage (12.04%) and eucalyptus (14.49%). After month-6, it was 1.17% and 3.92% in lemon grass; after eight months, 3.14% weight loss was in sweet flag followed by lemon grass with 5.27% (Table 2). The reduced

Table 3. Effect of essential oils on germination and vigour index in pea seeds

Treatment	* Mean seed germination (%)			*Mean seed vigour index-I			*Mean seed vigour index-II		
	Month			Month			Month		
	4	4	4	6	8	6	8	6	8
Camphor	78.33 (62.25)	1398.67	1874.29	1713.15	1561.99	1378.18	1251.22	69.33 (56.36)	53.67 (47.09)
Wild Marigold	53.67 (47.09)	791.26	1135.98	1010.71	929.98	733.60	640.68	46.67 (43.07)	29.33 (32.75)
Cone-bearing sage	54.33 (47.48)	765.98	1147.27	961.55	820.78	711.48	659.41	42.00 (40.38)	35.67 (34.21)
Eucalypts	62.67 (52.33)	919.20	1230.53	1106.09	979.68	860.64	796.55	55.33 (48.05)	32.21 (34.60)
Lemongrass	87.00 (68.87)	1716.61	2158.23	1962.72	1732.09	1672.89	1512.16	81.67 (64.62)	77.67 (61.78)
Sweet flag	89.00 (70.65)	1976.95	2280.17	2186.73	1965.90	1869.24	1796.62	85.00 (65.65)	82.67 (67.46)
Control	23.00 (28.63)	334.33	163.40	142.91	115.57	296.84	275.81	22.87 (28.56)	22.67 (28.40)
CD(p =0.05)	(3.39)	158.54	363.13	295.37	224.70	131.38	139.77	(2.07)	(5.32)

*Mean of three replications. Figure in parentheses√ x+0.5 transformed values

weight loss might be due to antifeedant activity in essential oils. These present findings corroborate with those of Anwar (2009) on sweet flag essential oil against *T. casteneum, T. granarium, R. dominica and S. granarius.*

Table 3 reveals that after month-4, sweet flag essential oil gave 89.00% seed germination whereas lemon grass 87.00%; after month-6, maximum seed germination (85.00%) was again with sweet flag essential oil and with lemon grass it was 81.67%; after month-8, it was 82.67% and 77.67%, respectively. These observations are as given in Yadava (1971). The data in Table 3 reveal that sweet flag essential oil resulted in higher (1976.95) seed vigour index-I after month-4, while with lemon grass it was 1716.61 followed by camphor (1398.67), while in others it was <919.20; after month-6, it was again maximum with sweet flag; after month-8,sweetflag and lemongrass resulted 1796.62 and1512.16 seed vigour index, respectively. Table 3 reveal that almost similar results were obtained as regards seed vigour index-II. These findings are in agreement with Vishwamitra et. al. (2014) who reported that pigeon pea seeds treated with eucalyptus essential oil resulted in increased seedling vigour index .

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PEST COMPLEX, BIOLOGY AND POPULATION DYNAMICS OF INSECT PESTS OF GINGER IN NORTHEAST INDIA

G. C. MOMIN*, D. M. FIRAKE, G. T. BEHERE** AND P. BAISWAR****

School of Crop Protection, College of Post Graduate Studies (Central Agricultural University), Umiam 793103, Meghalaya
***Division of Crop Protection, ICAR Research Complex for NEH region, Umiam 793103*
**Present address: Dakkopgre Dochakra, Tura, District: West Garo Hills, Meghalaya 794104*
**Email: grikresearch@gmail.com*

ABSTRACT

Insect pests are one of the most important constraints in the cultivation of ginger, *Zingiber officinale* (Rosc.) in Meghalaya. Although, ginger is a important cash crop in Meghalaya, the detailed information on pest complex of ginger and their population dynamics is lacking, which is crucial to formulate effective IPM strategies. Thus, a field experiment was conducted during 2013-2014 to study the ginger pest complex, their biology, and population dynamics. The rhizome fly (*Mimegralla coeruleifrons* complex), shoot borer (*Conogethes* (=*Dichocrocis*) *punctiferalis*), rhizome mealy bug (*Formicoccocus polysperes*), white grub (*Holotrichia* spp.), rhizome weevil (*Prodioctes haematicus*) were recorded as pests. In addition, infestation of rhizome scale (*Aspidiotus hartii*) and termite (*Odontotermes obesus*) were also observed at the time of harvesting. Weather parameters, particularly temperature and rainfall were found to have significant impact on pest populations.

Key words: *Zingiber officinale*, northeast India, pest complex, rhizome fly, shoot borer, mealy bug, white grub, rhizome weevil, scale, termite

Ginger, *Zingiber officinale* (Rosc.) is an important spice and medicinal crop grown in India and it is also a main cash crop of northeast India. Meghalaya state is a major producer of ginger and fresh ginger export, which accounts for more than 50% in volume, is mainly from the north eastern states (Anonymous, 2015). Insect pests are one of the important constraints in cultivation of ginger (Awal et al., 2003; Firake et al., 2015). Besides direct damage, some insects are also associated with transmission of diseases. About 20 species of insect pests had been known in ginger in India during different growth stages (Devashayam and Koya, 2005). Among these, white grub (*Holotrichia* spp.), a scale insect (*Aspidiella hartii*), rhizome fly (*Mimegralla coeruleifrons)* and shoot borer (*Dichocrocis punctiferalis)* are important (Jacob, 1980). Due to distinct climate, the pest complex is quite different in northeast India than other parts (Azad Thakur et al., 2012; Firake et al., 2013; 2016a,b; Lytan and Firake, 2012). Diversity of natural enemies of crop pests is also very high in this region (Firake et al., 2012a,b; 2014). Detailed information on pest complex of ginger is however not available, and hence the present study on the pest complex of ginger, their biology and population dynamics under field conditions.

MATERIALS AND METHODS

A field experiment was conducted during 2013-2014 at the experimental farm (25°41'01.91"N, 91°54'46.24"E) of Division of Crop Protection, ICAR Research Complex for NEH Region, Umiam (Dist: Ribhoi), Meghalaya. The ginger variety 'Nadia' was planted by adopting row-row spacing of 40 cm and plant- plant spacing of 30cm. The recommended agronomic practices were followed. Observations on insect pest infestation and damage were recorded regularly at weekly intervals starting one month after planting till harvesting. The infested plants were carefully observed for the presence of pests, pests attacking ginger were collected from the field and reared in the laboratory to study their life cycle under ambient conditions. Fresh food was provided regularly and containers were cleaned daily to avoid any microbial contaminations. Observations on egg, larval, pupal periods and adult longevity were recorded. The adults were provided with 50% honey solution until their death.

Observations on shoot borer infested plants were recorded counting the number of "dead hearts" or withered shoots with frass. Rhizome fly infestation

was evaluated with counting the number of rotten rhizomes (pseudostems) with maggots, which can be easily pulled up by hand. White grub infestation was recorded by counting the number of dead plants, by digging the infested plant and observing grubs ('C' shaped creamy white brown heads grubs clinging and feeding on roots and rhizomes). In case of shoot boring or rhizome weevil, the grubs bore into the pseudostems and feed on the growing shoot, resulting in yellowing and drying of central shoots. The plants showing withering and yellowing of leaves, the presence of ants with mealy bugs or scales near rhizomes were counted and considered as mealy bug or scale infested plants. Generally, all the plants showing mealybug damage symptoms did not die as many times plants recovered from the damage. Since this study aims population dynamics, a plant showing minor symptoms was also considered for counting mealybug damage, and thus data on actual plant mortality due to mealybug was different than data considered when analyzing their population dynamics. Termite affected rhizomes were also counted at the time of harvesting. Number of infested plants by respective pests and total number of plants were recorded and % damage computed.

Data on meteorological parameters *viz*., maximum and minimum temperature (°C), morning and evening relative humidity (%), wind speed (km/hr) and rainfall (mm) during the study period was collected from Division of Agricultural Engineering, ICAR Research Complex for NEH Region, Umiam, Meghalaya for correlation study (Table 1). Pearson's correlation coefficient (r) was calculated between pest damage and weather parameters. The IBM SPSS statistics 21 software was used for overall statistical analysis.

RESULTS AND DISCUSSION

Insect pest complex

The list of pests is given in Table 2 and their seasonal incidence depicted in Fig. 1. The rhizome fly or stilt legged fly (*Mimegralla coeruleifrons* complex) (Fig. 2), shoot borer (*Conogethes punctiferalis*) (Fig. 3), rhizome mealy bug (*Formicoccocus polysperes*) (Fig. 4), white grub (*Holotrichia* spp.) (Fig. 5) were recorded as major pests of ginger; whereas rhizome weevil (*Prodioctes haematicus*) (Figs. 6,7), leaf roller (*Udaspes folus*) (Figs. 8.9) and leaf eating caterpillar (unidentified) were observed as minor pests. Moderate infestation of rhizome scale (*Aspidiotus hartii*) (Fig. 10) and termite (*Odontotermes obesus*) (Fig. 11) was observed at the time of harvesting. In addition, another species of dipteran maggot (unidentified) was found feeding on decaying rhizomes. According to Shylesha et al. (2006) and Kalaisekar et al. (2008), the shoot borer (*C. punctiferalis*), shoot boring weevil (*Prodioctes haematicus*) and a scale insect (*Aspidiotus hartii*) are important pests in Meghalaya. Thus the present study has added more information on the pest complex of ginger in Meghalaya.

Table 1. Weather parameters in ginger growing season- Umiam, Meghalaya

Duration	Average temperature (°C)		Relative humidity (%)		Wind speed (km/hr)	Rainfall (mm)
	Maximum	Minimum	Morning (Max.)	Evening (Min.)		
End June	30.6	19.4	83.6	68.7	1.8	15.7
Early July	28.0	20.3	89.3	74.0	1.9	134.8
Mid July	27.9	20.1	84.7	73.4	1.8	52.1
End July	28.5	20.2	86.4	73.3	2.1	78.0
Early August	29.8	19.9	89.0	69.3	2.0	32.0
Mid August	27.7	19.2	91.1	76.7	1.4	103.4
End August	28.0	19.2	88.1	73.3	1.4	80.5
Early September	29.9	20.0	87.7	68.7	2.1	34.3
Mid September	28.0	18.8	88.4	70.6	1.8	45.4
End September	28.7	18.5	85.6	70.3	1.4	54.1
Early October	29.2	18.9	85.1	65.7	1.3	41.3
Mid October	26.3	17.7	86.6	71.7	1.6	54.9
End October	27.4	15.9	81.9	70.7	1.4	49.9
Early November	24.7	14.3	86.7	70.9	1.4	115
Mid November	25.6	7.8	80.4	40.6	1.3	0
End November	24.6	7.9	81	43.3	1.6	0

Table 2. Insect pest complex of ginger- Umiam, Meghalaya (2013-2014)

Common name	Scientific name	Order	Family
Rhizome fly	*Mimegralla coeruleifrons* complex	Diptera	Micropezidae
Shoot borer	*Dichocrocis punctiferalis*	Lepidoptera	Pyralidae
Leaf roller	*Udaspes folus*	Lepidoptera	Hesperidae
Rhizome mealy bug	*Formicoccocus polysperes*	Hemiptera	Pseudococcidae
White grub	*Holotrichia* spp.	Coleoptera	Melelonthidae
Rhizome weevil	*Prodioctes haematicus*	Coleoptera	Curculionidae
The termite	*Odontotermes obesus*	Isoptera	Termitidae
Rhizome scale	*Aspidiotus hartii*	Hemiptera	Diaspididae

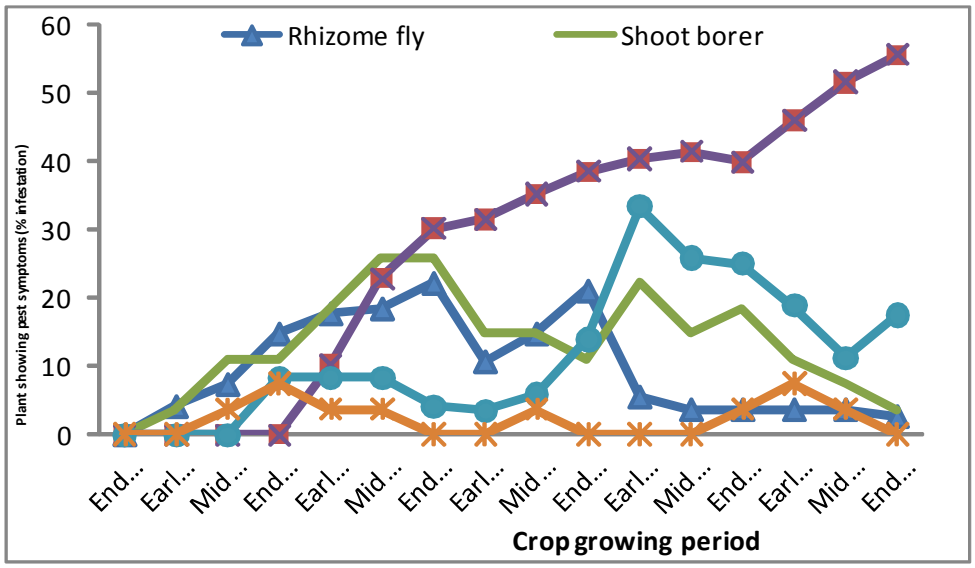

Fig. 1. Seasonal incidence of major insect pests of ginger (2013-14)

Fig. 2. Rhizome fly, *Mimegralla* spp.

Fig. 3. Shoot borer, *Dichocrocis punctiferalis*

Fig. 4. Rhizome mealy bug, *Formicoccocus polysperes*

Fig. 5. White grub, *Holotrichia* spp. larva

Fig. 6. Rhizome weevil, *Prodioctes haematicus* grub

Fig. 7. Rhizome weevil, *Prodioctes haematicus* adult

Fig. 8. Leaf roller, *Udaspes folus* larva

Fig. 9. Leaf roller, *U. folus* adult

In India, about 46 species of insect pests are associated with ginger and turmeric during different stages of its growth and in storage. Amongst these, white grub (*Holotricia consanguinea*), a scale insect (*Aspidiella hartii*), rhizome fly *(M. coeruleifrons* and *Calobata* spp.), shoot borer (*C. punctiferalis*) are important (Koya et al., 1991). The termite *Odontotermes obesus* had been known to attack rhizomes and roots, causing plants to wither and dry and sometimes leading to the secondary fungal infection of rhizomes in Himachal Pradesh (Garg, 2001).

Biology and seasonal incidence (Fig. 1)

Rhizome fly or stilt legged fly (*Mimegralla coeruleifrons*): Eggs were found at the base of the plants and mostly near diseased rhizomes; main egg

Fig. 10. Rhizome scale, *Aspidiotus hartii*

Fig. 11. Termite, *Odontotermes obesus*

laying period was from August to September. The incubation period varied from 2 to 3 days. The newly hatched maggots were transparent, segmented and pale white; soon after hatching, these bore into rhizomes and completely ate the internal content. Interestingly, this species was found associated with the soft rot disease. Although, adult females prefer to lay eggs near the diseased or rotten rhizomes, sometimes the maggots were also found attacking nearby rhizomes after completion of feeding on diseased rhizomes.

The full grown maggot was elongate, 10.03± 0.15 mm in length and 1.80± 0.03 mm in width and tapering gradually toward both ends. Larval period was found to be 14± 1days. The full grown maggots were found pupating in the tunnels of infested rhizomes. Infested plants can be easily pulled up by hand. The puparium was elongate (6.8± 0.1 x 1.23± 0.02 mm), much smaller than adult, and tapering gradually towards both ends; and were brownish initially and changed to dark brown to black at maturity, with the pupal period varying from 7± 1days. The adult fly was black with long legs, a long narrow body and wings; wings were marked or spotted with anal cells; females were larger than the males; males were found to be 16.5± 2.5 mm in length; whereas females measured 21± 2 mm. Adult longevity was found to be 8.5± 1.5 days and the total lifecycle was completed in 30± 3 days.

Rhizome fly infestation initially started during early July (4.16%) (Fig. 1); then increased by end of August (22.22%), and observed decreasing after October onwards and lowest was at the end of November (2.7%). Some important meteorological parameters, when correlated showed significant positive correlation of population with minimum temperature (r= 0.438) (Table 3). Various species of dipteran maggots bore into rhizomes and roots, and these are generally seen in plants affected by rhizome rot disease (Maxwell-Lefroy and Howlett, 1909). The rhizome fly, *Mimegralla coeruleifrons* is a species complex and very difficult to identify based on only external morphological characters. Sontakke (2000) stated that the rhizome fly (*Mimegralla* spp.) was mainly active and damaged more during August to September under field conditions in Odisha. Ghorpade et al. (1988) also stated that its infestation was at its peak during mid August to mid October, and this period is characterized by intermittent rains, cloudy weather, lower temperature and higher relative humidity.

White grub (*Holotrichia* spp.): The females were 37±2.5 mm in length and 18.85±1.35 mm in breadth. Eggs of the white grubs were found in soil near the newly planted rhizomes. Dead females were found in

Table 3. Correlation coefficients-pest infestation vs. weather parameters

Insect pests	Correlation coefficient (r)					
	Temperature (^{0}C)		R.H (%)		Wind speed	Rainfall
	Max.	Min.	Morning	Evening	(kmph)	(mm)
Rhizome fly	0.337	0.438**	0.598	0.400	0.069	0 .230
Shoot borer	0.153	0.337**	0.474	0.410**	-0.310	0.238**
White grub	-0.369	-0.340	-0.333	-0.205	-0.578	-0.136
Rhizome weevil	-0.276	-0.071**	0.059	0.125	0.085	0.268
Rhizome Mealy bug	-0.628**	-0.712**	-0.404	-0.566*	-0.662**	-0.316

** Significant at 5%

the soil near rhizomes. White grub larvae also enter in the field from the farm yard manure applied during planting. The fresh eggs were oval, creamy white, 4.25± 0.8 x 3.06± 0.5 mm. The newly hatched grubs were small, delicate, C-shaped with pale white body and pale brown head; grubs are voracious feeders and eat the portion of the ginger rhizomes and in case of severe damage, the infested plants die; and mature grubs measured 20 to 45 mm long. Larval period lasted for 90-110 days. The pupae were dark brown and 2.5±12.5 mm long.

The damage was initially seen during the end of July (8.33%) (Fig. 1). It remained low until mid September (3.57-5.88%) and was highest during October (24.99 to 33.33%). No significant correlation was not observed between infestation and weather parameters (Table 3). White grub species such as *Holotrichia consanguinea*, *H. fissa*, *H. coracea* and *H. seticollis* are known to attack ginger rhizomes in hilly areas of India (Koya et al., 1991; Misra, 1992). The rhizome damage due to white grub ranges from 5.7 to 26.5% at harvest (Misra, 1991). White grub, *Holotrichia* spp. had also been reported as an important pest of ginger in Sikkim (Indo-Swiss Project Sikkim, 2005). Adult beetles emerge from the soil at the onset of monsoon and remain in soil throughout the year after egg laying. White grub damage was also reported severe during September-October in Himachal Pradesh (http://ainpwhitegrubs.com/palampur.htm). These reports support the present findings.

Mealybug (*Formicoccocus polysperes*): The newly hatched nymphs were flat, oval and extremely mobile. The adult females were 3.08± 0.12 x 2.05±0.05 mm, with the field damage seen during early August and found increasing till crop maturity (Fig. 1). The infested plants withered, become yellow and ultimately die. About 55.48% plants showed symptoms of infestation at the end of November; its damage showed a significant positive correlation with morning relative humidity (r= 0.151) and negative correlation with maximum temperature (r= -0.628), minimum temperature (-0.712), evening relative humidity (r= -0.566) and wind speed (r=-0.662) (Table 3). This pest had been previously reported on ginger in Philippines and Thailand. Recently, it was observed feeding on ginger rhizomes in India (Firake et al., 2015).

Shoot borer (*Conogethes punctiferalis*): Eggs of this were found on leaves or tender stem, and the incubation period was observed to be 7±1 days. The larval period lasted from 18± 2 days, and throughout the larval period, the larvae remained in concealment under a cover of silk and frass or excreta and formed pupa inside it. The pupal period was found to be 7± 1 days. The life cycle was completed in 38± 2 days.

The shoot borer damage was initially seen at the onset of July (3.7%) (Fig. 1); its infestation was maximum during the mid and end August (25.9%), and showed a significant positive correlation with minimum temperature (r= 0.337), evening relative humidity (r= 0.410) and rainfall (r= 0.238) (Table 3). These present findings are supported by those of Nybe (2001) who stated that the incidence was higher during August to October. Shylesha et al. (2006) also reported that it one of the important pests in Meghalaya

Rhizome weevil (*Prodioctes haematicus*): Its damage was initially seen during mid of July (3.7%), but remained low throughout the season (3.7 to 7.4%). Significant negative correlation was found between its infestation and minimum temperature (r= -0.071) (Table 3). In contrast to our findings, Shylesha et al. (2006) reported that it is a major pest in NEH region, causing 30-40% damage during July-September.

Thus the present study reveals that *M. coeruleifrons*, *C. punctiferalis*, *F. polysperes*, *Holotrichia* spp., *Odontotermes obesus*, *Prodioctes haematicus*, *Udaspes folus* and *Aspidiotus hartii* are the important pests attacking the ginger in Meghalaya. Also, weather parameters, particularly temperature and rainfall have a significant impact on pest populations. The information generated would certainly be helpful to formulate effective IPM strategies against major pests of ginger in Meghalaya and other parts of northeast India

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VARIATION IN TOXICITY OF SOME INSECTICIDES AGAINST *SPODOPTERA LITURA*(F.) FED ON DIFFERENT HOSTS

MANJUSHA SOLANKI*, NIRAJ SATPUTE AND MAHESH SOLANKI

Department of Entomology
Dr. Panjabrao Deshmukh Krishi Vidyapeeth (Dr.PDKV), Akola 444104
**Email: manjusharajput888@gmail.com*

ABSTRACT

***Spodoptera litura* (F.) reared on three host plants *viz.*, castor, cotton and soybean showed variation in susceptibility to indoxacarb15.8EC and chlorantraniliprole 18.5SC. Against F_3 generation these two insecticides were more toxic when reared on castor (0.036 ppm LC_{50} -indoxacarb and 0.035 ppm-chlorantraniliprole) followed by soybean. Higher LC_{50} of indoxacarb and chlorantraniliprole (0.172, 0.184 ppm, respectively) was observed when reared on cotton indicating that feeding on cotton induced tolerance.**

Key words: *Spodoptera litura*, reared on castor, cotton, soybean, indoxacarb, chlorantraniliprole, LC_{50}, tolerance induced by cotton

Spodoptora litura (F.), commonly known as tobacco leaf eating caterpillar, is a pest of national importance causing economic damage to a number of agricultural crops *viz*.; tobacco, cole crops, castor, cotton, sunflower, soybean, chilli (Murthy *et al*., 2007). Several synthetic insecticides are being recommended for its management, but being polyphagous with high reproductive and damage potential, its suppression has become a concern. In particular, in the past decade with resistance to commonly used insecticides, field control failure is common (Kranthi *et al*., 2001; Ahmad *et al*., 2007). In recent years, there had been reports of resistance to recommended doses of several newer insecticides (Navatha and Murthy, 2006). These developments necessitate a relook at the dosages recommended taking into account the crop on which the pest has to be managed. This insect pest being polyphagous it was considered desirable to study the influence of some of the important host plants on its susceptibility to some newer insecticide molecules and hence the present study.

MATERIALS AND METHODS

The experiment was conducted during 2014-2015 in the Toxicology Laboratory, Department of Entomology, Dr. PDKV, Akola. *Spodoptera* larvae were collected from the soybean and cabbage fields during the cropping season of 2014-15, and reared on three different host plants *viz.*, castor, cotton and soybean up to three generations, and influence of these host plants on the LC_{50} value studied. During each generation, the third instar larvae from the respective hosts were exposed to concentrations of indoxacarb 15.8EC and chlorantraniliprole 18.5SC with leaf dip bioassays.

Concentrations of indoxacarb and chlorantraniprole were prepared for leaf dip method bioassays as suggested by Ahmed et al (1995). Before conducting the bioassays, preliminary experiments were conducted with each insecticide concentration which gave the mortality of larvae in the range of 20 to 80%. Ten larvae were released in each container with three such sets maintained as replications. Five concentrations of each of the insecticides along with control were used, and larvae were exposed to treated leaves in controlled condition for mortality assessment. The observations on mortality were observed after 24- 92 hr. The median lethal concentration (LC_{50}) of both the insecticides was worked out by subjecting the mortality data to probit analysis (Finney, 1971).

RESULTS AND DISCUSSION

The data given in Table 1 reveal that the toxicity of indoxacarb was less against *S. litura* fed on cotton (LC_{50} - 0.172 ppm) followed by that of soybean and castor during F_3 generation; lowest LC_{50} (0.036 ppm) was observed with castor. It was relatively less toxic against the population fed on cotton (LC_{50} of 0.172 ppm) during F_3 generation which might be due to the induction of certain detoxifying enzymes in *S. litura*

population. Thus it has tolerated indoxacarb to some extent as reported by Ugale *et al*. (2010) who inferred that different hosts induced GST and protein in *Helicoverpa* mid gut, which inturn reflected in terms of tolerance against insecticides including indoxacarb. Similarly, variation in toxicity of indoxacarb against *S. litura* reared on different hosts was reported by Jeughale (2013) which support the present findings.

As regards chlorantraniliprole, observations revealed that feeding on cotton leaves had induced tolerance in *Spodoptera* population followed by soybean (LC_{50} of 0.184 and 0.126 ppm, respectively during F_3 generation). *Spodoptera* reared on castor was found to be the most susceptible (Table 2). The variation in the toxicity of chlorantraniliprole is possibly due to the variation in induction of detoxifying enzymes in insect body during a course of three generations reared on the host plants under study (Dai *et al*., 2013).

Table 1. Influence of host plants on toxicity of indoxacarb against *S. litura*

Host plant	Generation	n	LC_{50} ppm	FL at 95 %	LC_{90} ppm	Chi Square(x^2)	Slope± S.E
Castor	* F_0	180	0.851	0.690-1.001	2.262	2.674	3.017±0.681
	F_1	180	0.347	0.222-0.516	3.459	3.870	1.283±0.290
	F_2	180	0.110	0.078-0.149	0.640	1.492	1.674±0.287
	F_3	180	0.036	0.022-0.056	0.446	0.775	1.169±0.339
Cotton	* F_0	180	0.851	0.690-1.001	2.262	2.674	3.017±1.521
	F_1	180	0.837	0.671-0.987	2.269	1.604	2.958±0.679
	F_2	180	0.169	0.106-0.245	1.526	1.737	1.342±0.286
	F_3	180	0.172	0.114-0.242	1.310	1.532	1.454±0.290
Soybean	* F_0	180	0.851	0.690-1.001	2.262	2.674	3.017±0.682
	F_1	180	0.195	0.123-0.300	2.273	0.684	1.200±0.251
	F_2	180	0.082	0.050-0.138	1.325	1.515	1.061±0.248
	F_3	180	0.050	0.030-0.079	0.678	1.573	1.134±0.244

*F_0- field collected population and values irrespective of host effect; n- no. of larvae; (Chi-Square (x^2) tabular value at p-0.05 = 7.815)

Table 2. Influence of host plants on toxicity of chlorantraniliprole against *S.litura*

Host plant	Generation	N	LC_{50} ppm	FL at 95 %	LC_{90} ppm	Chi Square(x^2)	Slope± S.E
Castor	* F_0	180	0.791	0.621-0.931	2.130	0.698	2.976±0.679
	F_1	180	0.213	0.137-0.323	2.265	1.149	1.247±0.280
	F_2	180	0.147	0.091-0.228	1.846	2.852	1.166±0.235
	F_3	180	0.035	0.023-0.051	0.302	1.734	1.369±0.292
Cotton	* F_0	180	0.791	0.621-0.931	2.130	0.698	2.976±0.681
	F_1	180	0.480	0.292-0.660	3.376	0.874	1.513±0.389
	F_2	180	0.224	0.126-0.349	3.237	4.046	1.104±0.235
	F_3	180	0.184	0.110-0.280	2.212	0.832	1.186±0.280
Soybean	* F_0	180	0.791	0.621-0.931	2.130	0.698	2.976±1.029
	F_1	180	0.491	0.338-0.640	2.435	1.557	1.843±0.400
	F_2	180	0.297	0.186-0.429	2.682	1.698	1.341±0.290
	F_3	180	0.126	0.081-0.194	1.316	0.478	1.257±0.315

*F_0- field collected population and values irrespective of host effect; n- no. of larvae; (Chi-Square (x^2) tabular value at p-0.05= 7.815)

Table 3. Detoxifying enzymes in *S.litura*, and corresponding LC50 values (after rearing on three hosts for 3 generations)

Host plant	Gen.	Indoxacarb LC_{50}(ppm)	Chlorantraniliprole LC_{50}(ppm)	GST µM mg protein^{-1} min^{-1}	Carboxylesterase mol/min/mg protein	Monooxygenase mOD min^{-1} mg-$^{-1}$protein
Castor	F_3	0.036	0.035	0.62	0.0075	1.85
Cotton	F_3	0.172	0.184	0.58	0.0090	3.84
Soybean	F_3	0.050	0.126	0.52	0.0037	0.59

Some plants have sufficient plant allelochemicals to tolerate the xenobiotics/ toxicants which are easily detoxified by different metabolic mechanisms. Plant can influence the toxicity of insecticides by activation of detoxifying enzymes in insects (Broston, 1988). Similarly, Basera and Srivastava (2011) had reported that *Spodoptera* larvae reared on soybean and castor were more susceptible to indoxacarb 14.5%SC and those reared on brinjal were relatively less susceptible. These results support the present findings indicating a lower dose requirement of indoxacarb as well as chlorantraniliprole against *S. litura* on castor and soybean as compared to other hosts like cotton.

The data in Table 3 reveal that the higher LC50 values of both indoxacarb and chlorantraniliprole during F3 generation of *Spodoptera* on cotton might be correlated with higher monooxygenase value as compared to other two hosts evaluated. This study shows that feeding of *Spodoptera* on different host plants can induce variation in insecticide susceptibilities as well as detoxifying enzyme activity, which could be exploited in planning the doses of insecticides for the management of *S. litura* on different hosts.

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BIODIVERSITY OF GRASSHOPPERS AT AMIRDHI FOREST AND ADJOINING AREAS OF VELLORE, TAMIL NADU

JOB GOPINATH M.* AND VIDHYA K.**

PG & Research Department of Zoology, Voorhees College, Vellore 632001
***PG & Research Department of Zoology, Auxilium College, Vellore 632006*
**Email: job.gopinath@gmail.com (corresponding author)*

ABSTRACT

As there is no systematic survey of grasshoppers and their fannistics are available, present study was conducted in Vellore. The grasshopper fauna and identification of grasshopper species found in the Amirdhi forest and the adjoining places was undertaken. The results revealed >15 species identified based on their external morphology.

Key words: Biodiversity, grasshoppers, Amirdhi forest, Vellore, agricultural lands, *Cyrtacanthris, Atractomorpha, Acrida, Heteracris, Trilophidia, Gastrimargus, Diabolo, Morphacris, Orthacris, Phlaeoba, Oedaleus, Spathosternum, Truxalis*

The superfamily Acridoidea of Phylum Arthropoda is one of the largest assemblages of phytophagus insects belonging to the order This superfamily comprises short horned non migratory grasshoppers and highly destructive migratory locusts (Davies, 1988). Acridordea has 14 families of which Acrididae and Pyrgomorphidae are represented in Tamil Nadu.

The population density, species diversity and distribution patterns of various grasshopper species in different parts of peninsular India had been well documented (Muralirangan *et al*., 1993). Their extensive studies had included the forest ecosystems found in Guindy shrub jungle, Yercaud hills, Ooty hills, Topslip, Valparai. However, no systematic study has been made in Amirdhi forest, Vellore District Eastern Ghats, and hence the present study was conducted.

MATERIALS AND METHODS

Amirdhi forest is a dry mixed deciduous forest situated at a distance of 20 km from Vellore towards south west direction. It is classified as low land forest category of the Eastern ghats. It contains lot of vegetations like sandalwood, tamarind, kadukkai, bamboo, avaram bark, konnai bark, wood apple, pungan, soapnut and grasses. Three different stations were selected for sample collection: Station 1 is a typical forest area; station 2 is the area converted in to agricultural land; and station 3 near the bank of Amirdhi river (naga nathi) three stations represented diversity and distribution pattern of various grasshopper species.

The grasshoppers were collected using sweep net, choosing nearly 6 to 8 random sites of 10 m^2 within the selected regions (100 m^2). Insects were killed using other and chloroform and preserved. Confirmation of identification of species was obtained from Dr. Muralirangan, Director, Gill Research Centre, Chennai. The seicesens were preserved in insect boxes with suitable preservatives.

RESULTS AND DISCUSSION

The collections of 20 species of which fifteen were led to identified and confirmed faunal load (Lockwood et al. 1988). Further density in forest ecosystem was based on visual estimation of acridid number (Pfadt, 1994). The survey resulted in the collections of nearly 20 species of which 15 have been identified and confirmed (Table 1). Figure 1-15 depicts these

Fig. 1. *Cyrtacanthris tetarica*

Table 1. Acrididea species collected

S.No	Name of the Species	Family
1.	*Cyrtacanthacris tartarica*	Acrididae
2.	*Atractomorpha crerulata* (green)	Acrididae
3.	*Atractomorpha crerulata* (brown)	Acrididae
4.	*Acrida exaltata* (green)	Acrididae
5.	*Acridaexaltata* (green banded)	Acrididae
6.	*Heteracris pulcher*	Acrididae
7.	*Trilophidia annulata*	Acrididae
8.	*Gastrimargus africanes africanus*	Acrididae
9.	*Diabolo catantops pinguis*	Acrididae
10.	*Morphacris fasciata sulcata*	Acrididae
11.	*Orthacris maindioni*	Pyrgomorphidae
12.	*Phlaeoba penteli*	Acrididae
13.	*Oedaleus abruptus*	Acrididae
14.	*Spathosternum prasiniferum*	Acrididae
15.	*Truxalis indica*	Acrididae

Fig. 2. *Atractomorpha cresulata* (green)

Fig. 4. *Acrida exaltata* (green)

Fig. 3. *Atractomorpha cresulata* (brown)

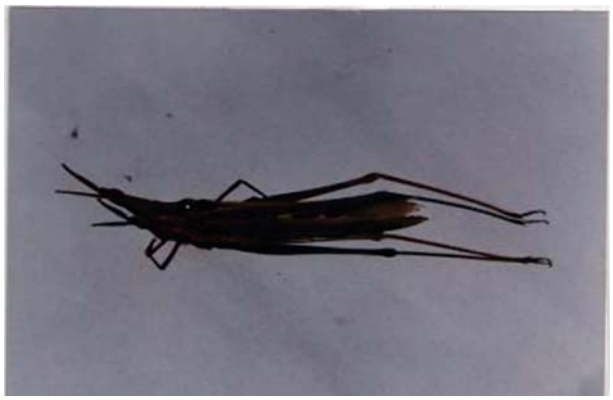

Fig. 5. *Acrida exaltata* (green banded)

Fig. 6. *Heteracris pulcher*

Fig. 7. *Trilophidia annulata*

Fig. 8. *Gastrimargus africanus africanus*

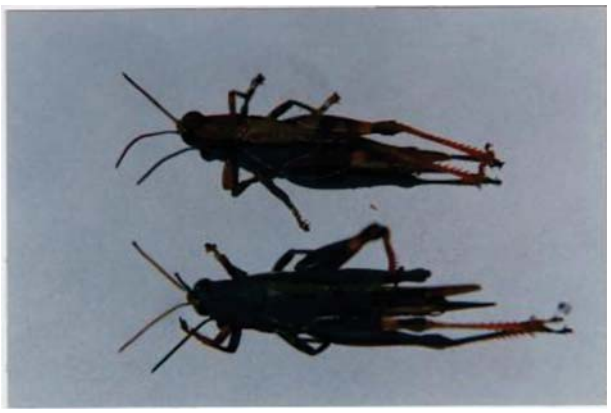

Fig. 9. *Diabolocatantops pinguis*

Fig. 11. *Orthacris maindioni*

Fig. 13. *Oedaleus abruptus*

Fig. 15. *Truxalis indica*

Fig. 10. *Morphacris fasciata sulcata*

Fig. 12. *Phlaeoba penteli*

Fig. 14. *Spathosternum prasiniferum*

grasshopperswhich belong to only the families Acrididae and Pyrgomorphidae as shown in Table 1. All of them are represented in all the three stations. As reported by Muralirangan *et al.* (1993), almost all of the agroecosystems were observed to support similar species of grasshoppers.

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WHITEFLY, *BEMISIA TABACI* (GENNADIUS) AS INFLUENCED BY HOST PLANTS IN HARYANA

S.C. KEDAR*, R.K. SAINI AND K.M. KUMARANAG

Department of Entomology
Chaudhary Charan Singh Haryana Agricultural University, Hisar 125004
** Email: santoshkedar56@yahoo.com*

ABSTRACT

Surveys at Hisar (Haryana) and nearby areas conducted at fortnightly intervals from 2011 to 2014 identified the host plants of whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) and evaluated its populations on them. The results revealed that among the 114 host plants (belonging to 32 families) identified, 35 were weeds, 25 ornamentals, 20 field crops, 17 vegetables, 13 medicinal plants and 4 fruit crops. Based on number of species/family serving as hosts and population density, it was observed that plants belonging to the family Fabaceae, Asteraceae, Solanaceae, Malvaceae and Cucurbitaceae were the most preferred and important families. Host plants supporting it during spring, summer and winter seasons are also categorised. Implications with respect to management are discussed.

Key words: *Bemisia tabaci*, Hisar, host plants, families, population, seasonal variations, intensity

The whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) is a devastating pest of vegetables, ornamentals and agricultural crops throughout the tropical and subtropical regions of the world (Oliveira et al., 2001). More than 900 plant species are known to be its hosts (Attique et al., 2003; Greathead, 1986; Mound and Halsey, 1978; Secker et al., 1998; Oliveira et al., 2001; GISD, 2005). Available literature indicates that it has greater attraction for the plants belonging to the families Fabaceae (=Leguminosae), Asteraceae, Malvaceae, Solanaceae, Cruciferae, Cucurbitaceae and Euphorbiaceae (Mound and Halsey, 1978; Li et al., 2011). In India, *B. tabaci* was first recorded on cotton from Pusa (Bihar) during 1905 and was described as *Bemisia gossypiperda* (Mishra and Lamba, 1929). Hussain and Trehan (1933) reported 44 host plants of *B. tabaci* in India. Some of its preferred host plants, particularly those present throughout the year or for most part of the year, can greatly help its perpetuation (Singh et al., 1994; Nehra et al., 2004).

In Haryana, the major cotton growing districts, Hisar, Fatehbad, Sirsa Jind, Bhiwani and Rohtak had been known to have almost similar composition of weed flora (Punia et al., 2010; Singh et al., 1995). Apart from supporting population, several weed species such as *Althea rosea, Achyranthus aspera, Chenopodium album, Convolvulus arvensis, Croton sperciflorus, Clerodeadron eneansi, Corchorus acutangularis, Eclipta alba, Parthenium hysterophorus, Lantana camara, Sida spinosa, Trianthema monogyna* and *Tribulus terrestris* also serve as a source of inoculum for diseases such as cotton leaf curl virus (Kranthi, 2014). Sivalingam et al. (2007) underlines the importance of such plants with respect to pest and disease management. Information on the host plants supporting *B. tabaci* through different seasons in Hisar, Haryana is lacking. Therefore, it was considered worthwhile to conduct surveys of the cotton growing areas for identifying host plants that play significant role in the pest survival (Hussain and Trehan, 1933, Abd-Rabou and Simmons, 2010).

MATERIALS AND METHODS

The host plants of *B. tabaci* were observed round the year at fortnightly intervals in and around Hisar from May, 2011 to December, 2014. Such plants included vegetables, ornamentals, field crops, medicinal plants and fruit trees, as well as weeds growing on farmland, and along roadsides and water channels. A plant was considered as the host of *B. tabaci* when all development stages were found on that plant. For each plant, whitefly nymphal population from a minimum of 30 plants taking 2-3 leaves/ plant from the upper half canopy was recorded. In case of trees, 2-3 leaves from branches in distributed in four directions were collected. For this purpose leaves of different host plants bearing nymphs and pupae were plucked and

collected in separate polyethylene bags. Leaf samples were processed in the laboratory for the preparation of slide mounts of fourth instars/pupae by adopting earlier methodology (Dubey and Ramamurthy, 2012). With puparia characters, taxonomic confirmation of the species using the keys provided by EPPO (EPPO, 2004) was made. Since leaf size varied from species to species, population density among host plants, the population data were converted to number of nymphs and puparia /10cm^2 leaf area as suggested by Attique et al. (2003). Based on population density, host plants were graded into four categories suggested by Qiu et al. (2001) as under:

Grade 1: <10 nymphs and puparia/10 cm^2 leaf area; Grade 2: 11–30 nymphs and puparia/10 cm^2 leaf area; Grade 3: 31–50 nymphs and puparia/10 cm^2 leaf area; and Grade 4: > 50 nymphs and puparia/10 cm^2 leaf area. Plant families with maximum number of host plants were identified.

RESULTS AND DISCUSSION

Bemisia tabaci was observed to breed and survive on as many as 114 host plants belonging 32 families in Hisar (Table 1). Such a wide host range had earlier been reported by many workers: 44 (Hussain and Trehan, 1933); 160 (Attique et al., 2003); 361 (Li et al., 2011); and 118 (Abd-Rabou and Simmons, 2010). Based on these number, three categories made viz., Category A- Families with 10 or >10 host plants; Category B- Families with 5-9 host plants; and Category C-- Families with < 5 host plants. Category A included Asteraceae, Fabaceae and Solanaceae; category B included Amaranthaceae, Brassicaceae, Cucurbitaceae, Lamiaceae, and Malvaceae; while the remaining belonged to category C (Fig.1). Family Fabaceae included the highest number of host plants i.e. 20. Earlier, Fabaceae had been reported to include 25 species (Li et al., 2011); 17 (Abd-Rabou and Simmons, 2010); and 14 (Attique et al., 2003).

Amongst these hosts, 35 were weeds, 25 ornamentals, 20 field crops, 17 vegetables, 13 medicinal plants and four fruit crops (Fig. 2); maximum were weeds and ornamentals, followed by field crops, vegetables, medicinal plants and fruit trees. Many weeds and ornamental plants harbour *B. tabaci* during off season (Li et al., 2011; Attique et al., 2003; Alegbejo and Banwo, 2005).

Round the year, some plants, particularly the perennials harboured this pest for longer duration, and

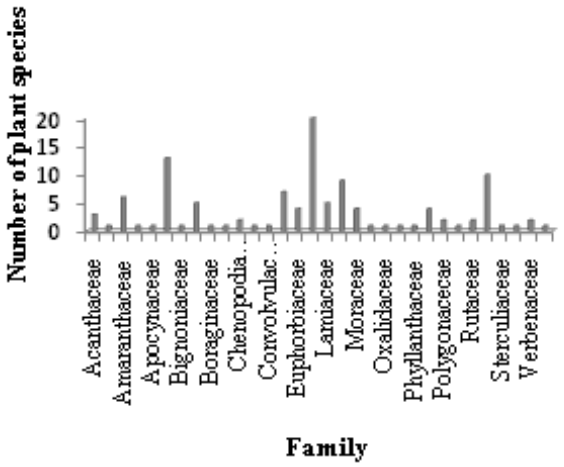

Fig. 1. Plant families infested by *B. tabaci*

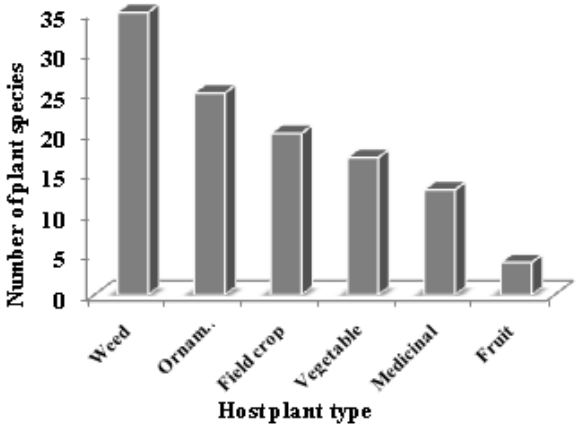

Fig. 2. Categories of plants infested by *B. tabaci*

these include: *Abutilon indicum*, *Duranta erecta*, *Lantana camara*, *Corchorus trilocularis*, *Oxalis corniculata*, *Ficus religiosa*, *Urena lobata*, *Crateva religiosa*, *Tecoma stans*, *Parthenium hysterophorus*, *Solanum nigrum*, *Sonchus oleraceus* and *Vernonia cinerea*. Singh et al. (1994) observed that whitefly remained active throughout the year in Punjab. *B. tabaci* population was observed on 25 plants during the *kharif* (Table 1); and in the off season (November to March), it survived on 26 plants.

Importance of winter host plants in overwintering was highlighted by Hussain and Trehan, 1933; Hussain et al., 1936; Mohyuddin et al., 1989; Sharma and Rishi, 2003; Attique et al., 2003; Alegbejo and Banwo, 2005; Li et al., 2011. However, due to the low temperature during winter, smaller population was observed in the present study. Rafiq et al. (2008) also reported that the during winter whitefly breeds at a slow rate and they further concluded that winter hosts play pivotal

Table 1. *Bemisia tabaci* activity vs. host plants and season

No.	Family	Host	Period	Host Type	Grade*
1	Acanthaceae	*Crossandra infundibuliformis* L.*	July-November	Ornamental	1
2		*Justicia adhatoda* L.*	June-September	Medicinal	1
3		*Ruellia tuberosa* L.*	June-October	Ornamental	2
4	Aizoaceae	*Trianthema portulacastrum* L.*	June- September	Weed	1
5	Amaranthaceae	*Achyranthes aspera* L.*	June- September	Weed	1
6		*Amaranthus spinosus* L.*	June- September	Weed	1
7		*Amaranthus viridis* L.*	June- September	Weed	1
8		*Celosia argentea* L.*	July-October	Ornamental	1
9		*Digeria arvensis* Forssk.*	June- September	Weed	1
10		*Spinacia oleracea* L.*	July-October	Vegetable	1
11	Apiaceae	*Coriandrum sativum* L.**	January-April	Vegetable	1
12	Apocynaceae	*Carissa carandas* L.*	July- October	Ornamental	1
13	Asteraceae	*Ageratum conyzoides* L.$	February-May	Weed	1
14		*Chrysanthemum morifolium* Ramat**	December-March	Ornamental	1
15		*Cirsium arvense* L.**	November-March	Weed	1
16		*Conyza canadensis* (L.)*	June-September	Weed	1
17		*Helianthus annuus* L.$	March-June	Field crop	2
18		*Launea asplenifolia (Willd.)* Hook.f.*	June- October	Weed	1
19		*Parthenium hysterophorus* L.**	January-December	Weed	1
20		*Sonchus oleraceus* L.**	January-December	Weed	1
21		*Tagetes erecta* L.**	September-December	Ornamental	1
22		*Tagetes patula* L.**	September-December	Ornamental	2
23		*Tridax procumbens* L.*	June- October	Weed	1
24		*Vernonia cinerea* (L.)**	January-December	Weed	1
25		*Xanthium strumarium* L.*	June- October	Weed	2
26	Bignoniaceae	*Tecoma stans* (L.) Juss. ex Kunth**	January-December	Ornamental	2
27	Brassicaceae	*Brassica napus* L.**	October -January	Field crop	1
28		*Brassica oleracea var. capitata* L.**	October -January	Vegetable	1
29		*Brassica oleracea var. botrytis* L.**	October -January	Vegetable	1
30		*Brassica rapa* L.**	October -January	Field crop	1
31		*Raphanus sativus* L.**	November-February	Vegetable	1
32	Boraginaceae	*Heliotropium indicum* L.$	March-July	Weed	1
33	Capparaceae	*Crateva religiosa* G. Forst.#	January-December	Ornamental	1
34	Chenopodiaceae	*Chenopodium album* L.**	February-April	Weed	1
35		*Chenopodium murale* L.**	February-April	Weed	1
36	Combretaceae	*Combretum indicum* (L.) DeFilipps	March-October	Ornamental	1
37	Convolvulaceae	*Convolvulus arvensis* L.**	January-March	Weed	1
38	Cucurbitaceae	*Cucumis sativus* L.*	June- August	Vegetable	2
39		*Momordica charantia* L.*	June- August	Vegetable	1
40	Cucurbitaceae	*Benincasa hispida* Thunb.$	March-May	Vegetable	2
41		*Cucurbita moschata* Duchesne.*	July-October	Vegetable	2
42		*Cucumis callosus* (Rottl.)*	July- September	Weed	2
43		*Lagenaria siceraria* (Molina) Standl.$	March-May	Vegetable	2
44		*Luffa acutangula* L.$	March-May	Vegetable	2
45	Euphorbiaceae	*Euphorbia hirta* L.*	June- September	Weed	1
46		*Jatropha curca* L.*	July- October	Field crop	1
47		*Jatropha pandurifolia* L.*	July- October	Ornamental	1
48		*Ricinus communis* L.*	July- October	Field crop	1
49	Fabaceae	*Arachis hypogaea* L.*	July- September	Field crop	1
50		*Bauhinia variegata L.***	October-December	Ornamental	1

51		*Caesalpinia pulcherrima* Sw.*	August-October	Ornamental	1
52		*Cajanus cajan* (L.) Millsp.*	August- October	Field crop	1
53		*Cassia fistula* L.*	August-October	Ornamental	1
54		*Cassia tora* L.*	June- October	Weed	1
55		*Cyamopsis tetragonoloba* L.*	July-September	Field crop	1
56		*Dalbergia sissoo* Roxb.*	June- October	Ornamental	3
57		*Glycine max* (L.) Merr.*	July-October	Field crop	4
58		*Lablab purpureus* L.*	July-October	Field crop	3
59		*Mucuna pruriens* L.*	July-September	Medicinal	3
60		*Pisum sativum* L.**	February-March	Field crop	1
61		*Psoralea corylifolia* L.*	July-December	Medicinal	1
62		*Sesbania aculeata* L.*	August-October	Field crop	1
63		*Trifolium alexandrinum* L.$	March-May	Field crop	1
64		*Trigonella foenum-graecum* L.*	June-August	Vegetable	1
65		*Vigna mungo* L.*	July-September	Field crop	3
66		*Vigna radiata* L.*	June-October	Field crop	2
67		*Vigna umbellata* (Thunb.) Ohwi & Ohashi*	July-October	Field crop	4
68		*Vigna unguiculata* (L.) Walp.*	July- September	Field crop	1
69	Lamiaceae	*Mentha spicata* L.*	June-October	Medicinal	1
70		*Ocimum basilicum* L*.	July-September	Medicinal	1
71		*Ocimum tenuiflorum* L.*	June- September	Medicinal	1
72		*Premna serratifolia* L.*	July-October	Medicinal	1
73		*Vitex negundo* L.*	June- September	Medicinal	1
74	Malvaceae	*Abutilon indicum* L.	January-December	Weed	3
75		*Gossypium hirsutum* L.*	June-November	Field crop	4
76		*Grewia asiatica* L.*	July- October	Fruit	1
77		*Sida cordifolia* L.$	March-May	Weed	1
78		*Urena lobata* L.	January-December	Weed	2
79	Malvaceae	*Abelmoschus esculentus* (L.) Moench.$	March-September	Vegetable	2
80		*Altea rosea* L.*	July- October	Ornamental	2
81		*Gossypium arboreum* L.*	June- November	Field crop	2
82		*Hibiscus rosa sinensis* L.*	May-November	Ornamental	2
83	Moraceae	*Ficus religiosa* L.	January-December	Medicinal	2
84		*Ficus benjamina* L.*	May-September	Ornamental	2
85		*Ficus infectoria* L.$	March-June	Ornamental	3
86		*Morus alba* L.$	March-June	Medicinal	1
87	Oleaceae	*Nyctanthes arbor-tristis* L.*	May-September	Ornamental	2
88	Oxalidaceae	*Oxalis corniculata* L.	January-December	Weed	1
89	Pedaliaceae	*Sesamum indicum* L.*	July-September	Field crop	1
90	Phyllanthaceae	*Bridelia montana* (Roxb.) Willd*	August-October	Medicinal	1
91	Poaceae	*Phalaris minor* Retz.**	January-March	Medicinal	1
92		*Cynodon dactylon* L.*	July-October	Weed	1
93		*Eleusine indica* (L.) Gaertn.*	July-October	Weed	1
94		*Echinochloa colona* L.*	July-October	Weed	1
95	Polygonacecae	*Polygonum plebejum* (J.)*	June-September	Weed	1
96		*Rumex dendatus* L.**	December-February	Weed	1
97	Rhamanaceae	*Zizyphus rotundifolia* Lamk.*	July- September	Fruit	1
98	Rutaceae	*Citrus sinensis* Osb.$	March-May	Fruit	1
99		*Citrus reticulata* L.$	March-May	Fruit	1
100	Solanaceae	*Capsicum annuum* L.*	July- October	Vegetable	1
101		*Cestrum diurnum* L.**	November-March	Ornamental	1
102		*Nicotina palembagnifolia* L.*	June-September	Weed	1
103		*Petunia hybrida* L.**	January-March	Ornamental	1

104		*Physalis minima* L.*	June- October	Weed	1
105		*Solanum lycopersicum* L.$	March-May	Vegetable	1
106		*Solanum melongena* L.*	July-November	Vegetable	3
107		*Solanum nigrum* L.	January-December	Weed	1
108		*Solanum tuberosum* L.**	October-January	Vegetable	1
109		*Withania somnifera* L.*	June- October	Medicinal	1
110	Sterculiaceae	*Abroma augusta* L.*	July-September	Ornamental	1
111	Tiliaceae	*Corchorus trilocularis* L.	January-December	Weed	1
112	Verbenaceae	*Lantana camara* L.	January-December	Weed	1
113		*Duranta erecta* L.	January-December	Ornamental	1
114	Zygophyllaceae	*Tribulus terrestris* L.*	July- September	Ornamental	1

*Grade 1: <10 nymphs and pupae/10 cm^2 leaf area; 2: 11–30; 3: 31–50; and 4: > 50; * kharif season; ** rabi; $- spring host plants

role in its carry over. After winter (i.e. from March onwards) increase in temperature results in rapid multiplication on almost all the available hosts.

Host plants growing during spring such *H. annuus, H. indicum, C. indicum, C. album, C. murale, B. hispida, L. siceraria, L. acutangula, T. alexandrinum, S. cordifolia, A. esculentus, M. alba, C. sinensis, C. reticulata* and *S. lycopersicum* greatly help in early population buildup. Role of these spring hosts as major source of infestation and contribution of these in the carry over is known (Mabbit, 1978; Butler et al., 1986; Johnson et al., 1982; Gerling, 1984; Mohyuddin et al., 1989.

As regards rate of incidence, based on density of nymphs and pupae per unit area, 20 plant species were categorized in the 2nd Grade; amongst these, six species belonged to Cucurbitaceae, five to Malvaceae, three to Asteraceae, two to Moraceae and one each to Fabaceae, Acanthaceae, Bignoniaceae and Oleaceae. Seven species are of 3rd Grade- of these four belonged to Fabaceae and one each to Solanaceae, Moraceae and Malvaceae. In the 4th Grade, two plant species belong to Fabaceae and one to Malvaceae. Li et al. (2011) from China also reported that the host plants belonging to families Asteraceae, Cruciferae, Cucurbitaceae, Solanaceae and Fabaceae were the most preferred. Other workers had also reported that a number of hosts belonging to the above families are favoured host plants (Hussain and Trehan, 1933; Azab et al., 1970; Attique et al., 2003; Alegbejo and Banwo, 5; Li et al., 2011; Zarei et al., 2013).

Thus the observations reveal that host plants belonging to Family Fabaceae, Asteraceae, Solanaceae, Malvaceae and Cucurbitaceae seemed to be more preferred. These harboured greater density of populations, and some perennial weed hosts and ornamentals served as reservoirs of population, particularly during winter and spring season. Successful management of whitefly would depend on estimating such variations in the population buildup on alternate weed host plants and preventing possible outbreaks. The surveillance of the entire crop ecosystem for the host plants that favour rapid increase in the populaion is essential for planning a successful IPM.

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EVALUATION OF INSECTICIDES AGAINST CHIKU MOTH *NEPHOPTERYX EUGRAPHELLA* RAGONOT

D. R. PATEL*, J. J. PATEL, D.V. MUCHHADIYA, R.R. PATEL AND K.G. PATEL

Department of Entomology, College of Agriculture
Navsari Agricultural University, Bharuch 392012
**Email: patel.devendra2829@yahoo.com*

ABSTRACT

A field trial was laid out at the College Farm, College of Agriculture, N. A. U., Bharuch (Gujarat) to evaluate the efficacy of newer insecticides against chiku moth, *Nephopteryx eugraphella* Ragonot infesting sapota during 2012-13 to 2014-15. All the treatments were observed to be significantly superior over control. Considering the effectiveness, yield, net return and economics, flubendiamide 39.35SC @ 0.0096% was found to be the most effective followed by emamectin benzoate 5SG @ 0.0022% and spinosad 45 SC @ 0.009%.

Key words: Sapota, *Nephopteryx eugraphella*, flubendiamide, emamectin benzoate, spinosad, yield, net return, efficacy

Sapota or sapodilla [*Manilkara achras* (Mill) Fosberg], synonym *(Achras sapota* L.) belongs to family Sapotaceae, commonly known as 'chiku' is evergreen fruit tree. Though it is considered as a hardy crop, various factors affect its yield. Amongst these, damage by various insect pests is a major constraint. As many as 25 insect pests had been reported attacking sapota in India (Butani, 1979). In Gujarat, 16 insect pests and mites had been found damaging sapota (Patel, 2001), and these include bud borer, chiku moth, midrib folder, leaf miner, fruit flies and sucking pests. Among these, chiku moth, *Nephopteryx eugraphella* Ragonot is the major pest as it affects the fruit yield considerably (Sandhu, 1974). Considering its importance, an experiment was conducted to evaluate the field efficacy of insecticides and the results presented herein.

MATERIALS AND METHODS

The experiment was carried out at the College Farm, College of Agriculture, N. A. U., Bharuch (Gujarat) during 2012-13, 2013-14 and 2014-15. Thirty trees of variety Kalipatti were selected and Randomized Block Design was used with three replications and seven treatments (one tree kept as treatment). The treatments include: T1-Spinosad 45 SC @ 0.009%; T2- Emamectin benzoate 5 SG @ 0.0022 %;T3- Novaluron 10 EC @ 0.01%; T4- Profenofos 40% + cypermethrin 4% @ 0.044%; T5- Lambda-cyhalothrin 5 SC @ 0.005%; T6- Flubendiamide 39.35 SC @ 0.0096% ; and T7- Control. Three sprays of respective insecticides were given at 30 days interval. Observations on % fruit damage were recorded 10, 20 and 30 days after each spray. For this 30 fruits/ tree were observed for infestation. The incremental cost benefit ratio (ICBR) was worked out on the basis of cost of various treatments including prevailing labour charges and producer sale price of fruits. Residual analysis of insecticides in fruits were carried out at the Food Quality Testing Laboratory, Navsari Agricultural University, Navsari.

RESULTS AND DISCUSSION

All the treatments were observed to be significantly superior over control in reducing the infestation. The pretreatment data was found to differ non significantly (Table 1). The post treatment pooled data after 10, 20 and 30 days of first spray showed significantly lower infestation with flubendiamide 39.35 SC @ 0.0096% (6.14%), than others but it was at par with emamectin benzoate 5 SG @ 0.0022% (6.94%) (Table 2). The next best was spinosad 45 SC @ 0.009% (7.59%) followed by novaluron 10 EC @ 0.01% (9.25%), profenofos 40% + cypermethrin 4% (9.61%) and lambda-cyhalothrin 5 EC @ 0.005% (10.61%).

More or less similar trend was observed after second spray, with the lowest infestation being with flubendiamide which was found at par with emamectin benzoate; pooled data after third spray revealed that the least infestation was again with flubendiamide and

Table 1. Field infestation of *Nephopteryx eugraphella* – pre treatment

Treatments		Mean % fruit infestation			
		2012-13	2013-14	2014-15	Pooled
1	Spinosad 45 SC @ 0.009%	19.16	21.14	18.26	19.52
	(11.11)	(11.11)	(13.33)	(10.00)	(11.48)
2	Emamectine benzoate 5 SG @ 0.0022 %	20.15	23.12	22.30	21.86
		(12.22)	(15.56)	(14.44)	(14.07)
3	Novaluron 10 EC @ 0.01%	19.16	23.64	19.16	20.65
		(11.11)	(16.67)	(11.11)	(12.96)
4	Profenofos 40% + cypermethrin 4%@ 0.044%	20.15	23.12	19.26	20.84
		(12.22)	(15.56)	(11.11)	(12.96)
5	Lambda-cyhalothrin 5 EC @ 0.005%	20.41	24.53	21.14	22.03
		(12.22)	(17.78)	(13.33)	(14.44)
6	Flubendiamide 39.35 SC @ 0.0096%	21.30	24.78	22.13	22.74
		(13.33)	(17.78)	(14.44)	(15.19)
7	Control (Water spray)	21.31	22.90	21.31	21.84
		(13.33)	(15.56)	(13.33)	(14.07)
	SE.m±	2.11	2.37	2.27	1.15
	CD @ 5%	NS	NS	NS	NS
	SE.m± (YxT)	-	-	-	2.25
	CD @ 5%	-	-	-	NS
	CV%	18.08	17.62	19.21	18.30

Figures outside parentheses arcsine transformed values

emamectin benzoate found at par with each other. Interactions (Y x T) were insignificant indicating the consistent performance of treatments over the years. A similar trend was also observed by Shinde et al. (2010) that emamectin benzoate 5% SG and lambda-cyhelotrin 5EC were effective against sapota bud borer.

As regards yield, pooled data indicate that all the insecticidal treatments were found to be significantly superior over untreated control (Table 3). The highest marketable fruit yield was obtained with flubendiamide 39.35 SC @ 0.0096% (53.28 kg/tree) in comparison to profenofos 40% + cypermethrin 4% (41.5 kg/tree) and lambda-cyhalothrin 5 EC @ 0.005% (41.4kg/tree); it remained at par with emamectin benzoate 5 SG @0.0022% (52.39 kg/tree), spinosad 45 SC @ 0.009% (50.67 kg/tree) and novaluron 10 EC @ 0.01% (48.89 kg/ha). The pooled data over periods on the interaction revealed insignificant differences indicating the consistent performance of treatments.

There were only below detectable level residue in fruit in the three best treatments i.e. flubendiamide 39.35 SC @ 0.0096%, emamectin benzoate 5 SG @ 0.0022% and spinosad 45 SC @ 0.009%, at 10 days after spraying as indicated by the residual analysis carried out in the Food Quality Testing Laboratory, NAU, Navsari.

The analysis of net return indicates that flubendiamide 48 SC @ 0.0096% was the best with maximum net return (Rs. 75575/ha) followed by emamectin benzoate 5 SG 0.002% (Rs.73034/ha), spinosad 45 SC @ 0.009% (Rs. 71323) and novaluron 10 EC @ 0.01% (Rs68941) (Table 4). In terms of CBR, lambda-cyhalothrin 5 SC @ 0.005 %(1:4.92) followed by profenofos 40% + cypermethrin 4% (1:4.49), flubendiamide 48 SC @ 0.0096% (1:3.64), spinosad 45 SC @ 0.009% (1:3.00) and emamectin benzoate 5 SG 0.002% (1: 2.86) were superior.

Thus flubendiamide, emamectin benzoate, spinosad, novaluron, profenofos 40%+ cypermethrin and lambda-cyhalothrin were effective and economical.

Table 2. Infestation of *Nephopteryx eugraphella* after first spary (2012-13 to 2014-15)

	Treatment	Mean % fruit infestation (pooled)											
		After first spray				After second spray				After third spray			
		10 DAS	20DAS	30DAS	Pooled	10 DAS	20DAS	30DAS	Pooled	10 DAS	20DAS	30DAS	Pooled
1	Spinosad 45 SC @ 0.009%	15.63 (7.25)	15.19 (6.86)	17.17 (8.71)	15.99 (7.59)	14.36 (6.15)	16.01 (7.60)	17.47 (9.01)	15.65 (7.28)	14.48 (6.25)	15.08 (6.77)	18.41 (9.97)	15.99 (7.59)
2	Emamectine benzoate 5 SG @ 0.0022 %	15.48 (7.12)	14.81 (6.53)	15.55 (7.19)	15.28 (6.94)	13.37 (5.34)	14.25 (6.06)	17.22 (8.77)	14.82 (6.54)	13.87 (5.74)	13.60 (5.53)	15.85 (7.46)	14.44 (6.22)
3	Novaluron 10 EC @ 0.01%	17.61 (7.58)	19.53 (9.15)	17.70 (11.18)	15.84 (9.25)	16.84 (7.45)	18.62 (8.39)	16.86 (10.20)	14.64 (8.41)	16.78 (6.39)	20.60 (8.33)	17.34 (12.38)	15.99 (8.88)
4	Profenofos 40% + cypermethrin 4% @ 0.044%	18.12 (9.67)	17.03 (8.57)	19.04 (10.64)	18.06 (9.61)	16.34 (7.91)	18.24 (9.79)	20.57 (12.35)	17.93 (9.48)	16.34 (7.91)	18.81 (10.39)	20.93 (12.76)	18.69 (10.27)
5	Lambda-cyhalothrin 5 EC @ 0.005%	19.27 (10.89)	17.79 (9.34)	19.95 (11.64)	19.00 (10.61)	15.95 (7.55)	18.99 (10.59)	20.63 (12.41)	18.29 (9.85)	16.23 (7.82)	20.24 (11.97)	21.02 (12.86)	19.17 (10.77)
6	Flubendiamide 39.35 SC @ 0.0096%	13.45 (5.40)	12.77 (4.89)	16.84 (8.39)	14.35 (6.14)	12.98 (5.05)	12.88 (4.97)	15.85 (7.46)	13.61 (5.54)	12.00 (4.32)	13.60 (5.53)	16.22 (7.80)	13.94 (5.80)
7	Control (Water spray)	22.90 (15.15)	23.35 (15.70)	24.59 (17.33)	23.61 (16.04)	21.55 (13.50)	22.88 (15.08)	23.41 (15.79)	22.51 (14.66)	22.79 (14.99)	21.61 (13.57)	25.98 (19.19)	23.46 (15.85)
	SE.m±	0.90	0.94	0.92	0.53	0.90	0.96	0.73	0.46	1.07	1.07	0.88	0.52
	CD @ 5%	2.56	2.70	2.62	1.49	2.59	2.78	2.12	1.30	3.08	3.32	2.53	1.47
	SE.m±(YxT)	1.48	1.78	1.57	0.92	1.56	1.67	1.28	0.80	1.86	1.30	1.53	0.91
	CD @ 5%(YxT)	NS	NS	NS	NS	NS	NS	NS	NS	NS	3.75	NS	NS
	CV%	14.92	18.30	14.37	15.64	17.18	16.92	11.61	14.19	20.48	13.25	13.36	15.59

Table 3. Fruit yield vs. insecticidal treatments (2012-13 to 2014-15)

	Treatments	Fruit yield (Kg/tree)			
		2012-13	2013-14	2014-15	Pooled
1	Spinosad 45 SC @ 0.009%	48.17	50.17	53.67	50.67
2	Emamectine benzoate 5 SG @ 0.0022 %	49.50	51.83	55.83	52.39
3	Novaluron 10 EC @ 0.01%	47.17	49.67	49.83	48.89
4	Profenofos 40% + cypermethrin 4% @ 0.044%	38.50	42.50	43.50	41.50
5	Lambda-cyhalothrin 5 EC @ 0.005%	37.67	42.17	44.50	41.44
6	Flubendiamide 39.35 SC @ 0.0096%	50.83	52.83	56.17	53.28
7	Control (Water spray)	29.50	33.50	33.33	32.11
	SE.m±	2.58	2.81	3.21	1.66
	CD @ 5%	7.97	8.66	9.88	4.77
	SE.m± (YxT)	-	-	-	2.87
	CD @ 5%	-	-	-	NS
	CV%	10.41	10.56	11.54	10.90

Table 4. Economics of insecticidal treatments

Sr. No.	Treatments	Total spray	Quantity of insecticides/ha (3 spray)	Cost of insecticides (Rs/ha)	Labour charges (Rs/ha)	Total cost of treatments (Rs/ha)	Fruit yield (kg/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Additional benefit over control (Rs.)	CBR
1	2	3	4	5	6	7	8	9	10	11	12
T1	Spinosad 45 SC @ 0.009%	3	360 ml	5760	1962	7722	7905	79045	71323	23194	1:3.00
T2	Emamectine benzoate 5 SG @ 0.0022 %	3	792 gm	6732	1962	8694	8173	81728	73034	24905	1:2.86
T3	Novaluron 10 EC @ 0.01%	3	1800 ml	6660	1962	8622	7756	77563	68941	20812	1:2.41
T4	Profenofos 40% + cypermethrin 4% @ 0.044%	3	1800 ml	1062	1962	3024	6474	64740	61716	13586	1:4.49
T5	Lambda-cyhalothrin 5 SC @ 0.005%	3	1800 ml	828	1962	2790	6465	64646	61856	13727	1:4.92
T6	Flubendiamide 39.35 SC @ 0.0096%	3	360 ml	5580	1962	7542	8312	83117	75575	27445	1:3.64
T7	Control (Water spray)	3	-	-	1962	1962	5009	50092	48130	-	-

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EMERGING INSECT PESTS IN INDIAN AGRICULTURE

MANDEEP RATHEE* AND PRADEEP DALAL

Department of Entomology
Chaudhary Charan Singh Haryana Agricultural University, Hisar 125004
**Email: mndprathee@gmail.com (corresponding author)*

ABSTRACT

One of the major challenges to humankind is threat to food security due to emerging and invasive pests. Increased global trade in agriculture has increased the chances of the introduction of exotic pests. Papaya mealybug (*Paracoccus marginatus* Williams and Granara de Willink), cotton mealybug *Phenacoccus solenopsis* (Tinsley), coconut mite (*Aceria guerreronis* Keifer), serpentine leaf miner (*Liriomyza trifolii* Burgess) and tomato leaf miner [*Tuta absoluta* (Meyrick)] are some examples. Insect pests on an average are estimated to cause 15-20% yield losses in principal major food and cash crops. Pest whose status has been changing from minor to major or secondary to primary pest is termed as an emerging pest. *Bemisia tabaci* (Gennadius) on cotton, *Helicoverpa armigera* (Hubner) on vegetables and pulses, *Spodoptera litura* (F.) on vegetables, cotton and oilseeds, *Pieris brassicae* L. on crucifers, *L. trifolii* on vegetables and *Atherigonia* spp. on spring maize, have become increasingly severe during last decade. Increasing incidence of aphid complex, comprising of *Sitobion avenae* (F.), *Rhopalosiphum maidis* (Fitch) and *Schizaphis graminum* (Rondani) is now observed on wheat, barley and oat. Mites of the Eriophyiidae and Tetranychidae family have emerged as major pests of bean, brinjal, cotton, cucurbits, okra, apple, ber, citrus and mango in Northern India. *Maruca vitrata* Geyer has emerged as a predominant pest in recent years in all pigeonpea and cowpea growing areas of India causing up to 42% damage in cowpea in Andhra Pradesh. The invasive pest, coconut eriopyhid mite, *Aceria gurrreronis* Keiffer caused 64.16- 89.42% nut infestation in at Thane, Maharashtra in 2014. During 2015-16 an epidemic of whitefly was noticed during August in the cotton growing areas of Haryana and Punjab (Kranthi, 2015). In this review the situation of emerging insect pests of crops is discussed along with the probable reasons for their changing pest status.

Key words: Emerging insect pests, climate change, invasive pests, defoliators, sucking pests, epidemics, changing pest status, reasons

With changes in the cropping pattern, injudicious use of pesticides, climate change and introduction of input intensive high yielding varieties / hybrids / and cultivars there is an imminent shift in pest status. Many pests have expanded their host horizon, developed resistance to pesticides and emerged as major pests. One of the major challenges to food security is due to these emerging and invasive pests. Increased global trade in agriculture has increased chances of the introduction of exotic pests. Papaya mealybug, cotton mealybug, tomato leaf miner, coconut mite and serpentine leaf miner are some recent examples. These invasive pests cause more harm in the absence of natural enemies in the new habitats. Insect pests on an average are estimated to cause 15-20% yield losses in principal food and cash crops. Sucking insect pests and defoliators like mirid bug, mealybug, whitefly, aphids, plant hoppers, shoot fly, and the defoliating tobacco caterpillar, leaf miner and leaf folder *Cnaphalocrocis medinalis* (Guenee) have emerged as major pests (Chakrabarty, 2015). *Helicoverpa armigera* (Hubner) on vegetables and pulses, *Spodoptera litura* (F.) on vegetables, cotton and oilseeds, *Pieris brassicae* (L.) on crucifers, *Liriomyza trifolii* Burgess on vegetables and *Atherigona* spp. on spring maize, have become increasingly severe during last decade. Increasing incidence of aphid complex, comprising of *Sitobion avenae* (F.), *Rhopalosiphum maidis* (Fitch) and *Schizaphis graminum* (Raondani) is being recorded on wheat, barley and oat (Arora and Dhawan, 2011).

Green mirid bug, *Creontiades biseratense* (Distant) has emerged as a pest of cotton in Karnataka, Tamil Nadu, Maharashtra and Andhra Pradesh (Udikeri et al., 2012). Mites belonging to the Eriophyiidae and Tetranychidae have emerged as major pests of bean, brinjal, cotton, cucurbits, okra, apple, ber, citrus and mango in Northern India (Singh and Raghuraman, 2011). *Maruca vitrata* (Geyer) has emerged as a

predominant pest in recent years in all pigeonpea and cowpea growing areas causing up to 42% damage in cowpea at Andhra Pradesh (Halder and Srinivasan, 2012). Bagde and Pashte (2014) reported 64.2-89.4% nut infestation in at Thane, Maharashtra due to an invasive pest, the coconut eriopyhid mite, *A. gurrreronis*. Dhawan et al. (2007) reported 30-40% losses due to mealybug infestation in cotton. In Punjab the losses caused by mealybug were estimated to be Rs. 159 crores to cotton growers during *kharif* season 2007. *B. tabaci* appeared in epidemic form in Punjab during 2015-16, destroying 2/3rd of cotton crop. Cotton crop suffered losses worth Rs. 4200 crores despite use of pesticides worth Rs. 150 crores (Kranthi, 2016). In this review the emerging insect pests of different crops are discussed along with probable reasons for changes in their pest status.

A. Emerging insect pests

The pest reported from an area on a particular crop whose population has been increasing considerably over a period of time causing or likely to cause economic damage is termed as an emerging insect pest. An already known insect pest whose incidence or geographical distribution has been increasing notably, or a newly described indigenous or invasive species is also designated as an emerging insect pest. In other words the pest insect whose status has been changing from minor to major or secondary to primary pest is termed as an emerging insect pest.

B. Reasons for exacerbation of insect pests

Important contributing factors that are expected to contribute towards the future changes in pest problems are climate change, change of genotypes (high yielding varieties), modification of cultural practices such as use of high yielding varieties, monoculture practices, excessive use of fertilizers, injudicious use of pesticides, absence of natural enemies, expansion of irrigation facilities and favourable prevailing microclimatic weather conditions.

a) Climate change

Expansion of geographic range from tropics and subtropics to temperate regions will be resulting in increased abundance of tropical insect species and their sudden outbreaks (Das et al., 2011). *H. armigera* might expand in Northern India on cotton, pulses and vegetables (Sharma et al., 2010).

Physiological and ecological impact due to which some species that are able to adapt to the warmer climates might become major pests. Differential response to temperature changes would disrupt synchronization in phenology between insects and host plants or natural enemies (Dillon et al., 2010). Stress in plants on account of climate change results in pest outbreaks as the plant defense system is lowered due to changes in physiological processes (Sharma et al., 2016).

Changes in insect herbivory due to which more sap feeding insects emerging as major pests when plants are grown at elevated levels of carbon dioxide is known (Hamilton, 2005). Lower foliar nitrogen content due to increased CO_2 cause an increase in food consumption by the herbivores up to 40% (Sharma *et al.*, 2010).

Increased overwintering survival happens due to the temperature expected to increase by 1-5^{o}C within this century (Arora and Dhawan, 2013). Accelerated metabolic rates at higher temperatures might shorten the duration of insect diapause due to faster depletion of stored nutrient resources (Sharma et al., 2010).

Increased number of generations, that occurs with every 2^{o}C rise, in which multivoltine insects might have 1-5 additional generations. Rice stem borer *Chilo suppressalis* (Walker) would produce two generations per year after 2^{o}C warming in Japan (Morimoto et al., 1998). Srinivasa Rao et al. (2014) predicted that the completion of generation of *S. litura* on peanut would be 5-6 days earlier in Gujarat in near future (2021-2025).

Breakdown of host plant resistance, for e.g., severe yield loss in sorghum might occur in India due to breakdown of resistance against midge *Stenodiplosis sorghicola* (Coquillett) and spotted stem borer *Chilo partellus* (Swinhoe) (Sharma et al., 2005).

b) Change of genotypes/impact of transgenics

Introduction of transgenic crops has declined the status of target pests *i.e.*, reduced bollworms in cotton but the population of secondary pests *viz*., whitefly, aphids, plant hoppers, mirid bugs and mealybugs has increased. The pest scenario in cotton ecosystem has changed and sap feeders like whitefly, aphids, plant hoppers, mirid bugs and mealybugs are emerging as serious pests. *Spodoptera litura* and other minor pests like thrips are also becoming serious on cotton (Sarode et al., 2009). New rice genotypes are more infested by rice leaf folder, *C. medinalis* due to higher tannin and phenol content as compared to IR 36 (Punithavalli et al., 2013).

c) Injudicious use of pesticides

The imbalanced indiscriminate use of insecticides has created many problems like of development of resurgence and resistance in many insect species. Important Indian insect pests that have shown resistance against insecticides during 1971-2012 are enlisted in Table 1.

d) Modification of cultural practices/tillage

Zero tillage, rotary tillage and bed planting have contributed to new pest problems in wheat (Singh et al., 2014). Direct seeded rice might also result in change in the pest complex of rice. Thirumurugan et al. (2011) reported the raised bed seedlings (single bud raised bed seedlings transplanted on both sides of the ridges) were more susceptible to shoot borer *Chilo infuscatellus* (Snellen) incidence (31.5%) as compared to conventional planting (two budded setts planted in furrows) (22.4%). Patel et al. (2015) reported that narrow spaced (120×45 cm) and more fertilized (360 kg N/ha) cotton crop was affected most by sucking insect pests *viz*., thrips, *Thrips tabaci* Lindeman (2.8/leaf), aphids, *Aphis gossypii* Glover (14.4/leaf) and leafhoppers, *Amrasca biguttula biguttula* (Ishida) (5.3/leaf).

C. Insects likely to become serious

Based on Puri and Ramamurthy (2009), Prasad and Bambawale (2010), Fand et al. (2012) and Sharma (2014; 2016) some emerging insect pests of major crops likely to become serious are given in Table 2.

Similarly, Arora and Dhawan (2013) presented the changing insect pests scenario in Northern Plains of India due to impact of global climate change. The insect pests like *H. armigera* on vegetables, pulses and seed crops, *S. litura* on vegetables, cotton and oilseeds, *Pieris brassicae* on crucifers, *Liriomyza trifolii* on vegetables, aphid complex in wheat and *Atherigonia* spp. on spring maize, have become increasingly severe during last decade. These are given in Table 3.

D. Recent insect pest invasions

Along with the native insect pests, global climate change has led to invasions of some exotic insect pests in India which might prove devastating to indigenous crops. Invasions by alien species upset the balance of native ecosystems and many of them cause considerable economic loss. Free trade propelled by economic liberalization, privatization and globalization has intensified the movement of goods across frontiers. Geographic barriers without much quarantine have enhanced chances of introduction of exotic pests into agroecosystems. The invaders proliferate in the absence of natural enemies in the new found home. Recently introduced exotic pests which have spread rapidly and established well in India continue to inflict considerable economic loss despite concerted efforts to contain them. Some of the recently introduced invasive insect pests are listed in Table 4.

Table 1. Insecticide resistance in important pests in India (1971-2012)

Common name	Scientific name	Cases
American bollworm	*Helicoverpa armigera* (Hubner)	176
Diamond back moth	*Plutella xylostella* (L.)	43
Pink bollworm	*Pectinophora gossypiella* (Saunders)	40
Sweet potato whitefly	*Bemisia tabaci* (Gennadius)	11
Tea mosquito bug	*Heliothis theivora* Waterhouse	11
Brown plant hopper	*Nilaparvata lugens* (Stal)	6
Spotted bollworm	*Earias vitella* (Fabricius)	3
Red rust flour beetle	*Tribolium castaneum* (Herbst)	3
Lesser grain weevil	*Sitophilus oryzae* (L.)	3
Pulse beetle	*Callosobruchus chinensis* (L.)	1

Source: http://www.pesticideresistance.org/search.php

Table 2. Insect pests likely to become serious (with changes in climate/cropping patterns)

Common name	Scientific name	Crop(s)
Whitefly	*Bemisia tabaci* (Gennadius)	Cotton and tobacco
Fruit fly	*Bactrocera* spp.	Fruits and vegetables
Mealybugs	*Paracoccus marginatus* (Williams and Granara de Willink) and *Phenacoccus solenopsis* Tinsley	Field and horticultural crops
Thrips	Several species *Scirtothrips dorsalis* Hood, *Frankliniella schultzei* Trybom, *Thrips tabaci* L., *Scirtothrips citri* (Moulton)	Groundnut, cotton and citrus
Wheat aphid	*Macrosiphum miscanthi* Takahashi	Wheat, barley and oat
Rice gall midge	*Orselia oryzae* (Wood Mason)	Rice
Serpentine leaf miner	*Liriomyza trifolii* Burgess	Cotton, tomato and cucurbits
Hoppers	*Nilaparvata lugens* Stal and *Nephotettix* spp.	Rice and mango
Pyrilla	*Pyrilla perpusilla* Walker	Sugarcane
Pink stem borer	*Sesamia inferens* Walker	Wheat, maize and sorghum

Table 3. Newly emerging major pests (during last decade in Northern Plains)

Crop(s)	Emerging Insect pests
Cotton	Cotton mealybug, whiteflies, tobacco caterpillar
Wheat, Barley, Oat	Aphid species
Rice	BPH, WBPH, Leaf folder
Maize, sorghum	Shoot fly, Pyrilla
Vegetables	Cabbage caterpillar, tobacco caterpillar (cole crops); American bollworm (okra, cole crops, chilli); leaf miner (cucurbits, tomato); spider mites (brinjal, okra) and aphids (tomato)
Oilseeds	Tobacco caterpillar, cabbage caterpillar
Fruits	Fruit moth (citrus), mealybugs, fruit flies
Cotton	Cotton mealybug, whiteflies, tobacco caterpillar

E. Emerging insect pests of cotton

Insect pest complex in India has substantially changed since the introduction of *Bt* cotton. Sucking insect pests and defoliators like *viz*., mirid bugs, mealybugs, whiteflies and the defoliating tobacco caterpillar which were minor prior to 2002 have become major pests of *Bt* cotton in recent times.

Green mirid bugs, *Creontiades biseratense* (Distant), *Campylomma livida* (Reuter) and *Hyalopeplus linefer* (Walker) (Hemiptera: Miridae): Udikeri et al. (2012) reported that three species of mirid bugs namely, *C. biseratense*, *C. livida* and *H. linefer* are infesting cotton since 2005 in Central and South India. *C. biseratense* is emerging as number one pest in Karnataka, Tamil Nadu, Maharashtra and Andhra Pradesh. In general a high population of mirids was recorded in Haveri (43.9 bugs/25 squares) followed by Belgaum (18.2 bugs/25 squares) and Gulbarga (15.0 bugs/25 squares) districts in 2011. The estimated loss was 449 kg/ha. Maximum incidence of *C. biseratense* was recorded in Haveri district (10 and 13 bugs/5 squares) followed by Dharwad (6 and 9 bugs/5 squares) during 2009 and 2010, respectively, which were recognized as hotspots.

Table 4. Recent insect pest invasions in India

Common name	Scientific name	Crop(s)	Reference(s)
Tomato leaf miner	*Tuta absoluta* (Meyrick)	Tomato	(Sridhar et al., 2014)
Western flower thrips	*Frankliniella occidentalis* (Pergande)	Fruits and vegetables	(Tyagi and Kumar, 2015)
Coffee berry borer	*Hypothenemus hampei* (Ferrari)	Coffee	Singh and Ballal, 1991)
Coconut eriopyhid mite	*Aceria guerreronis*	Coconut	(Sathiamma et al., 1998)
Coconut leaf beetle	*Brontispa longissima* (Gestro)	Coconut	(CPCRI, 2015)
Eucalyptus gall wasp	*Leptocybe invasa* Fisher and La Salle	Eucalyptus	(Jacob et al., 2007)
Papaya mealybug	*Paracoccus marginatus* (William Granara de Willink)	Papaya, cotton and mulberry	(Muniappan et al., 2008)

It was found that the peak incidence of the pest mirids was coinciding with luxuriant reproductive growth of the crop; hence more damage (Rohini et al., 2009).

Cotton whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae): In Punjab, cotton production in 1998 decreased by 75% when compared to 1990 production statistics (Singh et al., 1999). This pest was also reported to cause indirect damage to the crop being a vector of cotton leaf curl virus disease (CLCV). Singh et al. (1994) estimated a loss of 10.6-92.2% in seed cotton yield. In India, CLCV was first detected from Sri Ganganagar in 1993 and Punjab in 1994 (Singh et al., 1999). Many biological characteristics, including multivoltinism, broad host range, ability to migrate, high reproductive rate, tolerance for high temperature, ability to vector a variety of devastating plant viruses and a propensity to develop resistance to wide classes of insecticides underlie its pest potential and have contributed to the difficulty in developing robust and sustainable management system (Naranjo, 2001). Patel et al. (2010) reported whiteflies as a major threat to *Bt* grown throughout the country. Kedar (2014) revealed that *B. tabaci* was present on as many as 114 host plants belonging to 32 families in Haryana.

According to Kranthi (2015) the whitefly has been on a song in North India, three years in a row, especially in Punjab, Haryana and Rajasthan. There was hardly any cotton hybrid that was unaffected with the whitefly and CLCV. the cotton leaf curl virus disease that it transmits, because more than 90% of the *Bt* cotton hybrids under cultivation are highly susceptible to the whiteflies and the cotton leaf curl virus. Other reasons for its resurgence are excessive or indiscriminate use of broad spectrum insecticides such as Fipronil and insecticide mixtures like tank-mix of pyrethroids and acephate. Fields sprayed with repeated insecticide sprays and mixtures of fipronil and pyrethroids had the highest levels of whitefly infestation. A combination of factors such as a) susceptible hybrids, b) hairy or bushy genotypes, c) late sowing, d) high nitrogenous fertilizers, e) inadequate phosphorus and potassium in the soil, f) indiscriminate use of pyrethroids, acephate, fipronil and mixtures, g) whitefly resistance to insecticides (neonicotinoids and pyriethroids), h) scant regard for proper choice of control measures, i) improper spray application methods, j) hormoligosis, k) availability of alternate hosts like guar and moong, and wide range of host plants throughout year and l) favourable weather.

Current status in Haryana and Punjab: During the cotton season 2015-16 an epidemic of whitefly incidence was noticed during August in the cotton growing areas of Haryana and Punjab. The weather during July 2015 (maximum temperature-33.88^{o}C, minimum temperature-26.15^{o}C, relative humidity-67.49 to 88.13%) was ideally suited for whiteflies. Prolonged cloudy conditions and intermittent scanty rains (July-August) caused high humidity and hot weather leading led to whitefly outbreaks. The whitefly populations were above economic thresholds (6 whitefly adults/leaf) in almost all the regions surveyed. Whitefly infestation and the CLCuV disease were noticed from early June to July-August. The insect infestation and whitefly incidence were higher than the previous three years (2012-2014). The virus caused leaf curl symptoms during August in > 90% of

the hybrids surveyed in the three states, except in early sown crop.

Whitefly incidence ranged from 1.6 to 90 adults/3 leaves during July-August in at Sirsa. Thus far, high levels of whitefly infestations were noticed in the second week of August in all the three states. The whitefly population ranged between 20-140 whiteflies/ 3 leaves. In Punjab, whitefly incidence was very severe in Abohar, Faridkot, Fazilka, Muktsar and Mansa districts, to an extent of about 60-90 insects / leaf in some fields. Infestation was also severe in Hansi and Hisar region of Haryana mainly due to planting of susceptible *Bt* cotton hybrids. Cotton in Haryana suffered less whitefly infestations than Punjab during 2015-16 (Kranthi, 2015).

Haryana farmers cultivated hybrids that were tolerant to the leaf curl virus CLCV, while Punjab farmers didn't. Further, more than 75% of Punjab's cotton was sown later than 15th May. In comparison, only about as against 47% of Haryana's cotton area was sown after 15th May. Whereas, more than 85% sowing in Haryana was got completed by the third week of May, and Punjab could not exceed 49.0% sowing even by the third week of May same time. Late sowing in the four main cotton growing districts of Punjab was the main factor that triggered whitefly infestations. Another important reason was success of CICR implemented voicemail mobile weekly advisory programme called through 'E-Kapas' in Haryana as compared to Punjab. The initial messages on the need for timely sowing sent to Haryana farmers resulted in timely sowing in Haryana in 53.1 % of the area before 15th May and 84.0 % of the area by 25th May. On the contrary, the less number of registered farmers for receiving advisories in Punjab resulted in cotton sown at 24.0 % by 15th May and only 49.1 % by 25th May 2015 (Kranthi, 2016).

Cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae): This polyphagous pest has been reported to invade multiply on 154 plant species belonging to 53 families. (Arif et al., 2009). Seventy one, 141, 124 and 194 species of plants belonging to 27, 45, 43 and 50 families serve as hosts for *P. solenopsis* at North, Central, South and across all cotton growing zones in India, respectively (Venilla et al., 2011). *P. solenopsis* was recorded as an invasive and serious pest of *Gossypium hirsutum* L. first at Gujarat (Jhala et al., 2008). In Haryana, the pest was first time reported in 2006 in some villages of Sirsa district, an area adjoining Punjab and spread to more areas during 2007 (Anonymous, 2009a). Dhawan et al. (2007) reported 30-40% losses due to mealybug infestation in cotton. In Punjab the losses caused by mealybug were estimated to be Rs. 159 crores to cotton growers during *kharif* season 2007. Nagrare et al. (2009) also reported that mealybug reduced cotton yields in several parts of Gujarat up to 40-50 %.

Tobacco caterpillar, *Spodoptera litura* (F.) (Lepidoptera: Noctuidae): The intensity of *S. litura* is likely to further increase under the potential climate change, as it has been found to consume more than 30.0 % cotton leaves at elevated CO_2 levels in cotton crop. As Cry1Ac and Cry2Ab are moderately toxic of to *S. litura*, it is likely that the pest may be able to feed and survive on Bollgard II (Kranthi et al., 2009). Incidence of *S. litura* has increased in Punjab on cotton crop in recent years probably due to rise in average minimum temperature (0.07 ºC /year) (Arora and Dhawan, 2013).

Tea mosquito bug or Guava kajji bug, *Helopeltis bryadi* Waterhouse (Hemiptera: Miridae): It is a common pest on guava and tea. However, it appears rarely on cotton crop. It was first time reported on DCH-32 cotton crop in 1996 in at Davangere district and during 2002 in severe form on the same genotype in at Uttar Kannada and Mysore districts of Karnataka. The affected genotypes were interspecific hybrids, a main reason behind the incidence of tea mosquito bug (Udikeri et al., 2012).

Flower bud maggot, *Dasineura gossypii* Fletcher (Diptera: Cecidomyiidae); It appeared as potential pest for the first time in the history of cotton entomology in India during 2009 in at Haveri, Karnataka. It caused 90.0 % fruiting body damage in largely cultivated *Bt* cotton cultivars *viz*., Kanaka and Neeraj. In recent survey cotton hybrids have shown 50-92% square damage. The yield loss attributed was more than 60.0 % during 2009 (Udikeri et al., 2012).

F. Emerging insect pests of rice

Plant hoppers, Brown Plant Hopper, *Nilaparvata lugens* (Stal) and White Backed Plant Hopper, *Sogatella furcifera* (Hovarth) (Hemiptera: Delphacidae): BPH and WBPH have emerged in severe form in Northern India and resulted in failure of more than 3, 33, 000 ha crop during 2008-2009. In Delhi, 40-50% hopper burn damage was recorded occurred during 2009. The main

reasons for hopper outbreak were high humidity (>90%) with temperature between 25-32°C, excessive use of nitrogenous fertilizers, closer crop canopy (spacing 15x10 cm), indiscriminate use of pesticides, hoppers tolerance to neonicotinoids and mortality of natural enemies (Chander and Patel, 2010).

Randhawa et al. (2015) reported that temperatures of 26.4-30.0°C, relative humidity 55-99% and few showers of rain are conducive for BPH population buildup in Punjab. Prasannakumar et al. (2012) studied the effect of elevated CO_2 on BPH population on Pusa Basmati 1 and reported that females laid more eggs (324.3 ± 112.3eggs/female) on the rice plants exposed to elevated CO_2 (570 ± 25 ppm) than at 380 ppm ambient CO_2 (231.7 ± 31.8 eggs). More than two fold increase in population (435.4 ± 62.0 hoppers/hill) at peak incidence compared to ambient CO_2 (121.4 ± 36.8 hoppers/hill) was reported during *kharif* 2010. Crop under elevated CO_2 suffered higher yield loss (26.5%) due to higher BPH population and sucking rate compared to ambient CO_2 (12.4%).

Rice swarming caterpillar, *Spodoptera mauritia* Boisd. (Lepidoptera: Noctuidae): In Eastern India, it has emerged as a regular pest in Odisha, Jharkhand, Bihar and Chhatisgarh. During 2008, a severe outbreak was observed in Cuttack and Sonepur districts of Odisha, where 6-8 larvae/hill were recorded in the at initial crop stage. During 2009, severe outbreak of this pest *S. mauritia* was observed in about 1.25 lakh ha of *kharif* paddy in 13 districts of Western Odisha recording about 80-90% damage (Anonymous, 2009b; Tanwar et al., 2010).

G. Emerging insect pests of wheat

Aphid complex- Grain aphid, *Sitobion avenae* (Fabricius), Corn aphid, *Ropalosiphum maidis* (Fitch) and Wheat aphid/Greenbug, *Schizaphis graminum* (Rondani) (Hemiptera: Aphididae): Increasing incidence of aphid complex, comprising of *S. avenae*, *R. maidis* and *S. graminum* is being recorded on wheat, barley and oat (Arora and Dhawan, 2011). Similarly, Katare et al. (2015) studied the effect of tillage techniques (FIRBS: Furrow irrigated raised bed system, ZT: Zero tillage and CT: Conventional tillage) on aphids in wheat in North-Western plains in of India and reported increased incidence of root aphids in FIRBS (10.4/ tiller) as compared to conventional tillage (8.5/tiller), and attributed to the fact that crop remained dry in FIRBS throughout the crop growth period and thus providing suitable conditions for survival of insect pests (Table 5).

Table 5. Effect of tillage on aphids in on wheat in North-Western plains

Tillage Technology	Root aphids/ tiller	Foliar aphids/ tiller
FIRBS	10.4	25.1
ZT	7.8	27.5
CT	8.5	34.3

Pink stem borer, *Sesamia inferens* Walker (Lepidoptera: Noctuidae): Modification of cultural practices like zero tillage has led to increased incidence of many insect pests including pink stem borer in wheat crop. Singh et al. (2014) studied the effect of tillage on pink stem borer in rice-wheat cropping system in India and reported that maximum damage was seen in zero tillage (1.38%) followed by rotary tillage (1.20%) and zero tillage + mulch (0.97%), while least damage was observed in the conventional tillage (0.62%).

H. Emerging insect pests of forage crops

Maize leaf roller, *Cnaphalocrosis trapezalis* Guenee (Lepidoptera: Crambidae) on sorghum: Nair (1970) reported it as a minor pest of sorghum. Outbreak occurred in Karnataka during 2013 due to climate change and severe incidence was noticed on sorghum crop, mostly in the early stages (4-5 leaf stage). The overall incidence ranged from 35.0 to 58.7% with an average of 46.8% (Murthy and Nagaraj, 2014).

Sugarcane leaf hopper, *Pyrilla perpusilla* Walker on sorghum and pearl millet: The sugarcane leafhopper has emerged as major pest on sorghum and pearl millet during 1990-91 and thereafter outbreaks are of regular occurrence. Heavy incidence of *Pyrilla* was recorded on grain and fodder sorghum in the entire northern belt of the country. Short sorghum genotypes (PGN 47, PGN 113) having tan type plants and light colored leaves comparable to sugarcane were highly susceptible to *P. perpusilla* as compared to tall, non-type varieties (PGN 66, PGN 69). Genotypes MH 410, MH 285, MP 207, MP 234, MP 246 and MP 241 exhibiting 4.1 to 6.0 egg masses/plant, were susceptible to *P. perpusilla*. The colour of leaves of these sorghum genotypes was pale green and comparable with the leaf colour of sugarcane (Kishore, 2005).

I. Emerging insect pests of vegetables and pulses

Over the past 100 years, annual rise in temperature with an average of 0.56°C, along with warming during post monsoon and winter seasons has led to exacerbation of pest problems like *Spilosoma obliqua* (Walker) on oilseeds and vegetable crops, *H. armigera* on vegetables, pulses and seed crops, *P. brassicae* on crucifers, *L. trifolii* on vegetable crops and several other sucking pests (Arora et al., 2015). Some of the emerging insect pests of vegetable crops are being dealt in detail below.

Peach potato aphid, *Myzus persicae* (Sulzer) and cotton aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae) on potato: In Punjab, during 2010-12, severity of damage by thrips, mites, aphids and butterfly ranged between 7.54 to 15.08% in early sown seed crop and from 0.01 to 0.62% in the normally planted crop. *M. persicae* and *A. gossypii* have shown deviations from earlier trends and the persistence of these insects throughout the season has made an alert to initiate research to develop suitable IPM programmes (Sharma, 2015).

Gram pod borer, *Helicoverpa armigera* (Lepidoptera: Noctuidae) and spotted pod borer, *Maruca vitrata* Geyer (Lepidoptera: Pyralidae) on pigeonpea and chickpea: Changes in cropping patterns, and climate change has resulted in emergence of serious pests such as *H. armigera, M. vitrata* and the pod sucking bug, *Clavigralla gibbosa* Spinola (Sharma, 2005). Heavy rains during October-November often result in outbreaks of *H. armigera* and *M. vitrata* in Southern India, while early warming of weather in North India (3-5°C higher than the normal in March) result in heavy *H. armigera* damage in on pigeonpea and chickpea in North India (Sharma et al., 2014). *Maruca vitrata* is becoming predominant insect pest in recent years in all pigeonpea and cowpea growing areas of India. Wider host range and coincidence of high humidity and moderate temperature with the flowering of the crop in India are related with high incidence. This pest not only damage the pods of the plant but also feeds on flowers, buds and sometimes stem of the plants are infested. Incidence was high in late sown conditions and also in varieties having clustering type of branching habit. Up to 42% damage has been recorded in cowpea during *rabi* season in Andhra Pradesh (Halder and Srinivasan, 2011).

Tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) on tomato and potato: Tomato leaf miner was observed for the first time infesting tomato and potato crop in Pune, Ahmadnagar, Dhule, Jalgaon, Nasik and Satara regions of Maharashtra, and six districts of Karnataka in 2014. This pest has been classified as the most serious threat for tomato production worldwide. Severe infestation (50-87% plants affected) was observed in several tomato fields. If *T. absoluta* invades rest of the world, the tomato pest management cost may raise up to $ 500 million per year (Sridhar et al., 2014).

Hadda beetle, *Henosepilachna vigintioctopunctata* Fab. (Coleoptera: Coccinellidae) on cowpea: Hadda beetle is emerging as serious foliage feeder in many parts of the country particularly eastern Uttar Pradesh and Bihar. More than 80% leaves were infested by the grubs and adults of this beetle on cowpea during 2009-10 (Halder and Srinivasan, 2011) (Halder et al., 2011). Similarly, its serious incidence was also observed from bitter gourd, *Momordica charantia* at Allahabad (Maurice and Ramteke, 2012) and Jammu (Jamwal et al. 2013).

Gall wasp, *Eurytoma* sp. (Hymenoptera: Eurytomidae) on clusterbean: Survey in Haryana revealed that gall wasp is emerging as a serious threat. Yadav et al. (2015) reported heavy incidence of the gall wasp on clusterbean in at Bhiwani, Mahendergarh and Rewari districts of Haryana during 2014. Pooled mean incidence of gall wasp on plant basis was recorded on 18.7% plants (0-72.2%). Among the different blocks of Haryana, highest incidence was observed at Bahal (30.1), followed by Badhra (27.1) and Charkhi-Dadri (25.2).

Western flower thrips (WFT), *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae): It had been reported for the first time from Kolkata in 2015. It is highly polyphagous and the most destructive pest species in Thysanoptera. WFT transmits Tomato Spotted Wilt Virus (TSWV). Considering its economic importance and ability to transmit tospoviruses, occurrence of this pest in other parts of India has to be monitored systematically (Tyagi and Kumar, 2015).

Serpentine leaf miner, *Liriomyza trifolii* Burgess (Lepidoptera: Agromyzidae): It is an introduced pest (1991) from USA and has spread along with *Chrysanthemum* flowers. Larval mining on leaves and ovipositional injury by adults are major damage symptoms (Viraktamath et al., 1993; Puri and Mote, 2004). It has wider host range covering 55-79 plant species. It is a polyphagous species affecting more

than 78 annual plant species being especially serious on greens, cucurbits, tomato, castor and ornamental plants (Srinivasan et al., 1995). In vegetables, three species of leaf miner have been reported infesting tomato, French bean, cowpea, clusterbean, summer squash, cucumber, melons etc. The losses to the extent of 15-70% in French bean, 41% in cucumber and 35% in tomato (Viraktamath, 2002; Krishnakumar, 1998).

Silver leaf whitefly, *Bemisia argentifolii* Bellows & Perring (Hemiptera: Aleyrodidae): The silver leaf whitefly or 'B' biotype of *B. tabaci* was identified for the first time in India, at Kolar district, Karnataka in 1999. This whitefly has wider host range, rapid reproduction ability inflicting more damage and more resistantce to insecticides. Recently, high incidence caused failure of the tomato crop in Bangalore, through direct damage to plants by sap feeding on cell sap and indirectly transmitting tomato leaf curl virus. The silver leaf whitefly could spread to affect a wider range of crops, including many vegetables, tobacco and cotton (Ananthakrishnan, 2009).

Spiraling whitefly, *Aleurodicus dispersus* Russel (Hemiptera: Aleyrodidae): Spiraling whitefly was introduced in India in 1994. Spiraling whitefly and is a threat to many crops as 280 plant species are hosts. 53% yield loss of tapioca and heavy yield loss have been observed in groundnut, banana, papaya, guava and chilli in India. It has emerged as a new pest of mulberry in 2010 causing huge economic damage to silk worm rearing (Mani, 2010).

J. Emerging insect pests of horticultural crops

Citrus: Arora et al. (2015) studied the current status of insect pests of citrus in Punjab and reported that in recent years insect pests like fruit sucking moths, mealybugs, grasshopper, brown marmorated fruit sucking bug and citrus bark borer have emerged as major pests of citrus in Punjab. The various species of insect pests affecting citrus crop are listed **(**Table 6**)**.

Litchi: Two new insect pest threats to litchi in India have been recorded recently namely, red weevil, *Apoderus blandus* Faust (Coleoptera: Curculionidae) and fruit borer, *Conopomorpha cramerella* Snellen (Lepidoptera: Gracillariidae). The studies conducted by Kumar et al. (2015) indicated that trees having highly damaged canopies (>50% foliage) by these pests represented as much as 40% while partially damaged (10-30% foliage) plants represented up to 20.8%. Indiscriminate use of pesticides to control fruit borer complex in litchi, particularly synthetic pyrethroids by the farmers seem to be responsible for higher incidence of both these pests.

Papaya mealybug, *Paracoccus marginatus* (Hemiptera: Pseudococcidae): In India, the pest was reported for the first time in Coimbatore, Tamil Nadu in 2008 on papaya, *Carica papaya* L. (Muniappan et al., 2008) and since then the list of agricultural and horticultural crops being damaged by this noxious exotic pest is growing at an alarming rate (Muniappan et al., 2011). It has wide host range including cotton, mulberry, tapioca, papaya, brinjal, potato and jatropha in Tamil Nadu. In 2009 it caused severe damage in Coimbatore, Erode, Tirupur and Salem districts of Tamil Nadu. Now it has spread to Pune area of Maharashtra, Karnataka and Andhra Pradesh (Tanwar et al., 2010).

Table 6. Current status of insect pests of citrus in Punjab

Common name	Scientific name	Location	Month/Year
Fruit sucking moths	Many species	Hoshiarpur	2011-14
Grasshopper	*Ailopus thalasinnus* Fabricius	Hoshiarpur and Ludhiana	Oct., 2013
Brown marmorated fruit sucking bug	*Hylomorpha picus* (Fabricius)	Hoshiarpur	Oct., 2013
Citrus bark borer	*Argilus citri* Thery	Ludhiana	Feb.-Mar., 2014
Mealybugs	*Drosicha mangiferae* Green *D. stebingi stebbingi* (Green)	Hoshiarpur and Ludhiana	Feb.-Mar., 2014

Outbreak occurred in 2009 due to which in 1,500 ha of standing mulberry crop was destroyed by the pest in at Tirupur, Karnataka (Shekhar et al., 2011). Seni and Sahoo (2013) reported it from jackfruit, eggplant, cotton, mango, guava and jatropha. The temperature range in West Bengal also favoured this pest for its successful establishment and rapid multiplication. During 2013-14, it has emerged as a major pest of mulberry plantations in West Bengal because of erratic monsoons, prolonged dry weather conditions, intensive cropping system and pruning pattern in mulberry (Lalitha et al., 2015). The pest attack has been reported in a large number of cultivated plants, including brinjal, guava, aonla, tomato, plantations, custard apple and colocasia, across the Kerala state. Crop losses to the tune of 10-15% are expected. The warm and sunny days are conducive for the spread of this pest (The Hindu, 30 March, 2015, Kerala).

Anar butterfly, *Deudorix isocrates* (F.) (Lepidoptera: Lycaenidae) on aonla: Sharma et al. (2015) reported that anar butterfly has emerged as major pest of seedling aonla and other root stocks in Punjab in recent years. The fruit infestation and fruit drop in different cultivars is listed below (Table 7).

Table 7. Anar butterfly infestation and damage on Aonla in Punjab

Cultivars	Fruit infestation (%)	Fruit drop (%)
Seedling Aonla	20.4	51.3
Banarsi	14.4	42.9
Francis	12.2	36.3
Kanchan	7.8	22.9
Chakayia	6.8	9.3

Mango leaf weevil, *Rhynchaenus mangiferae* (Marshall) (Coleoptera: Curclionidae): It is a serious pest of tropical and subtropical fruits. It is native to South China and Taiwan. It has emerged as a devastating pest of mango and litchi in Punjab. Sharma et al. (2015) have reported mango leaf weevil infesting mango trees from Ludhiana, Patiala, Amritsar, Moga, Firozpur, Jalandhar, Hoshiarpur, Kapurthala and PAU Campus.

Sapota seed borer, *Trymalitis margarias* Meyrick (Lepidoptera: Tortricidae): This pest was first reported from Dahanu areas of Maharashtra and infestation resulted in 40-90% fruit damage (Patel et al., 2001). During 2003-04, losses to the tune of 21 and 40% were recorded in at Thane and Ganevi districts, respectively, and 25% incidence was recorded in Bangalore Bengaluru during 2006-07. It is a monophagous pest attacking immature fruits of sapota. The pest has 'jump' dispersed *i.e. via* infected fruits to much larger distances down the South *viz*., Karnataka and Tamil Nadu causing 35% annual losses (Kamala Jayanthi and Verghese, 2010).

Banana skippers, *Erionota torus* Evans (Lepidoptera: Hesperiidae): These also called as banana leaf roller or palm red eye are native of South East Asia. They are serious defoliators of banana in East Asian countries. South Karnataka was surveyed for its incidence, in seven of the nineteen villages surveyed had infestation ranging from 1.25-100%. On average skipper damage reported was 23.71%. Widespread and moderate levels of damage preclude that skipper is an emerging pest on banana in South India (Naik et al., 2016).

Mites: Singh and Raghuraman (2011) studied the emerging status of mites in fruits and vegetables. Some of the mite pests are listed below (Table 8).

K. Emerging insect pests of plantation crops

Mirid bug, *Mecistoscelis sp.* (Hemiptera: Miridae) on bamboo plantations: A new mirid bug, *Mecistoscelis* sp. was found to attack leaves of four species of bamboos (*Bambusa balcooa, B. pallida, Dendrocalamus asper* and *D. strictus*) in Karnataka. The pest attained epidemic proportions in plantations at Koppa and Chickmangalur districts of Karnataka. Over 95% reduction in shoot yield has occurred from heavy attacks (Remadevi and Revathi, 2012).

Sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner (Hemiptera: Aphididae): This pest on sugarcane was first recorded in West Bengal. Invasion in Maharashtra in 2002 was the pest's reaction to climate change. The aphid appeared in epidemic form in July, 2002 in Sangli Province of Maharashtra. It spread to other parts of Maharashtra covering an area of 143 lakh ha by 2003 and caused 30% losses in sugarcane yields. Now it has spread to parts of Karnataka, Tamil Nadu, Kerala, UP, Bihar and Andhra Pradesh (Joshi and Viraktamath, 2004).

Mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on jute: This sucking and polyphagous pest was first recorded on cotton during 2005. During, 2013 it attained the status of serious pest of jute in West Bengal. Warm and dry condition during the seedling stage of the crop, surge in the

Table 8. Emerging scenario of mite pests in fruits and vegetables in North India

Common name	Scientific name	Crop(s)
Citrus brown mite	*Eutetranychus orientalis* (Klein)	Apple, ber, citrus and cucurbits
Red tea mite	*Oligonychus coffeae* Nietner	Coffee, mango and tea
Two spotted spider mite	*Tetranychus urticae* Koch	Bean, brinjal, cucurbits and okra
Red vegetable mite	*Tetranychus neocaledonicus* (Andre)	Mango and vegetables
Litchi mite	*Aceria litchii* (Keifer)	Litchi
Mango bud mite	*Aceria mangiferae* Sayed	Mango

maximum and minimum temperature and decrease in rainfall and number of rainy days are attributed as main reasons for emerging status of this pest in jute crop (Gotyal et al., 2014).

Coconut leaf beetle, *Brontispa longissima* (Gestro) (Coleoptera: Chrysomelidae): The coconut leaf beetle is one of the most damaging pests of coconut and other palms. It is native to Indonesia and has caused extensive loss in recent years in Maldives, Myanmar and Indonesia. 80-90% of seedlings were found infested by the pest, damaging 40% of the leaf area at Kasargod, Kerala recently. 'Red alert' has been issued for quarantine and thorough screening of baggage for ornamental palms at entry points into the country (CPCRI, 2015).

Coconut eriopyhid mite, *Aceria guerreronis* Keifer (Acari: Eriophyidae): It was first noticed in 1997 in at Ernakulam, District of Kerala (Sathiamma et al., 1998). Now it has spread to Tamil Nadu, Karnataka and Andhra Pradesh (Nair, 2000). Copra production dropped from 18-20 to 10-12 kg per 100 nuts after the coconut mite upsurge at the end of the 1990s (Haq, 1999). Weight loss of copra was reported by Haq and Sobha (2010). Annually more than Rs. 100 crores is being spent towards management of this pest (Sreejith, 2011). Bagde and Pashte (2014) reported 64.2 - 89.4% nut infestation in Thane district of Maharashtra. Yield reduction of 67.2% due to intense early and late nut fall has been recorded in Kerala (Sangeetha, 2015).

Eucalyptus gall wasp, *Leptocybe invasa* Fisher and La Salle (Hemiptera: Eulophidae): *Eucalyptus* gall wasp or blue gum chalcid was first reported in 2001 in at Mandya, District of Karnataka and Pondicherry in 2002. It was introduced in India from Australia through planting material. By 2007, the *Eucalyptus* gall wasp spread to Tamil Nadu, Andhra Pradesh, Kerala, Pondicherry, Gujrat, Madhya Pradesh, Uttar Pradesh, Maharashtra, Goa and Delhi (Jacob et al., 2007). Severe damage was observed in 2007-08 and infested seedlings were destroyed in huge numbers to avoid further spread (Krishankumar and Jacob, 2010). Eleven species of *Eucalyptus* are hosts for this pest. In India this pest poses serious threat to eight million ha of *Eucalyptus* plantation, paper industry and forest areas.

Erythrina gall wasp (EGW), *Quadrastichus erythrinae* Kim (Hymenoptera: Eulophidae): It was first reported damaging *Erythrina sp.* in Mauritius and Singapore in 2003 (Kim et al., 2004). It has emerged as major invasive pest on *Erythrina* spp. in black pepper plantations of Kerala and Karnataka, earlier is widely used as a live standard for trailing black pepper. The EGW was first noticed in Southern districts of Kerala, including Thiruvananthapuram district in 2005 and by 2006 spread to all districts of Kerala, Karnataka and Maharashtra (Issac and Pillai, 2006). Nearly 60% damage of *Erythrina* plants was observed in Wayanad District of Kerala in 2006 (Jacob and Devasahayam, 2008).

Coffee berry borer, *Hypothenemus hampei* (Ferrari) (Coleoptera: Scolytidae): It was first reported in 1990 at Wayanad, Kerala. It got introduced accidentally either though coffee brought by refugees from Sri Lanka or through illegally imported coffee seeds in India (Singh and Ballal, 1991). It attacks both arabica and robusta types of coffee. The coffee berry borer has spread to the major coffee growing areas (3,88,000 ha) in Southern States of India. Annually more than Rs. 20 crores is spent towards control measures (Sathyanarayana and Satyagopal, 2013; Vijayalakshmi et al., 2013).

Tea mosquito bug, *Helopeltis theivora* Waterhouse (Hemiptera: Miridae): It was considered a major pest of tea in the past and it continues in the recent times also in the North-East India and West Bengal. It attacks only

young shoots, which actually yield tea. Besides, considerable losses of tea shoots, it causes deterioration in quality of prepared tea, lowering its market value. Debnath and Rudrapal (2011) estimated that 90% sub-Himalayan Dooars tea plantation was affected by *H. theivora* with crop losses to the tune of 10-50%.

Kalita et al. (2015) reported this as an emerging pest of red cherry pepper (*Capsicum annum* var. *cerasiforme*) and large cardamom, for the first time, which are the main spice as well as cash crops of Sikkim. It's symptoms resemble leaf streak. In future, it may pose a potential danger to tea industry and two most important spice crops of Sikkim, red cherry pepper and large cardamom. Investigations on organic management of this pest have been initiated.

L. Strategies to manage emerging insect pests

- Study the ecology of the invasive alien species
- Careful tracking of geographical distribution
- Identify, conserve and augment natural enemies of emerging insect pests
- Study the biology and ecology of known insect pests, their natural enemies under changing climatic conditions
- Develop cultivars resistant to insect pests
- Judicious use of insecticides to prevent resistance and resurgence development
- Modifying crop management practices
- Developing suitable integrated pest management programmes
- Phytosanitary regulations to prevent or limit the introduction of risky insect pests
- Better weather forecasting

CONCLUSIONS

Insect pests on an average cause 15-20% yield losses in principal food and cash crops. Climate change and other agronomic factors have strongly affected diversity and abundance of insect pests and extent of losses. Chronic, emerging and invasive pests are considered as one of the major threats to food security. Sucking insect pests and defoliators like mirid bugs, mealybugs, whiteflies and the defoliating tobacco caterpillar on cotton; BPH, WBPH, leaf folder on rice; maize shoot fly on maize; cabbage butterfly on crucifers; tobacco caterpillar on cole crops; tea mosquito bug on tea; gall wasp on cluster beans and aphids on wheat crop have emerged as major pests in recent years in India. Efforts must be undertaken to modify current management strategies and devise appropriate IPM measures to manage emerging insect pests and mitigate the otherwise incalculable losses, to sustain production of major crops in future.

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BIOCONTROL PERFORMANCE OF EGG PARASITOID *USCANA MUKHERJII* (MANI)

VIVEK SHARMA, VISTER JOSHI AND NUTAN KAUSHIK

The Energy and Resources Institute (TERI), New Delhi 110003
Email: viveksc2008@gmail.com (corresponding author)

ABSTRACT

Experiments on biological control of two bruchid pests *Callosobruchus maculatus* (Fabricius) and *C. chinensis Linnaeus* with an egg parasitoid, *Uscana mukherjii* (Mani) (Hymenoptera: Trichogrammatidae) were conducted. *Cajanus cajan (L.) Mill sp, Vigna radiata (L.)* Wilczek and *Cicer arietinum L.* were used as hosts for these bruchids. The parasitoid reduced *C. maculatus* survival by 34.7, 42.4 and 25.4% and reduction in weight loss by 30.6, 34.8 and 18.7% on *C. cajan, V. radiata* and *C. arietinum*, respectively under no choice condition. Whereas in free choice test, 48.1, 37.7 and 33.14% reduction in survival was recorded which resulted in 48.5, 39.6 and 43.0% reduction in weight loss on *C. cajan, V. radiata* and *C. arietinum*, respectively. While in case of *C. chinensis*, reduction in survival was 29.8, 32.0, and 22.6% which resulted with 24.5, 19.9, and 20.45 weight loss on *C. cajan, V. radiata* and *C. arietinum*, respectively in no choice test. In free choice test, 26.8, 28.8 and 28.7% reduction in population of *C. chinensis* was recorded with reduction in weight loss being 30.7, 21.4 and 44.9% on *C. cajan, V. radiata* and *C. arietinum*, respectively. Results conclude that *U. mukherjii* could be a useful component of IPM to manage *C. maculatus* and *C. chinensis* on the stored pulses.

Key words: *Callosobruchus chinensis*, *C. maculatus*, biological control, *Uscana mukerjii*, pigeonpea, cowpea, bengal gram, survival, weight loss

Despite being largest producer and consumer, India is also the world's largest importer of pulses. Estimated annual losses due to bruchids are reported to the nearby the quantity of pulse imported (Rathore and Sharma, 2002). Hence, management of bruchids might help in avoiding these losses and attain self sufficiency in production. Chemical pesticides are being used to protect the pulses, but there is high economic and health risks to poor farmers, consumers and grain handlers. Biological control provides a safe, self-replicating, non-hazardous and economic tool because it replicates on the cost of host life.

Bruchids are attacked by parasitoids belonging to ten families of Hymenoptera and one of Diptera (Southgate, 1979). However, there is a great dearth of information on these to facilitate suitable level of control. Egg parasitoid *Uscana mukherjii* (Mani) (Hymenoptera: Trichoyrammatidae) can provide this option to strengthen the IPM against bruchids. This study examines the biocontrol potential of *U. mukherjii* in population reduction of *Callosobruchus maculatus* and *C. chinensis.*

MATERIALS AND METHODS

The study was carried out under laboratory conditions at The Energy and Resources Institute, New Delhi. Laboratory culture of *C. chinensis* and *C. maculatus* was raised at 27±0.5°C and 60-65% R.H.in BOD incubator. All the experiments were conducted at 12-14% seed moisture content-moisture content was analyzed by the *Indosaw* moisture meter. *U. mukherjii* adults were collected from pigeonpea field in Hapur (District Panchsheel Nagar), Uttar Pradesh and were placed on pigeonpea grains (cv. UPAS 120) freshly infested with *C. maculatus* eggs. After 24 hr grains kept in the laboratory were observed for parasitoid emergence. Emerged parasitoids were further released on to freshly laid eggs for multiplication. Parasitoid culture was maintained in separate BOD at 25±1°C and 60±5% R.H., with honey water solution (1:1), provided for adults. The identification was confirmed by the Insect Identification Service, Division of Entomology, Indian Agricultural Research Institute, New Delhi.

Mungbean (*Vigna radiata* cv. SML 668), pigeonpea (*Cajanus cajan* cv. UPAS 120) and chickpea (*Cicer arietinum* cv. p. 362) were used and seeds were equilibrated in controlled temperature and humidity for a week to ensure uniformity of moisture. All seed lots were conditioned in shallow layers for one week at 27±1°C and 70±5% R.H. Ten gm of seeds of each *V. radiata*, *C. cajan* and *C. arietinum* (T_1, T_2 and T_3) were taken in small screw capped plastic containers

(55 x 35 mm) in four replicates and a separate set for control was taken in the same kind of plastic container (T_4, T_5 and T_6). Two pairs of freshly emerged (0-12 hr old) bruchids were released in each container maintained separately for egg laying. After 48 hr, bruchids were removed and one pair of egg parasitoids released in each which provided no choice condition for parasitoid. Experiments were also conducted in free choice condition in circular glass trough (30x15 cm). Ten gm seeds of each (*C. cajan, V. radiata* and *C. arietinum*) were taken in open plastic petri plates (50x20 mm) and kept in a circular position at equidistance from the center of glass trough. Twenty pairs of bruchids released in the middle of the trough for egg lying provided free choice for oviposition and were removed after 48 hr followed by introduction of ten pairs of *U. mukherjii* in the center of glass trough. Trough was covered with thick muslin cloth. A separate trough was also arranged with same treatment without release of *U. mukherjii* as control. All the treatments were replicated 4 times.

After 4th day, parasitized and unparasitized eggs were counted in each vial with a magnifying glass and were kept for emergence of host and parasitoid. Emerged adults were counted daily and removed.After emergence, net weight of grain, parasitization, and weight loss were calculated. Separate experiments were conducted for *C. maculatus* and *C. chinensis*.

RESULTS AND DISCUSSION

Callosobruchus maculatus

Interaction of *U. mukherjii* with *C. maculatus* in no choice condition when observed with eggs laid by *C. maculatus* on *C. cajan, V. radiata* and *C. arietinum* was found statistically non-significant. As a host, *C. maculatus* eggs were highly parasitized (29.8%) on *C. cajan* (T_1), moderately (26.8%) on *V. radiata* (T_2), and the least with *C. arietinum* (T_3, 24.0%). No parasitization was recorded in control. Similarly, Garmain *et al*. (1987) reported 33% of *C. maculatus* eggs on cowpea grains parasitized by *Uscana ariophaga* Steffan. Survival of *C. maculatus* was highest in control (T_5 Mungbean 94.7%, T_4*C. cajan* 90.0%, and T_6*C. arietinum* 85.5%) and lowest survival was recorded on T_2*V. radiata* 54.3%, T_1*C. cajan* 59.02% and T_3 *C. arietinum* 64.4%. Survival of bruchid was directly linked with grain weight loss which was highest in control (Table 1). On an average 42.4, 34.7 and 25.4% reduction was recorded in *C. maculatus* survival which resulted in 34.8, 30.6 and 18.7% reduction in weight loss in *V. radiata*, *C. cajan* and *C. arietinum*, respectively.

Interaction of *U. mukherjii* with *C. maculatus* in free choice condition when observed for egg deposition by *C. maculatus* varied from 91.2 to 132.7 and highest preference was given to *C. cajan* followed by *V. radiata* and *C. arietinum*. Parasitization was highest on T_2*V. radiata* (25.6) and it was statistically at par with T_1 *C. cajan* (25.0), and the least was with T_3 *C. arietinum* (18.7), whereas, nil parasitization was recorded from control (T_4, T_5 and T_6). Thakur (2006) reported that 22% of *C. theobromae* eggs were parasitized by *Uscana formoralis* on cowpea. *C. maculatus* survival was highest in unreleased control ($T_5$90.6%, $T_4$87.5%, and $T_6$81.4%) and the least was recorded in parasitoid released treatments $T_2$56.4%, $T_3$45.2% and $T_1$54.2% which significantly differed from control. Per cent weight loss was maximum in control (39.9, 37.0 and 32.5%), while it was the least in treatments (24.1, 19.0 and 18.5%) on *V. radiata*, *C. cajan* and *C. arietinum*, respectively (Table 1).

C. maculatus population was reduced by 48.1% in *C. cajan*, 37.7% in *V. radiata* and 33.14% in *C. arietinum* which resulted in reduced weight loss by 48.5, 39.6 and 43%, respectively. Van Huis *et al*. (1998) reported 68-80% reduction in *C. maculatus* population and 13-19% reduction in cowpea damage by egg parasitoid,*U. lariophaga*.

Callosobruchus chinensis

Interaction of *U. mukherjii* with *C. chinensis* under no choice condition showed that parasitization was more in *C. arietinum* (21.5%) followed by *C. cajan* (17.5%) and *V. radiata* (16.0%). All the treatments were statistically at par but significantly differed from control. Survival was highest in respective controls (92.4, 87.0, and 91.3% in *C. cajan*, *C. arietinum* and *V. radiata*, respectively). In treated condition survival was 63.7, 63.6 and 67.2% on *C. cajan*, *C. arietinum* and *V. radiata*, respectively which was almost reduced to 29.8, 32.0 and 22.6%. Weight loss that was highest with control (26.3,24.1 and 29.9 in *C. cajan*, *C. arietinum* and *V. radiata), respectively* was reduced in parasitoid released condition (19.8, 19.2 and 24.0% on *C. cajan*, *C. arietinum* and *V. radiata*, respectively) (Table 2).

Interaction of *U. mukherjii* with *C. chinensis* in free choice condition showed that it was 21.6, 18.7 and 17.3 in *C. cajan*, *V. radiata* and *C. arietinum*, respectively, in treated condition but it was nil under

Table 1. Biocontrol attributes of *Uscana mukherjiii* on *Callosobruchus maculatus* under no choice and free choice condition

Treatment	No choice condition					Free choice condition				
	No. of eggs	No. of parasitized eggs$	% parasitization*	% bruchid emergence*	% weight loss*	No. of eggs	No. of parasitized eggs$	% parasitization*	% bruchid emergence*	% weight loss*
T1 (*C. cajan*)	92.7	28.0 (5.3)$	29.8 (33.0)*	59.0 (50.3)*	20.8 (27.6)*	111	14.7 (3.4)$	25.0 (29.2)*	45.2 (42.2)*	19.0 (25.8)*
T2 (*V. radiata*)	100.2	27.0 (5.2)	26.8 (31.0)	54.3 (47.6)	20.2 (26.6)	114.5	15.0 (3.9)	25.6 (30.0)	56.5 (48.6)	24.1 (29.3)
T3 (*C. arietinum*)	92.7	22.7 (4.7)	24.0 (28.9)	64.4 (53.4)	22.6 (28.3)	91.2	17.2 (3.9)	18.7 (24.6)	54.2 (47.4)	18.5 (25.4)
Control										
T4 (*C. cajan*)	87.7	0 (0.7)	0(4.05)	90.0 (73.1)	29.9 (33.1)	132.7	0(0.7)	0 (4.05)	87.5 (69.8))	37.0 (37.4)
T5 (*V. radiata*)	85.5	0 (0.7)	0(4.05)	94.7 (76.7)	31.1 (33.8)	125.0	0(0.7)	0 (4.05)	90.6 (72.3)	39.9 (39.1)
T6 (*C. arietinum*)	88.2	0 (0.7)	0(4.05)	85.5 (70.0)	27.8 (31.7)	113.2	0(0.7)	0 (4.05)	81.4 (64.5)	32.5 (34.7)
±*S.E (m)*	-	1.2	7.3	6.4	1.5	7.0	0.8	6.2	6.4	2.9
CD at 5%	-	0.8	5.1	9.0	3.7	20.4	1.6	6.6	6.2	3.9

$Figures in parentheses square root transformed; values arcsine transformed

control. Survival of *U. mukherjii* was 66.8, 66.2 and 62.4% in *C. cajan*, *V. radiata* and *C. arietinum*, respectively, compared to 90.9, 91.0 and 86.7% in *C. cajan*, *V. radiata* and *C. arietinum*, respectively in control. Weight loss was highest in *V. radiata* (28.7) followed by *C. cajan* (28.1) and *C. arietinum* (19.8) (Table 2). Due to *U. mukherjii*, survival got reduced by 26.8, 28.8 and 28.% which resulted in 30.7, 21.4 and 44.9% reduction in weight loss of *C. cajan*, *V. radiata* and *C. arietinum*, respectively.

Thus, it might be concluded that *U. mukherjii* is capable of reducing *C. maculatus* and *C. chinensis* infecting *C. cajan*, *V. radiata* and *C. arietinum*. Most preferred host for *U. mukherjii* is *C. maculatus* on pigeonpea and *V. radiata* seeds equally.

Table 2. Biocontrol attributes of *Uscana mukherjiii* on *Callosobruchus chinensis* under no choice and free choice condition

Treatments	No choice condition					Free choice condition				
	No. of eggs	No. of parasitized eggs$	% parasitization*	% bruchid emergence*	% weight loss*	No. of eggs	No. of parasitized eggs$	%* parasitization	% bruchid emergence*	% weight loss*
T1 (*C. cajan*)	84.2	26.7 (5.1)$	17.5 (21.9)*	63.7 (54.4)*	19.8 (26.2)*	119.7	25.2 (5.0)$	21.6 (27.5)*	66.8 (48.1)*	28.1 (31.9)*
T2 (*V. radiata*)	99.2	17.5 (4.0)	16.1 (23.2)	67.2 (55.1)	24.0 (29.1)	120.7	16.2 (3.9)	18.7 (25.4)	66.2 (53.9)	28.7 (32.2)
T3 (*C. arietinum*)	81.7	28.7 (5.3)	21.5 (26.0)	63.6 (52.1)	19.2 (25.0)	89.2	21.7 (4.7)	17.3 (24.4)	62.4 (51.7)	19.8 (26.0)
Control										
T4 (*C. cajan*)	82.5	0 (0.7)	0 (4.05)	92.4 (74.0)	26.3 (30.8)	124.7	0 (0.7)	0 (4.05)	90.9 (72.9)	40.6 (39.5)
T5 (*V. radiata*)	87.0	0 (0.7)	0 (4.05)	87.0 (69.1)	29.9 (33.1)	115.0	0 (0.7)	0 (4.05)	91.0 (72.4)	36.6 (37.2)
T6 (*C. arietinum*)	90.7	0 (0.7)	0 (4.05)	91.3 (73.0)	24.1 (29.4)	113.2	0 (0.7)	0 (4.05)	86.7 (69.7)	36.0 (36.8)
±*S.E (m)*	-	1.1	5.4	5.0	1.4	-	1.0	5.9	5.6	2.4
CD at 5%	-	0.9	12.4	10.9	5.1	-	0.8	4.5	9.6	6.6

$Figures in parentheses square root transformed; values arcsine transformed

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KINETICS OF α -AMYLASE ACTIVITY IN ASIA-I AND ASIA II-1 GENETIC GROUPS OF WHITEFLY, BEMISIA TABACI (HEMIPTERA: ALEYRODIDAE)

ARCHANA ANOKHE*, SABTHARISHI SUBRAMANIAN AND RAHUL CHANDEL

Division of Entomology, ICAR, Indian Agricultural Research Institute, New Delhi 110012
**Email: anokhearchana@gmail.com*

ABSTRACT

Whitefly, *Bemisia tabaci* (Gennadius.) has drawn global attention in recent past with its wide distribution across the world as it causes severe damage to crops directly by sucking the plant sap and indirectly as vector of several viral diseases. This pest is considered as a species complex and Asia represents the largest diversity with the distribution of about 16 out of 35 genetic groups recorded so far. Investigations were carried out on kinetics of a key digestive enzyme, á-amylase in adults of isogenic female lines of *B. tabaci* genetic groups Asia I and Asia II-1. Asia I has shown the higher specific activity of 0.267±0.007 µmol/ml/mg compared to that of 0.209±0.009 µmol/ml/mg in Asia II-1. However, kinetics of á-amylases revealed the high affinity of this enzyme in Asia II-1 with the least K_m value of 0.03372±0.001 compared to that of 0.0353 ±0.002 in Asia I genetic group. Highest enzyme activities were recorded at 35° C in both the genetic groups of *B. tabaci*. Kinetics study of metabolically important digestive enzymes would improve our understanding on the metabolic capabilities of *B. tabaci* species complex.

Key words: *Bemisia tabaci*, species complex, genetic groups, enzyme kinetics, á–amylase, affinity,

Whitefly, *Bemisia tabaci* (G), a tiny sap sucking insect is a pest of diverse agricultural and horticultural crops. It has become a pest of economic importance owing to its polyphagous pest status with a host range of over 700 different plant species and because of its ability to transmit more than 200 viruses specifically belonging to the genus *Begomovirus* (Brown, 2001). It has become difficult to control this pest as a large number of genetic groups of this pest are prevalent globally. As per our current understanding, it is regarded as a species complex comprising of at least 35 genetic groups commonly referred as biotypes (Ahmed *et al.*, 2012). These biotypes vary with respect to geography, fecundity, dispersal behaviour, insecticide resistance, natural enemy complex, invasiveness and plant virus transmission. Asia has the greatest diversity of *B. tabaci* species complex (Horovitz *et al*., 2005) with the presence of 16 of the 35 genetic groups described so far. However, our knowledge on indigenous members of *B. tabaci* complex in Asia is very limited, compared to the two invading species of *B. tabaci*, *viz*., Middle East-Asia Minor 1 (B biotype) and Mediterranean (Q biotype).

Amylases have been characterized in larval midgut tissue from several species of insects belonging to Hymenoptera, Orthoptera, Diptera, Coleoptera and Lepidoptera (Terra and Ferreira, 1994). Enzyme kinetics and molecular characterization of á-amylase have been done in some Coleopteran midgut extracts (Terra and Ferreira, 1994).These enzymes are primarily involved in carbohydrate metabolism in insects. However, to date relatively little information is available on enzyme kinetics of amylases from Aleurodids including *B. tabaci*. The present study elaborates on the kinetics of á-amylase in isogenic lines of Asia I and Asia II-1 genetic groups predominant in India.

MATERIALS AND METHODS

Maintenance of populations: The *B. tabaci* populations evaluated in the study were originally collected from cotton fields of Guntur and from and New Delhi, India. The insects were maintained at 26±2°C & 70±5% RH in the Insect proof climate control chambers (IPCC) at Division of Entomology in Indian Agricultural Research Institute, New Delhi, India.

Species and genetic group status authentication: Species authentication of *B. tabaci* was done by using distinct taxonomic characters (Martin, 2007) and genetic group status of *B. tabaci* populations was determined by using allele specific primers of *Mitocondrial cytochrome oxidase 1* (*mtCO1*) genes (Dinsidale *et al.,* 2010). Partial sequencing of

mitochondrial cytochrome oxidase I *(mtCOI)* gene was done to ascertain the genetic group status of *B. tabaci* populations used in this study. DNA was extracted from single adult female using DNeasy blood and tissue kit (*Qiagen GmbH*, Hilden, Germany). After the PCR amplification, the final product was subjected to sequencing by outsourcing with SciGenom Labs (Cochin, Kerala, India). The *mtCO1*gene sequence obtained from each population was subjected to homology search using *Basic Local Alignment Search Tool* (nBLAST) algorithm at NCBI (http://www.ncbi.nlm.nih.gov). Primer sequence used are CI-J (10 µM) (5'→TTGATTTTTTGGTCATC CAGAAGT→3') and TL2 (10µM), (5'→TCCAATG CACTAATCTGCCATATTA→3')

Development of isofemale lines of *B. tabaci*: Homogenous populations were raised from a single isofemale line using clip cages on cotton plants. One adult female of whitefly was transferred into a clip cage soon after emergence and allowed to proliferate for further generation. About 40 clip cages were used for raising homogenous populations of Asia I and Asia II-1 genetic groups of *B. tabaci* and they were maintained in isolated chambers. Homogeneity and purity of the genetic group status was ascertained by periodical *mtCO1* analysis of random samples from these populations.

Biochemical characterization of α-amylase: α -amylase activity was estimated by microplate assay using 1.0% (w/v) starch- as substrate (Bernfeld, 1955).Ten adult female insects of *B. tabaci* drawn from both Asia I and Asia II 1 populations were homogenized using a hand held homogenizer in 50µl of ice cold 0.02M succinate, glycine and 2-morpholinoethanesulphonic acids buffer (pH 7). Samples were centrifuged at 13000rpm at 4ºC for 15 min and the supernatant was taken for enzyme assay.

α-amylase activity was measured by adding 10µl of enzyme source to the well of microtiter plate containing 80µl of universal buffer (0.02M, pH 7) (Ramzi, 2010). Reaction mixtures were incubated at 30ºC for 30 min. After incubation, 100µl Dinitrosalicylic acid (DNS) (Bernfeld, 1955) was added and heated for 10 min at boiling temperature to stop the reaction. The heating stops the α-amylase activity and catalyses the reaction between DNS and the reducing groups of sugars. End point assay was done by taking absorbance at 540nm. One unit of α-amylase activity was defined as the amount of enzyme required to produce 1 ìmol maltose in 1 min at 30 °C. It was determined from the linear standard curve of Glucose in 100mM TAPS (pH-7.8). The total protein content of the enzyme sources used in the experiment was determined by the *coomassie* brilliant blue method (Bradford, 1976) using BSA as standard.

Kinetics of α-amylase: To determine kinetics of α-amylase, five concentrations (0.01%, 0.1%, 1%, 2%, and 3%) of substrate (starch) were prepared in universal buffer (0.02M, pH 7) (Ramzi, 2010). Enzyme activity and specific activity were measured by using the protocols mentioned above and absorbance was recorded for all the concentrations at 540nm. α-amylase activity in both the populations were analysed by Students *t*-test and tukey test. The parameters of enzyme kinetics *viz.*, V_{max} and K_m were calculated using non-linear regression analysis in GraphPad Prism 6.0 programme. Data analysis was conducted with Statistical analysis software (SAS) through General linear model (GLM) procedure. Enzyme activity and specific activity of both the genotype with respect to different substrate concentration is given in Table 1. The effect of temperature on activity of α-amylase was estimated by measuring its activity in universal buffer (0.02M, pH 7) (Ramzi, 2010) at temperatures ranging from 15-40ºC. Incubation of reaction mixtures was done at a range of temperatures *viz*., 15 ºC, 20 ºC, 25 ºC, 30 ºC, 35 ºC, 45 ºC and activity was measured at 540nm by end point assay.

RESULTS AND DISCUSSION

Characterization of α-amylase in two genetic groups of *B. tabaci viz*., Asia I and Asia II-1 was done by measuring enzymatic activity, specific activity, temperature optima and enzyme kinetics parameters like V_{max} and K_m. Asia I has shown the highest specific activity i.e. and 0.267± 0.007µmol/ml/mg as compared to Asia II-1 with the specific activity of 0.209± 0.009 µmol/ml/mg. Analysis of the kinetic parameters of amylase revealed that significant difference in V_{max} and K_m values between the two whitefly populations. The Asia I population showed significant increase in V_{max} value compared to Asia II-1 and there was significant decrease in K_m value in Asia I indicate that this population have high affinity towards the substrate and showing high catalytic efficiency as compared to Asia II-1.

The temperature optima for α-amylase were found to be 35ºC. At this temperature Asia I has shown higher enzyme activity of 0.266±0.004µmol/ml/min in

Table 1. α amylase activity/ specific activity in *B. tabaci* (Asia 1, Asia II-1 genetic groups)

Treatment	Guntur (Asia I)	Delhi (Asia II 1)	Guntur (Asia I)	Delhi (Asia II 1)
	Enzyme activity µmol/ml/min		Specific activity µmol/ml/mg	
Concentration of sucrose (%)	Mean± SE*	Mean± SE*	Mean± SE*	Mean± SE*
0.01	$0.170\pm0.005_{C}$	$0.137\pm0.005_{D}$	$0.169\pm0.004_{C}$	$0.128\pm0.004_{C}$
0.1	$0.218\pm0.005_{B}$	$0.175\pm0.005_{A}$	$0.214\pm0.004_{B}$	$0.164\pm0.004_{C}$
1	$0.289\pm0.005_{A}$	$0.221\pm0.005_{B}$	$0.283\pm0.004_{A}$	$0.207\pm0.004_{B}$
2	$0.291\pm0.005_{A}$	$0.220\pm0.005_{B}$	$0.281\pm0.004_{A}$	$0.210\pm0.004_{B}$
3	$0.291\pm0.005_{A}$	$0.220\pm0.005_{B}$	$0.283\pm0.004_{A}$	$0.210\pm0.004_{B}$
Treatment mean	$0.252\pm0.002_{A}$	$0.195\pm0.002_{B}$	$0.246\pm0.002_{A}$	$0.184\pm0.002_{B}$

*Standard error; Values mean of five replications; Same letters followed means not statistically significant.

comparison to Asia II-1 where it has shown lower enzyme activity (0.247±0.004µmol/ml/min). Graphical representation of effect of temperature on á-amylase activity is shown in Fig. 1

Among the several groups of digestive enzymes, amylases convert starch to maltose, which is then hydrolyzed to glucose by α-glucosidase. In insects, only α-amylases that hydrolyse α-1, 4- glucan chains such as starch or glycogen have been found. Due to their importance, different forms of α-amylases are unique to the insect species, to guarantee the digestive process efficiency. Several insects synthesize at least two isoforms of α- amylases in the digestive tract while several isozymes of α- amylases were detected for *Drosophila melanogaster*, *Sitophilus zeamais Callosobruchus maculatus*, (Baker, 1983; Silva *et al.,* 1999; Franco *et al.,* 2005.). The sap sucking insects including whitefly, *B. tabaci* mainly feed on the phloem sap containing high amount of sugars. Knowledge on enzyme dyanamics will help to understand the metabolic capabilities and consequently physiological fitness of different *B. tabaci* genetic groups.

Distinct differences in α- amylase activities in *B. tabaci* genetic group were noticed as reflected by the values of enzyme activity and specific activity. In the present study, it was observed that Asia I was found to have significantly higher enzyme velocities as shown by significantly higher V_{max} values of 0.2817±0.002µmol/ml/min in comparison to that of Asia II-1 (0.2142±0.001µmol/ml/min). However, the affinity of the enzyme for the substrate was more in Asia II-1 as evidenced by significantly lower K_m values 0.03372±0.00 µmol than that of Asia I. Change in kinetic behaviour of α- amylase in both the genotype are well explained by Lineweaver-Burk and Michaelis Menton graph (Fig. 2). The role of α-amylase in adaptation on host plants has been described in insects (Silva *et al.,* 2001a, b). The role of α-amylases in polyphagous insect pests like *B.tabaci* is highly emphasized as this enzyme would probably be implicated in carbohydrate metabolism and as such in manovering host adaptation of this polyphagous pest.

Preponderance of *B. tabaci* in geographic regions is driven by factors like insecticide resistance, host

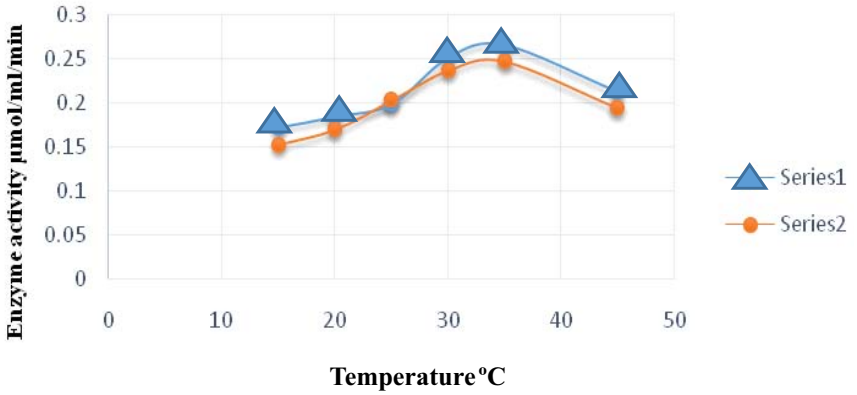

Fig. 1. Effect of temperature on α amylase activity in Asia I (series 1) & Asia II-1 (series 2)

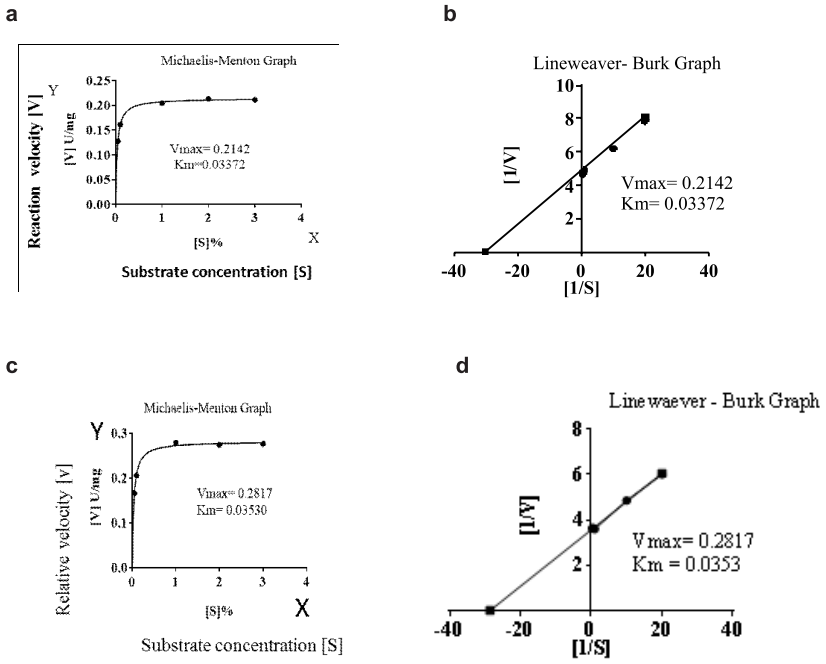

Fig. 2. Lineweaver-Burk (a &c) and Michaelis Menton (b, d) : α- Amylase activity in *B. tabaci* Asia I (a, b) and Asia II (c, d) genetic groups

plant plasticity and efficiency in transmission of viruses. A number of studies have highlighted the physiological differences between B and Q biotypes of whitefly, *B. tabaci*. However, studies are limited on the physiological characterization on the Asian genetic groups of *B. tabaci*. The present study assumes significance as it highlights the differences in kinetics of α-amylases in Asia I and Asia II-1, two predominant genetic groups of *B. tabaci* distributed across the agro-climatic zones of India (Ellango *et al*., 2015). However, further studies on characterization of isoforms of α-amylases in the salivary glands and and digestive tracts are required to elaborate the physiological role of α-amylases in *B. tabaci* genetic groups. Distinct differences in the specific activities of the enzyme were observed in the adults of Asia I and Asia II-1 genetic groups of *B. tabaci*

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INSECT FAUNAL CHECKLIST OF MUGA ECOSYSTEM IN NORTH EAST INDIA

RAJESH KUMAR*, PREETIREKHA CHUTIA AND B.K. SINGH

Central Muga Eri Research and Training Institute, Central Silk Board, Ministry of Textiles, Govt. of India, Lahdoigarh 785700, Jorhat
**Email: rajesh.ento@gmail.com*

ABSTRACT

Muga silkworm, *Antheraea assamensis* (Helfer) (Lepidoptera: Saturniidae) is endemic species, which produce golden natural silk. Muga silkworm is found exclusively in rain forest ecosystem of Himalayan Foot Hills in North Eastern India, especially in Assam and Meghalaya due to its unique climatic conditions. Muga culture is of considerable economic importance and closely associated with the life, tradition and culture of the tribal people. This study was conducted in six states (Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland) of North East India for collection, preservation and identification of insect pests, predators, pollinators, and natural enemies of muga ecosystem. This study updates the earlier status that only 30 species had been known from muga ecosystem to 203 species, as enlisted herein.

Key words: Muga ecosystem, *Antheraea assamensis*, host plants, insect pests, predators, natural enemies, pollinators, Assam, Meghalaya, Arunachal Pradesh, Manipur, Mizoram, Nagaland

The "Golden Silk" obtained from muga silkworm, *Antheraea assamensis* (Helfer) (Lepidoptera: Saturniidae) is endemic and found exclusively in rain forest ecosystem of Himalayan Foot Hills in North Eastern India, especially in Assam and Meghalaya due to its unique climatic conditions. Muga culture is of considerable economic importance and closely associated with the life, tradition and culture of the tribal people. It is from a polyphagous insect feeding on two primary host plants (Som – *Persea bombycina* and Soalu – *Litsaea monopetala*) of the family Lauraceae. The North Eastern region of India comprises of the states of Arunachal Pradesh, Assam, Meghalaya, Manipur, Tripura, Mizoram, Nagaland and Sikkim, which can be physiographically categorized as the Eastern Himalayas.

The North Eastern India is a biodiversity hotspot among 34 hotspots of the world and natural abode for insect biodiversity. Out of 9241 ha of existing muga plantation here, Assam alone possesses around 6755 ha with commercial rearing mostly confined to the upper Brahmputra valley of Assam. Muga culture is an agrobased small scale industry here with around 30000 families are directly and indirectly engaged (Rajan and Hazarika, 2012). Muga silkworm is polyphagous and multivoltine insect having 5-6 generations/ year *viz*., *Jethua* (spring: April-May), *Aherua* (summer: June-July), *Bhodia* (Late summer: Aug-Sept.), *Kotia* (Autumn: Oct.-Nov.), Jarua (winter: Dec.-Jan.) and *Chatua* (Early spring: March-April) and completes its lifecycle in 35-45 days. Of these, *Jethua* and *Kotia* are considered as commercial, *Chatua* and Bhodia as seed and *Jarua and Aherua* as pre-seed crops (Singh et al., 2000). Rearing muga silkworm in outdoor condition faces several challenges, amongst these, the infestation by pests, predators and diseases is critical (Kumar and Rajkhowa, 2012). There is an urgent need to document the insect fauna of pests and predators in the muga ecosystem, to enable their scientific management, and the present study is an attempt for the same.

MATERIALS AND METHODS

The standard methodology was adopted for sampling and data collection of insects in muga ecosystem (Kumar and Ramamurthy, 2010). The collection was made by visiting selected localities, deploying portable light traps at night, and net sweeping/ other methods during day time as given below. Field photographs were taken before collecting, and mature and immature stages were collected for studying the lifecycle in the laboratory. The collections were made with the following methods:

Net collection: A sweep net collection was adopted to collect the adults; *Aspirator:* Aspirator methods were adopted to collect small insects (micro moths, weevils

and other sucking pests). *Handpicking:* larval stages were collected by handpicking method in vials and jars; *Butter paper envelope:* Lepidopteran insects were collected by this; *Light trap collection*: mercury light trap was installed in the field during night; *Pit fall trap*: it was adopted to collect soil/surface dwellers; *Yellow sticky traps*: it was adopted to collect the sucking pests; and *Leaf litter sampling*: Leaf litter was observed to collect the mature and immature stages.

The database is based on 615 specimens belonging to 203 species, and few identified up to family and genus level. The selected localities were surveyed from two primary host plants (Som- *Persea bombycina*, Soalu - *Litsea monopetala*) (Family : Lauraceae). The four insect groups *viz.*, Coleoptera, Lepidoptera, Hemiptera, Hymenoptera and other groups (Diptera, Mantodea, Neuroptera, Odonata) were focused. The map for six states was prepared using DIVA GIS software. All specimens are preserved at the Insect repository, Entomology Department, CMERTI, Lahdoigarh.

RESULTS AND DISCUSSION

Muga silkworm (*Antheraea assamensis* Helfer) is generally reared on two primary host plants viz., *Litsea monopetala* (Soalu) and *Persea bombycina* (Som) of the family Lauraceae. Six states of North Eastern states were surveyed for collection of pests, predators, other natural enemies and pollinators (Fig. 1; Table 1). The survey was conducted from 2012 to 2015. Two

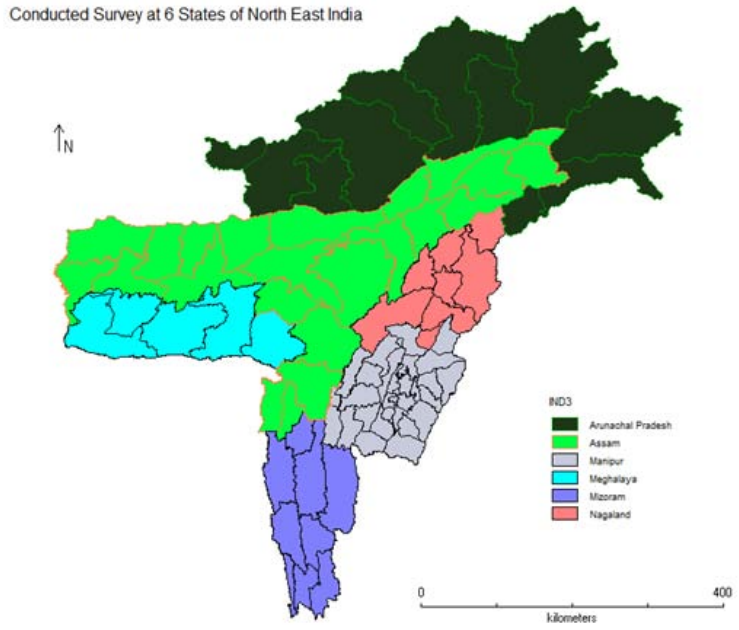

Fig. 1. North Eastern states surveyed

Table 1. North Eastern States with state wise localities covered

S. No.	States	Localities
1	Arunachal Pradesh	Pashighat, Roing, Itanagar, Nirjuli, Ziro
2	Assam	Udalguri (BTC), Tamulpur (BTC), Lakhimpur, Tejpur, Tinisukia, Jorhat, Golaghat, Bogori, Bokaghat, Moran, Sivasgar, Nazira, Dibrugarh, Goalpara, Sadiya, Khwong, Jungle Block, Titabar, Mariani, Mangaldoi, Tupia,
3	Manipur	Imphal, Urkhul
4	Meghalaya	Barapani, Shillong, Mawflong, Nongpoh (Khasi Hills); Tura, Damalgiri, Silsela, Balpakram National Park, Bagmara, Kanai, Dalu (Garo Hills), Mawsentei, Mergner
5	Mizoram	Aizawl
6.	Nagaland	Mokockchung, Zuniboto

hundred and three species were identified up to species and genus level, and these listed in Table 2. Maximum number of species, i.e., 174 were recorded from Assam followed by Meghalaya (149), Mizoram (84), Nagaland (75), Arunachal Pradesh (69) and Manipur (64) (Fig. 2, 3; Table 3). Many species listed are reported for the first time from these plants and some species for the first time from India. *Synorchestes indicus* Ayri and Ramamurthy, sp. nov. (Coleoptera: Curculionidae) is endemic and found only in Assam. During survey, it was observed in other states. The genus *Synorchestes* includes only two species (gall making), while another

Table 2. Number of identified specimens (order and state wise)

Order	Assam	Mizoram	Arunachal Pradesh	Meghalaya	Manipur	Nagaland	Total
Coleoptera	48	12	7	41	6	11	125
Lepidoptera	81	60	52	73	49	55	370
Diptera	3	1	1	1	1	1	8
Hemiptera	35	11	9	32	8	8	103
Odonata	1	0	0	0	0	0	1
Neuroptera	4	0	0	0	0	0	4
Mantodea	2	0	0	2	0	0	4
Total	174	84	69	149	64	75	615

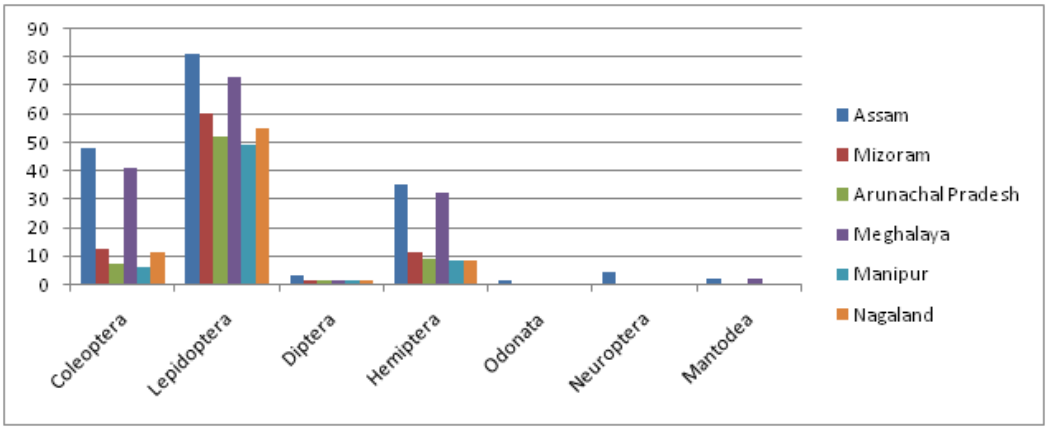

Fig. 2. Number of species collected (group wise)

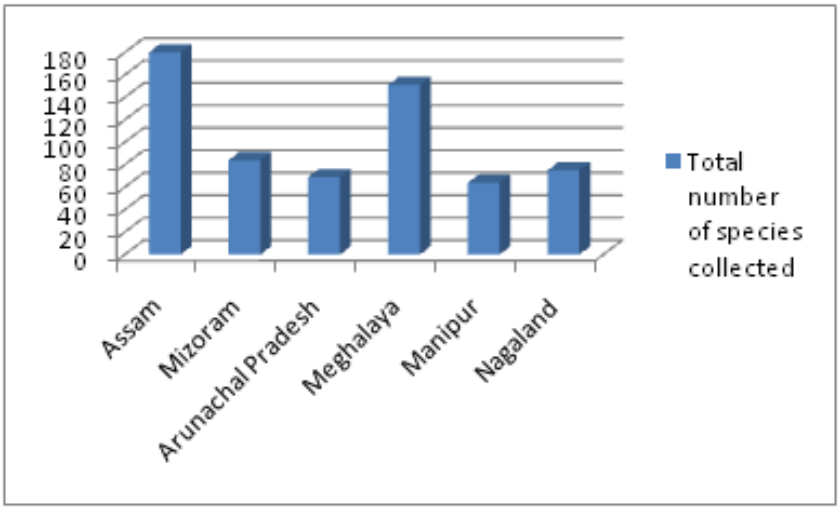

Fig. 3. Statewise number of species collected

Table 3. Order and family wise list of species

S. No.	*Scientific Name*	Family	Host
COLEOPTERA			
1.	*Apion clavipes* Gerst.	Apionidae	Som
2.	*Apion* sp.	Apionidae	Soalu
3.	*Lamprolabus pseudobispinosus* Legalov & Liu	Attelabidae	Soalu
4.	*Cicindela aurulenta* F.	Carabidae	Som
5.	*Cicindela sexpunctata* F.	Carabidae	Som
6.	*Cicindela* sp.	Carabidae	Som
7.	*Cicindela* sp.	Carabidae	Som
8.	*Cassida circumdata* Herbst	Chrysomelidae	Som
9.	*Laccoptera quadrimaculata* Thunberg	Chrysomelidae	Som
10.	*Aegosoma bowringi* Gahan	Cerambycidae	Som
11.	*Chlorophorus annualris* F.	Cerambycidae	Soalu
12.	*Glenea cantor* (F.)	Cerambycidae	Som
13.	*Megopis bowringi* Gahan	Cerambycidae	Som
14.	*Oberia* sp. nov.	Cerambycidae	Som
15.	*Xylorhiza adusta* Wiedemann	Cerambycidae	Soalu
16.	*Xylorhiza* sp.	Cerambycidae	Soalu
17.	*Aspidomorpha* sp.1	Chrysomelidae	Som
18.	*Aspidomorpha* sp.2	Chrysomelidae	Som
19.	*Aspidomorpha* sp.3	Chrysomelidae	Som
20.	*Aulacophora atripennis* F.	Chrysomelidae	Som
21.	*Aulacophora excavata* Baly	Chrysomelidae	Som & Soalu
22.	*Aulacophora frontalis* Baly	Chrysomelidae	Som & Soalu
23.	*Chilocorus nigrita* (F.)	Coccinellidae	Som & Soalu
24.	*Chirida septumnotata* Boheman	Chrysomelidae	Som & Soalu
25.	*Dercetis flavocincta* (Hope)	Chrysomelidae	Som
26.	*Gynandrothalma* sp.	Chrysomelidae	Som
27.	*Nonarthra variabilis* Baly	Chrysomelidae	Som
28.	*Coccinella septumpunctata* L.	Coccinellidae	Predator
29.	*Coelophora bowringii* Crotch	Coccinellidae	Predator
30.	*Coelophora saucia* (Mulsant)	Coccinellidae	Predator
31.	*Harmonia dimidiata* (F.)	Coccinellidae	Predator
32.	*Jauravia quadrinotata* Kapur	Coccinellidae	Predator
33.	*Micraspis discolor* (F.)	Coccinellidae	Predator
34.	*Phrynocaria decemguttata* (Weise)	Coccinellidae	Predator
35.	*Phrynocaria unicolor* (F.)	Coccinellidae	Predator
36.	*Crinorrhinus* sp.	Curculionidae	Som
37.	*Dereodus squamosus* Herbst	Curculionidae	Som
38.	*Diocalandraquadrinotata* Wiedemann	Curculionidae	Som & Soalu
39.	*Episomus lacerta* (F.)	Curculionidae	Som
40.	*Lepropus chrysochlorus* Wiedemann	Curculionidae	Som
41.	*Myllocerus*sp.	Curculionidae	Som
42.	*Odoiporus longicollis* Olivier	Curculionidae	Som
43.	*Tanymecus indicus* Faust	Curculionidae	Som
44.	*Luciola chinensis* (L.)	Lampyridae	Som

45.	*Sagara femorata* Olivier	Chrysomelidae	Som
46.	*Onthophagus catta* F.	Scarabaedae	Soalu
47.	*Anomala chloropus* Arrow	Scarabaeidae	Soalu
48.	*Anomala xanthoptera* Blanchard	Scarabaeidae	Som
49.	*Xylotrupes gideon* (L.)	Scarabaeidae	Som
50.	*Euwallacea fornicatus* (Eichhoff)	Scolytidae	Som
51.	*Synorchestes indicus Ayri & Ramamurthy, sp. nov.*	Curculionidae	New species on Som
52.	*Epilachna vigintioctopunctata* (Fabricius)	Coccinellidae	Som & Soalu
53.	*Oryctes rhinoceros* (L.)	Dynastinae	
DIPTERA			
54.	*Asphondylia* sp.	Cecidomyiidae	As gall on som
55.	*Blepharipa* sp.	Tachinidae	On silkworm
56.	*Megaselia* sp.	Phoridae	On uzifly adults
HEMIPTERA			
57.	*Darthula hardwickii* Gray	Aetalionidae	Som
58.	*Icerya* sp.	Monophlebidae	Soalu
59.	*Pseudaulacaspis* sp.	Coccidae	Som
60.	*Euonymus* sp.	Coccidae	Som
61.	*Darthula* sp.	Aetalionidae	Som
62.	*Aleurodicus dispersus* Russell	Aleyrodidae	Som
63.	*Dialeuropora decempuncta* (Quaintance & Baker)	Aleyrodidae	Som
64.	*Agonoscelis nubila* F.	Pentatomidae	Som
65.	*Aiceona robustiseta* Ghosh & Raychaudhuri	Aphididae	Som and Soalu
66.	*Aphis cracivora* Koch	Aphididae	Som
67.	*Lipaphis erysimi* (Kaltenbach)	Aphididae	Soalu
68.	*Myzus persicae* (Sulzer)	Aphididae	Som
69.	*Mylabris* sp.	Cercopidae	Som
70.	*Platylomia radha* (Distant)	Cicadidae	Som
71.	*Leptocorisa acuta*(Thunberg)	Coriedae	Som
72.	*Aonidiella aurantii* (Maskell)	Diaspididae	Soalu
73.	*Pyrops candelaria* (L.)	Fulgoridae	Soalu
74.	*Hypsauchenia subfusca* Buckton	Membracidae	Soalu
75.	*Eucanthecona furcellata* (Wolff)	Pentatomidae	Muga silkworm
76.	*Homoeocerus marginellus* (H.-Sch.)	Pentatomidae	Som
77.	*Nezara viridula* L.	Pentatomidae	Som
78.	*Podius* sp.	Pentatomidae	Som
79.	*Poecilocoris latus* (Dallas)	Pentatomidae	Soalu
80.	*Megacopta cribraria* F.	Plataspididae	Soalu
81.	*Pauropsylla beesoni* L.	Psyllidae	Soalu
82.	*Dysdercus koenigii* Fabricius	Pyrrhocoridae	Soalu
83.	*Endochus* sp.	Reduviidae	Muga Silkworm
84.	*Isyndus* sp.1	Reduviidae	Muga silkworm
85.	*Isyndus* sp.2	Reduviidae	Muga silkworm
86.	*Polydidus* sp.	Reduviidae	Muga Silkworm
87.	*Sycanus collaris* Fabricius	Reduviidae	Muga silkworm
88.	*Cantao ocellatus* (Thunberg)	Scutelleridae	Som
89.	*Galeatus darthula* Kirkaldy	Tingidae	Som
90.	*Strphanitis typicus* Distant	Tingidae	Som

91.	*Coptosoma cribrarium* F.	Pentatomidae	Soalu
92.	*Ophion* sp.	Ichneumonidae	Limacodid pest
93.	*Triscolia* sp.	Scoliidae	Muga silkworm
HYMENOPTERA			
94.	*Odontotermes* sp.	Termitidae	Som and Soalu
95.	*Xylocopa* sp.	Apidae	Muga silkworm
96.	*Cotesia glomeratus* L.	Braconidae	Muga silkworm
97.	*Brachymeria lasus* (Walker)	Chalcididae	On papilionid larva
98.	*Brachymeria* sp.	Chalcididae	Emerged from Lymantriid pupa
99.	*Dirhinus intermedius* Mani & Dubey	Chalcididae	Emerged from uzi fly pupa
100.	*Exoristobia philippinensis* Ashmead	Chalcididae	Emerged from uzi fly pupa
101.	*Psyllaephagus ramamurthyi* Hayat	Encyrtidae	Emerged from uzi fly pupa
102.	*Nesolynx thymus* Girault	Eulophidae	Emerged from uzi fly pupa
103.	*Camponotus* sp.	Formicidae	Feeding on muga silkworm
104.	*Oecophyla smaragdina* F.	Formicidae	Feeding on muga silkworm
105.	*Polistes* sp.	Vespidae	Feeding on muga silkworm
106.	*Polistes olivaceus* De Geer	Vespidae	Feeding on muga silkworm
107.	*Polistes hebraeus* F.	Vespidae	Feeding on muga silkworm
108.	*Subancistrocerus sichelii* (Schulthess)	Vespidae	Feeding on muga silkworm
109.	*Vespa orientalis* L.	Vespidae	Feeding on muga silkworm
110.	*Encarsia* sp.	Aphelinidae	Feeding on muga silkworm
111.	*Vespa tropica* (L.)	Vespidae	Feeding on muga silkworm
LEPIDOPTERA			
112.	*Zeuzera indica* Herrich-Schäffer	Cossidae	Soalu
113.	*Zeuzera multistrigata* Moore	Cossidae	Soalu
114.	*Cyclidia substigmaria* Hubner	Drepanidae	Soalu
115.	*Radhica elesabethae*	Lasiocampidae	New Report on Soalu
116.	*Macroglossum* sp.	Sphingidae	Soalu
117.	*Erebus* sp.	Noctuidae	Soalu
118.	*Eterusia aedea magnifica* (Butler)	Zygaenidae	Soalu
119.	*Eterusia aedea edocela* (Doubleday)	Zygaenidae	Soalu
120.	*Gynautocera papilionaria* Guerin	Zygaenidae	Soalu
121.	*Krananda* sp.	Geometridae	Som and Soalu
122.	*Nyctemera* sp.	Erebidae	Som and soalu
123.	*Creatonotos gangis* L.	Arctiidae	Soalu
124.	*Creatonotos transiens* Walker	Arctiidae	Soalu
125.	*Mangina* sp.	Arctiidae	Som and soalu
126.	*Utetheisa pulchelloides* Hampson	Arctiidae	Som and soalu
127.	*Aetholix* sp.	Crambidae	Soalu
128.	*Conogethes punctiferalis* (Guenee)	Crambidae	Som and soalu
129.	*Desmia* sp.	Crambidae	Som
130.	*Diaphania indica* Saunders	Crambidae	Som
131.	*Areas* sp.	Arctiidae	Light trap
132.	*Aglaomorpha* sp.	Arctiidae	Light trap
133.	*Alpenus* sp.	Acrtiidae	Light trap
134.	*Pygospila tyres* Cramer	Crambidae	Som
135.	*Danaus chrysippus* L.	Danaidae	Adults visiting during flowering period

136.	*Danaus genutia* Cramer	Danaidae	Adults visiting during flowering period
137.	*Parantica aglea melanoides* (Stoll)	Danaidae	Adults visiting during flowering period
138.	*Parantica sita* (Kollar)	Danaidae	Adults visiting during flowering period
139.	*Cyana* sp.	Erebidae	Light trap
140.	*Euproctis scintillans* (Walker)	Lymantriidae	Soalu
141.	*Perina nuda* Walker	Erebidae	Soalu
142.	*Corymica* sp.	Geometridae	Som
143.	*Ourapteryx* sp.	Geometridae	Light trap
144.	*Fascellina* sp.	Geometriidae	Som
145.	*Pingasa* sp.	Geometriidae	Som
146.	*Acrocercops* sp.	Gracillariidae	Som and Soalu
147.	*Bibasis gomata gomata* (Moore)	Hesperiidae	Light trap
148.	*Setothosea asigna* van Eecke	Limacoididae	Som
149.	*Cheromettia* sp.	Limacoididae	Som
150.	*Darna* sp.	Limacoididae	Som
151.	*Parasa pastoralis* Butler	Limacoididae	Som
152.	*Lymantria* sp.	Lymantriidae	Som and Soalu
153.	*Arctornis* sp.	Lymantriidae	Som and Soalu
154.	*Achaea janata*, L.	Noctuidae	Som and Soalu
155.	*Eudocima salaminia* (Cramer)	Noctuidae	Light trap
156.	*Hypena sagitta* F.	Noctuidae	Light trap
157.	*Spirama* sp.	Noctuidae	Light trap
158.	*Ariadne merione* Cramer	Nymphalidae	Adults visiting during flowering period
159.	*Charaxes aristogiton* Felder	Nymphalidae	Pollinating period
160.	*Charaxes bernardus* F.	Nymphalidae	Adults visiting during flowering period
161.	*Charaxes solon* F.	Nymphalidae	Adults visiting during flowering period
162.	*Elymnias hypermnestra caudate* L.	Nymphalidae	Soalu
163.	*Elymnias hypermnestra* L.	Nymphalidae	Soalu
164.	*Elymnias malelas* Hewitson	Nymphalidae	Soalu
165.	*Elymnias nesa* Doubleday	Nymphalidae	Soalu
166.	*Euploea mulciber* Cramer	Nymphalidae	Adults visiting during flowering period
167.	*Euthalia aconthea garuda* (Hewitson)	Nymphalidae	Som
168.	*Hypolimnas bolina* L.	Nymphalidae	Adults visiting during flowering period
169.	*Junonia almana* L.	Nymphalidae	Adults visiting during flowering period
170.	*Junonia atlites* L.	Nymphalidae	Adults visiting during flowering period
171.	*Junonia hierta* F.	Nymphalidae	Adults visiting during flowering period
172.	*Neptis hylas astola* Moore	Nymphalidae	Adults visiting during flowering period

173.	*Pantoporia perius* (L.)	Nymphalidae	Adults visiting during flowering period
174.	*Polyura athamas* Drury	Nymphalidae	Som
175.	*Symbrenthia hippoclus* Hewitson	Nymphalidae	Adults visiting during flowering period
176.	*Graphium sarpedon luctatius* L.	Papilionidae	Som
177.	*Pachliopta aristolochiae* (F.)	Papilionidae	Som
178.	*Papilio demoleus* L.	Papilionidae	Adults visiting during flowering period
179.	*Papilio helenus* L.	Papilionidae	Adults visiting during flowering period
180.	*Papilio polytes romulus* Cramer	Papilionidae	Adults visiting during flowering period
181.	*Catopsilia pomona* F.	Pieridae	Adults visiting during flowering period
182.	*Catopsilia pyranthe* L.	Pieridae	Adults visiting during flowering period
183.	*Delias agostina* Hewitson	Pieridae	Adults visiting during flowering period
184.	*Eurema hecabe fimbriata* L.	Pieridae	Adults visiting during flowering period
185.	*Leptosia nina* F.	Pieridae	Adults visiting during flowering period
186.	*Pieris canidia indica* Evans	Pieridae	Adults visiting during flowering period
187.	*Pieris melete* Ménétriés	Pieridae	Adults visiting during flowering period
188.	*Perina nuda* (F.)	Erebidae	Som and Soalu
189.	*Pleuroptya silicalis* (Guenee)	Pyralidae	Som and Soalu
190.	*Attacus atlas* L.	Saturniidae	Soalu
191.	*Cricula trifenestrata* Heifer	Saturniidae	Som
192.	*Samia canningi* (Hutton)	Saturniidae	Soalu
193.	*Melanitis leda ismene* L.	Satyridae	Adults visiting during flowering period
194.	*Mycalesis mineus mineus* L.	Satyridae	Adults visiting during flowering period
195.	*Mycalesis perseus blasius* F.	Satyridae	Adults visiting during flowering period
196.	*Syntomoides imaon* (Cramer)	Syntomidae	Som
DICTYOPTERA			
197.	*Hierodula westwoodi* Kirby	Mantidae	Muga silkworm
198.	*Statilia maculata* (Thunberg)	Mantidae	Muga silkworm
NEUROPTERA			
199.	*Climaciella quadrituberculata* (Westwood)	Mantispidae	Feed on pests
200.	*Chrysacanthia esbeniana* Lacroix	Chrysopidae	Feed on sucking pests
201.	*Chrysoperla* sp.	Chrysopidae	Feed on sucking pests
202.	*Italochrysa* sp.	Chrysopidae	Feed on sucking pests
ODONATA			
203.	*Rhyothemis variegata* (L.)	Libellulidae	Predate on small insects

Table 4. Order, family wise list of species in states -Assam (As), Mizoram (Mi), Arunachal Pradesh (AP), Meghalaya (Me), Manipur (Ma), Nagaland (Na)

S. No.	*Scientific Name*	Family	As	Mi	AP	Me	Ma	Na
COLEOPTERA								
1.	*Apion clavipes* Gerst.	Apionidae	+	-	-	-	-	-
2.	*Apion* sp.	Apionidae	+	-	-	-	-	-
3.	*Lamprolabus pseudobispinosus* Legalov & Liu	Attelabidae	-	-	-	+	-	-
4.	*Cicindela aurulenta* F.	Carabidae	+	+	+	+	+	+
5.	*Cicindela sexpunctata* F.	Carabidae	+	+	+	+	+	+
6.	*Cicindela* sp.	Carabidae	+	-	-	+	-	-
7.	*Cicindela* sp.	Carabidae	+	+	+	+	+	+
8.	*Cassida circumdata* Herbst	Chrysomelidae	+	-	-	-	-	-
9.	*Laccoptera quadrimaculata* Thunberg	Chrysomelidae	+	-	-	-	-	-
10.	*Aegosoma bowringi* Gahan	Cerambycidae	+	-	-	-	-	-
11.	*Chlorophorus annualris*, F.	Cerambycidae	+	-	-	-	-	-
12.	*Glenea cantor* (F.)	Cerambycidae	+	-	-	+	-	-
13.	*Megopis bowringi* Gahan	Cerambycidae	+	-	-	+	-	-
14.	*Oberia* sp. nov.	Cerambycidae	+	-	-	+	-	-
15.	*Xylorhiza adusta* Wiedemann	Cerambycidae	+	-	-	+	-	-
16.	*Xylorhiza* sp.	Cerambycidae	+	-	-	+	-	-
17.	*Aspidomorpha* sp.1	Chrysomelidae	+	-	+	-	-	+
18.	*Aspidomorpha* sp.2	Chrysomelidae	+	-	+	-	-	+
19.	*Aspidomorpha* sp.3	Chrysomelidae	+	-	-	-	-	-
20.	*Aulacophora atripennis* F.	Chrysomelidae	+	-	-	+	-	-
21.	*Aulacophora excavata* Baly	Chrysomelidae	+	-	-	+	-	-
22.	*Aulacophora frontalis* Baly	Chrysomelidae	+	-	-	+	-	-
23.	*Chilocorus nigrita* F.	Coccinellidae	+	-	-	+	-	-
24.	*Chirida septumnotata* Boheman	Chrysomelidae	+	-	-	+	-	-
25.	*Dercetis flavocincta* (Hope)	Chrysomelidae	+	-	-	+	-	-
26.	*Gynandrophalma* sp.	Chrysomelidae	+	-	-	+	-	-
27.	*Nonarthra variabilis* Baly	Chrysomelidae	+	-	-	+	-	-
28.	*Coccinella septumpunctata*, L.	Coccinellidae	+	-	-	+	-	-
29.	*Coelophora bowringii* Crotch	Coccinellidae	+	-	-	+	-	-
30.	*Coelophora saucia* (Mulsant)	Coccinellidae	+	-	-	+	-	-
31.	*Harmonia dimidiata* (F.)	Coccinellidae	+	-	-	+	-	-
32.	*Jauravia quadrinotata* Kapur	Coccinellidae	+	-	-	+	-	-
33.	*Micraspis discolor* (F.)	Coccinellidae	+	-	-	+	-	-
34.	*Phrynocaria decemguttata* (Weise)	Coccinellidae	+	-	-	+	-	-
35.	*Phrynocaria unicolor* (F.)	Coccinellidae	+	-	-	+	-	-
36.	*Crinorrhinus* sp.	Curculionidae	+	+	-	+	+	+
37.	*Dereodus squamosus* Herbst	Curculionidae	+	+	-	+	+	+
38.	*Diocalandra quadrinotata* Wiedemann	Curculionidae	+	+	-	+	-	+
39.	*Episomus lacerta* (F.)	Curculionidae	+	+	-	+	-	+
40.	*Lepropus chrysochlorus* Wiedemann	Curculionidae	+	+	-	+	-	+
41.	*Myllocerus* sp.	Curculionidae	+	-	-	+	-	-
42.	*Odoiporus longicollis* Olivier	Curculionidae	-	+	-	+	-	-
43.	*Tanymecus indicus* Faust	Curculionidae	-	+	-	+	-	-

44.	*Luciola chinensis*	Lampyridae	+	-	-	+	-	-
45.	*Sagara femorata* Olivier	Chrysomelidae	-	-	-	+	-	-
46.	*Onthophagus catta* F.	Scarabaedae	+	+	+	+	-	-
47.	*Anomala chloropus* Arrow	Scarabaeidae	+	-	-	+	-	-
48.	*Anomala xanthoptera* Blanchard	Scarabaeidae	+	-	-	+	-	-
49.	*Xylotrupes gideon* (L.)	Scarabaeidae	+	-	-	-	-	-
50.	*Euwallacea fornicatus* (Eichhoff)	Scolytidae	+	-	-	-	-	-
51.	Synorchestes indicus Ayri &Ramamurthy, sp. nov.	Curculionidae	+	-	-	-	-	-
52.	*Epilachna vigintioctopunctata* (F.)	Coccinellidae	+	+	+	+	+	+
53.	*Oryctes rhinoceros* (L.)	Dynastinae	-	-	-	+	-	-
DIPTERA								
54.	*Asphondylia* sp.	Cecidomyiidae	+	+	+	+	+	+
55.	*Blepharipa* sp. nov.	Tachinidae	+	-	-	-	-	-
56.	*Megaselia* sp.	Phoridae	+	-	-	-	-	-
HEMIPTERA								
57.	*Darthula hardwickii*, Gray	Aetalionidae	-	+	-	+	-	-
58.	*Icerya* sp.	Monophlebidae	-	-	-	+	-	-
59.	*Pseudaulacaspis* sp.	Coccidae	+	+	-	+	-	+
60.	*Euonymus* sp.	Coccidae	+	+	-	+	-	+
61.	*Darthula* sp.	Aetalionidae	+	+	-	+	-	-
62.	*Aleurodicus dispersus* Russell	Aleyrodidae	+	-	-	-	-	-
63.	*Dialeuropora decempuncta* (Quaintance & Baker)	Aleyrodidae	+	-	+	+	-	-
64.	*Agonoscelis nubila* F.	Pentatomidae	+	-	-	+	-	-
65.	*Aiceona robustiseta* Ghosh & Raychaudhuri	Aphididae	+	-	-	+	-	-
66.	*Aphis cracivora* Koch	Aphididae	+	-	+	+	-	-
67.	*Lipaphis erysimi* (Kaltenbach)	Aphididae	+	-	-	+	-	-
68.	*Myzus persicae* (Sulzer)	Aphididae	+	-	-	+	-	-
69.	*Mylabris* sp.	Cercopidae	+	-	-	+	-	-
70.	*Platylomia radha* (Distant)	Cicadidae	+	-	-	+	-	-
71.	*Leptocorisa acuta* (Thunberg)	Coriedae	+	-	-	+	-	-
72.	*Aonidiella aurantii* (Maskell)	Diaspididae	+	-	-	+	-	-
73.	*Pyrops candelaria* (L.)	Fulgoridae	+	-	-	-	-	-
74.	*Hypsauchenia subfusca* Buckton	Membracidae	+	+	+	+	+	+
75.	*Eucanthecona furcellata* (Wolff)	Pentatomidae	+	-	-	+	-	-
76.	*Homoeocerus marginellus* (H.-Sch.)	Pentatomidae	+	-	-	+	-	-
77.	*Nezara viridula* L.	Pentatomidae	+	+	+	+	+	+
78.	*Podius* sp.	Pentatomidae	+	+	-	+	-	-
79.	*Poecilocoris latus* (Dallas)	Pentatomidae	+	-	-	-	-	-
80.	*Megacopta cribraria* F.	Plataspididae	+	-	+	+	+	+
81.	*Pauropsylla beesoni* Laing	Psyllidae	+	+	+	+	+	+
82.	*Dysdercus koenigii*, F.	Pyrrhocoridae	+	+	+	+	+	+
83.	*Endochus* sp.	Reduviidae	+	-	-	-	-	-
84.	*Isyndus* sp.1	Reduviidae	+	-	-	+	-	-
85.	*Isyndus* sp.2	Reduviidae	+	-	-	+	-	-
86.	*Polydidus* sp.	Reduviidae	+	-	-	+	-	-
87.	*Sycanus collaris* F.	Reduviidae	+	+	+	+	+	+
88.	*Cantao ocellatus* (Thunberg)	Scutelleridae	+	+	-	+	+	-

89.	*Galeatus darthula* Kirkaldy	Tingidae	+	-	+	+	+	-
90.	*Statphanitis typicus* Distant	Tingidae	+	-	-	+	-	-
91.	*Coptosoma cribrarium* F.	Pentatomidae	+	-	-	+	-	-
HYMENOPTERA								
92.	*Ophion* sp.	Ichneumonidae	+	-	-	-	-	-
93.	*Triscolia* sp.	Scoliidae	+	-	-	+	-	-
94.	*Odontotermes* sp.	Termitidae	+	-	-	-	-	-
95.	*Xylocopa* sp.	Apidae	+	+	+	+	+	+
96.	*Cotesia glomeratus*, L.	Braconidae	+	-	-	+	-	-
97.	*Brachymeria lasus* (Walker)	Chalcididae	+	-	-	-	-	-
98.	*Brachymeria* sp.	Chalcididae	+	-	-	-	-	-
99.	*Dirhinus intermedius* Mani & Dubey	Chalcididae	+	-	-	-	-	-
100.	*Exoristobia philippinensis* Ashmead	Chalcididae	+	-	-	-	-	-
101.	*Psyllaephagus ramamurthyi* Hayat	Encyrtidae	+	-	-	-	-	-
102.	*Nesolynx thymus* Girault	Eulophidae	+	-	-	+	-	-
103.	*Camponotus* sp.	Formicidae	+	-	-	+	-	-
104.	*Oecophyla smaragdina* F.	Formicidae	+	+	+	+	+	+
105.	*Polistes* sp.	Vespidae	+	+	+	+	+	+
106.	*Polistes olivaceus* De Geer	Vespidae	+	+	+	+	+	+
107.	*Polistes hebraeus* F.	Vespidae	+	+	+	+	+	+
108.	*Subancistrocerus sichelii* (Schulthess)	Vespidae	+	+	+	+	+	+
109.	*Vespa orientalis*, L.	Vespidae	+	+	+	+	+	+
110.	*Encarsia* sp.	Aphlinidae	+	+	+	+	+	+
111.	*Vespa tropica* (L.)	Vespidae	+	+	+	+	+	+
LEPIDOPTERA								
112.	*Zeuzera indica* Herrich-Schäffer	Cossidae	+	-	-	+	-	-
113.	*Zeuzera multistrigata* Moore	Cossidae	+	-	-	+	-	-
114.	*Cyclidia substigmaria* Hubner	Drepanidae	+	+	-	+	-	-
115.	*Radhica elesabethae*	Lasiocampidae	-	-	-	+	-	-
116.	*Macroglossum* sp.	Sphingidae	+	-	-	+	-	+
117.	*Erebus* sp.	Noctuidae	+	-	-	+	-	-
118.	*Eterusia aedea magnifica*	Zygaenidae	+	-	-	+	-	-
119.	*Eterusia aedea edocela* (Doubleday)	Zygaenidae	+	-	-	-	-	-
120.	*Gynautocera papilionaria* Guerin	Zygaenidae	+	-	-	+	-	-
121.	*Krananda* sp.	Geometridae	+	-	-	-	-	-
122.	*Nyctemera* sp.	Erebidae	+	-	-	+	-	-
123.	*Creatonotos gangis*, L.	Arctiidae	+	+	-	-	-	-
124.	*Creatonotos transiens* Walker	Arctiidae	+	-	-	+	-	-
125.	*Mangina* sp.	Arctiidae	+	+	+	-	-	+
126.	*Utetheisa* pulchelloides Hampson	Arctiidae	+	+	-	+	-	+
127.	*Aetholix* sp.	Crambidae	-	+	+	+	-	-
128.	*Conogethes punctiferalis* Guenee	Crambidae	+	+	+	+	+	+
129.	*Desmia* sp.	Crambidae	+	+	+	+	+	+
130.	*Diaphania indica* Saunders	Crambidae	+	+	+	+	+	+
131.	*Areas* sp.	Arctiidae	+	+	+	+	+	+
132.	*Aglaomorpha* sp.	Arctiidae	+	+	+	+	+	+
133.	*Alpenus sp.*	Acrtiidae	+	+	+	+	+	+
134.	*Pygospila tyres* Cramer	Crambidae	-	+	-	-	-	+

135.	*Danaus chrysippus*, L.	Danaidae	+	+	+	+	+	+
136.	*Danaus genutia* Cramer	Danaidae	+	+	+	+	+	+
137.	*Parantica aglea melanoides* (Stoll)	Danaidae	+	+	+	+	+	+
138.	*Parantica sita* (Kollar)	Danaidae	+	+	+	+	+	+
139.	*Cyana* sp.	Erebidae	+	+	+	+	+	+
140.	*Euproctis scintillans* (Walker)	Lymantriidae	+	-	-	+	-	+
141.	*Perina nuda* Walker	Erebidae	+	-	-	-	-	-
142.	*Corymica* sp.	Geometridae	+	-	-	-	-	-
143.	*Ourapteryx* sp.	Geometridae	-	+	-	-	-	-
144.	*Fascellina* sp.	Geometriidae	+	-	-	+	-	-
145.	*Pingasa* sp.	Geometriidae	+	+	-	+	-	+
146.	*Acrocercops* sp.	Gracillariidae	+	-	-	+	-	-
147.	*Bibasis gomata gomata* (Moore)	Hesperiidae	+	+	+	+	+	+
148.	*Setothosea asigna* van Eecke	Limacoididae	+	-	-	-	-	-
149.	*Cheromettia* sp.	Limacoididae	+	-	-	-	-	-
150.	*Darna* sp.	Limacoididae	+	-	-	-	-	-
151.	*Parasa pastoralis* Butler	Limacoididae	+	-	-	-	-	-
152.	*Lymantria* sp.	Lymantriidae	+	-	-	+	-	-
153.	*Arctornis* sp.	Lymantriidae	+	-	-	+	-	-
154.	*Achaea janata* L.	Noctuidae	+	-	-	+	-	-
155.	*Eudocima salaminia* (Cramer)	Noctuidae	+	-	-	+	-	-
156.	*Hypena sagitta* F.	Noctuidae	+	+	-	+	-	-
157.	*Spirama* sp.	Noctuidae	+	+	-	+	-	-
158.	*Ariadne merione* Cramer	Nymphalidae	+	+	+	+	+	+
159.	*Charaxes aristogiton* C. Felder	Nymphalidae	+	+	+	+	+	+
160.	*Charaxes bernardus*, F.	Nymphalidae	+	+	+	+	+	+
161.	*Charaxes solon* F.	Nymphalidae	+	+	+	+	+	+
162.	*Elymnias hypermnestra caudate* L.	Nymphalidae	+	+	+	+	+	+
163.	*Elymnias hypermnestra* L.	Nymphalidae	+	+	+	+	+	+
164.	*Elymnias malelas* Hewitson	Nymphalidae	+	+	+	+	+	+
165.	*Elymnias nesa* Doubleday	Nymphalidae	+	+	+	+	+	+
166.	*Euploea mulciber* Cramer	Nymphalidae	+	+	+	+	+	+
167.	*Euthalia aconthea garuda* (Hewitson)	Nymphalidae	+	+	+	+	+	+
168.	*Hypolimnas bolina* L.	Nymphalidae	+	+	+	+	+	+
169.	*Junonia almana* L.	Nymphalidae	+	+	+	+	+	+
170.	*Junonia atlites* L.	Nymphalidae	+	+	+	+	+	+
171.	*Junonia hierta* F.	Nymphalidae	+	+	+	+	+	+
172.	*Neptis hylas astola* Moore	Nymphalidae	+	+	+	+	+	+
173.	*Pantoporia perius* (L.)	Nymphalidae	+	+	+	+	+	+
174.	*Polyura athamas* Drury	Nymphalidae	+	+	+	+	+	+
175.	*Symbrenthia hippoclus* Hewitson	Nymphalidae	+	+	+	+	+	+
176.	*Graphium sarpedon luctatius* L.	Papilionidae	+	+	+	+	+	+
177.	*Pachliopta aristolochiae* (F.)	Papilionidae	+	+	+	+	+	+
178.	*Papilio demoleus* L.	Papilionidae	+	+	+	+	+	+
179.	*Papilio helenus* L.	Papilionidae	+	+	+	+	+	+
180.	*Papilio polytes romulus* Cramer	Papilionidae	+	+	+	+	+	+
181.	*Catopsilia pomona* F.	Pieridae	+	+	+	+	+	+
182.	*Catopsilia pyranthe* L.	Pieridae	+	+	+	+	+	+

183.	*Delias agostina* Hewitson	Pieridae	+	+	+	+	+	+
184.	*Eurema hecabe fimbriata* L.	Pieridae	+	+	+	+	+	+
185.	*Leptosia nina* F.	Pieridae	+	+	+	+	+	+
186.	*Pieris canidia indica* Evans	Pieridae	+	+	+	+	+	+
187.	*Pieris melete* Ménétriés	Pieridae	+	+	+	+	+	+
188.	*Perina nuda* (F.)	Erebidae	+	+	+	+	+	+
189.	*Pleuroptya silicalis* (Guenee)	Pyralidae	+	+	+	+	-	-
190.	*Attacus atlas* L.	Saturniidae	+	+	+	+	+	+
191.	*Cricula trifenestrata* Helfer	Saturniidae	+	+	+	+	+	+
192.	*Samia canningi* (Hutton)	Saturniidae	+	+	+	+	+	+
193.	*Melanitis leda ismene* L.	Satyridae	+	+	+	+	+	+
194.	*Mycalesis mineus mineus* L.	Satyridae	+	+	+	+	+	+
195.	*Mycalesis perseus blasius* F.	Satyridae	+	+	+	+	+	+
196.	*Syntomoides imaon* (Cramer)	Syntomidae	+	-	-	+	-	-
MANTODEA								
197.	*Hierodula westwoodi* Kirby	Mantidae	+	-	-	+	-	-
198.	*Statilia maculata* (Thunberg)	Mantidae	+	-	-	+	-	-
DICTYOPTERA								
199.	*Climaciella quadrituberculata* (Westwood)	Mantispidae	+	-	-	-	-	-
200.	*Chrysacanthia esbeniana* Lacroix	Chrysopidae	+	-	-	-	-	-
201.	*Chrysoperla* sp.	Chrysopidae	+	-	-	-	-	-
202.	*Italochrysa* sp.	Chrysopidae	+	-	-	-	-	-
ODONATA								
203.	*Rhyothemis variegata* (L.)	Libellulidae	+	-	-	-	-	-

species is found in Japan. Two new species collected had published as new species observed feeding on som plants *viz*., *Psyllaephagus ramamurthyi* Hayat sp. nov. (Hymenoptera: Encyrtidae) and *Synorchestes indicus* Ayri and Ramamurthy, sp. nov. (Coleoptera: Curculionidae). Two more new species, one is pest of Som plant as borer *Oberia sp. nov*. (Coleoptera: Cerambycidae) and muga silkworm major pest, *Blepharipa* sp. nov. (Diptera: Tachinidae) are under the process of description. Earlier reports indicate only 30 species from muga ecosystem (Singh et al., 2000; Kumar et al. 2011), and the present listing includes 203 species. The host plant wise checklist in Table 3, and all the 203 species in Table 4 are included.

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A NEW SPECIES OF PIPUNCULIDAE (DIPTERA) FROM INDO-NEPAL BORDER OF CHAMPARAN DISTRICT, BIHAR

SHAILENDRA KUMAR AMOGH*, ASHWANI KUMAR AND PRAKASH MICHAEL*****

*Department of Biological Sciences, SHUATS, Allahabad 211007; **Department of Entomology*
****Department of Zoology, R.L.S.Y College, BRABU, Bettiah 845438*
**Email: shailendrakamogh@gmail.com*

ABSTRACT

The paper describes and illustrates a new pipunculid (big headed fly) species *Pipunculus* (*Cephalops*) *pokharensis*, sp. nov. The specimens were collected from localities in the Indo-Nepal border of Champaran district which has humid, mountainous, low tropical vegetation. The new species resembles *Pipunculus* (*Cephalops*) *deminitens* Hardy but can be differentiated in its smaller body, propleural fan with 4-5 bristles, 1st abdominal segment with 3 stout black bristles on both sides, and piercer of ovipositor reaching up to 4th abdominal segment.

Key words: Big headed fly, *deminitens*, *Pipunculus*, new species, Indo Nepal border, *Cephalops*, propleural fan, bristles, ovipositor

Pipunculids belongs to the family Pipunculidae and order Diptera with a worldwide distribution. It is a sister group of the flower flies (Syrphidae and Platypezidae) but can easily be differentiated by their wing venation, the cell r_{4+5} being open and the vena spuria being absent (Papp and Schumann, 2000). These have affinities with Conopidae (Cumming et al., 1995). Individual flies vary in body length from 1.5 mm to 5 mm and can be distinguished by their large spherical or hemispherical head which is extremely mobile and composed almost entirely of compound eyes. These flies are therefore called ''big-headed flies''.

These live generally in shades of herbs, shrubs, in grasses, and garden in hilly places.The life history is interesting as these are endoparasites of members of the various families of Homoptera including Cicadellidae, Delphacidae and Fulgoridae (Ferrar, 1987), and adult Tipulidae (Koenig and Young, 2007). A total of 1400 species of Pipunculidae from the world are known (Rafael and Skevington, 2010) under 20 genera. Among these 10 and 3 genera (*Eudorylas*, *Pipunculus* and *Tomosvaryella*) had been so far reported from India and Nepal, respectively. A total of 75 species are known from India (Maiety et al., 2014).

The genus *Pipunculus* is represented by 5 species from the Indo-Nepal region, of which only two species viz., *Pipunculus deminitens* Hardy and *Pipunculus exsertus* Hardy (Hardy, 1966) are from Nepal. This genus can be easily distinguished by the presence of a stigma or dark marking, in the subcostal cell and presence a fan of hairs on each propleuron. It is distributed in mid and east Nepal. As far as the taxonomy of these flies is concerned, it is largely neglected in India and Nepal. In this paper, a new species, *Pipunculus* (C*ephalops*) *pokharensis* sp. nov., is described from Nepal, and a key to the species provided.

MATERIALS AND METHODS

The collection of flies was made during July 2014 to June 2016 from Indo-Nepal border stretching between 81.5^0, 86.5^0 and between 27^0 and 29^0 longitudinal range. The area consists of hilly zones close to the Himalayan foot hill ranges between 1500 to 6000 ft. from the sea level i.e. Valmikinagar, Ramnagar, Hetauda and Pokhara etc., having the lower vegetations in grassland along the paths of riverbanks, grassy area around the water bodies, marshy or swampy places in the forest of hilly areas in shades non windy sunny days. Hand sweep net method was used to collect flies.These flies were generally collected over flowers, garden, grass, herbs, shrubs and rice field in sunshine and non windy day. As these insects are rarely found, in 3 to 4 hours sweep only one to two insects, sometimes none, were collected. Dissections and observations were done under the SV11 Zeiss stereozoom microscope. For temporary mounting, glycerol was used while permanent

preparation were made after passing the material through the alcohol series and finally mounted in Canada balsam. Diagrams were made with the help of camera lucida (mirror type). The descriptions of the new species are based on the morphological characters proposed by Cammerson (1974) and according to the classification adopted by Hardy (1972a.,b).

RESULTS AND DISCUSSION

A. Key to the species

1. 3rd section of costa very short compared to 4th section and lacking a distinct stigma……*Tomosvaryella*……..…....2
- 3rd section of costa with brown stigma usually equal or longer than 4th section and propleural fan absent…….*Eudorylas*……4
- 3rd section of costa with brown stigma usually equal or longer than 4th section and propleural fan present……..….*Pipunculus* (C*ephalops*)…....6
2. Wings entirely hyaline…… ……..3
- Wings not entirely hyaline…… ……..4
3. Hypopygium about one half of the 5th abdominal tergum…….....*T. nitens* Brunette
4. Third antennal segment acute. Male hypopygium with an apical membranous area and with a membranous protrusion from the apex……..*Eudorylas discors* Hardy

   - Third antennal segment not acute……....……5
5. Third antennal segment acuminate. Male hypopygium with a prominent cleft extending longitudinally down the right side, surstyle broad, left surstyle has a narrow pointed end……*Eudorylas* .....*distocruciator* Hardy
- Third antennal segment more acuminate. Abdomen curved and body small oval. Arista and Ovipositor smaller *Eudorylas ovatum* .....Michael
6. Small bodied, 3rdantennal segment acute apex, 3rdcoastal section slightly more than half of 4thcoastal section. Piercer straight. Cross vein r-m situated at 2/5th of discal cell……*Pipunculus (Cephalops) deminitens* Hardy.....
- Body smaller, 1/3rd propleural fan with 4-5 bristles, 1st abdominal segment with 3 stout black bristles on both sides; piercer of ovipositor straight , cross vein r-m situated at 1/3rd of discal cell. 3rd antennal segment short and obtuse……*Pipunculus* (C*ephalops*) *pokharensis*, sp. nov. …….....

B. *Pipunculus* (*cephalops*) *pokharensis* sp. nov. (Figs. 1-3)

Female: Small bodied, yellowish black.

Head: Hemispherical as broad as long, junction of the compound eye rather long about one half longer than frontal triangle. Frons- deep silvery grey pubescent, First two antennal segment brown, 3rd segment is pale yellow, short obtuse apically. Arista black having double the length of the 3rd segment (Fig. 2)

Thorax: Mesonotum- Sub shining black brown with brown dusty surface having minute hairs sparsly distributed. Propleural fan with 4-5 bristles. Halter yellow with brown knob.

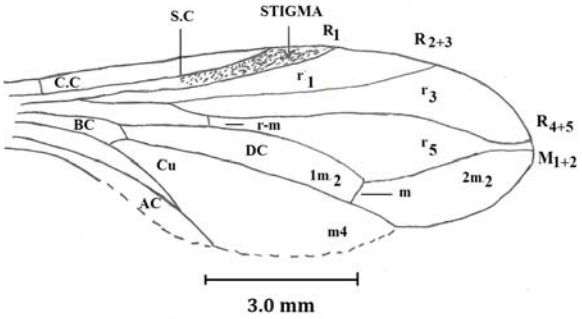
Wing: Hyaline highly tinged with pink brown, stigma fills the apical 2/3rd of 3rd costal section, 3rd costal section is slightly more than half as long as 4th. Cross vein marking of the base of the stigma very prominent covers about 3/4th as long as 4th section (Fig. 1). Cross vein r-m is situated at basal 1/3rd of discal cell.

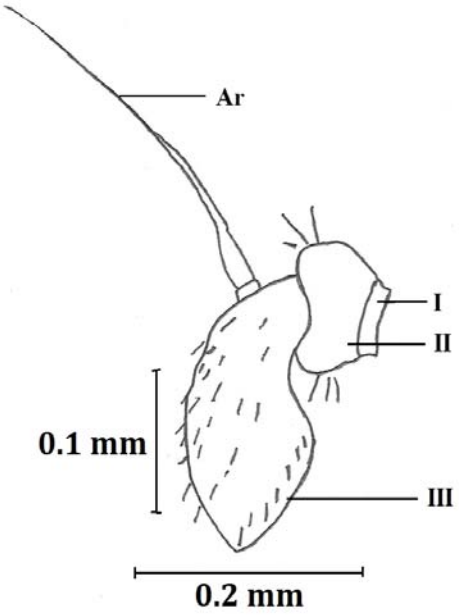
Legs: Predominantly yellowish brown. Coxa- brown black, Trochanter- yellow. Front and mid femora yellow shining posteroventrally. Hind femora yellow but black brown tinge on posterolateral apex. Each with well developed anteroventral and posterovental black spicules. Tibia yellow with both ends hyaline having dispersed rows of short pale hairs. Tarsi yellow, last tarsal segment slightly darkened, pulvilli well developed longer than the segment. Claw equal to the size of pulvilli.

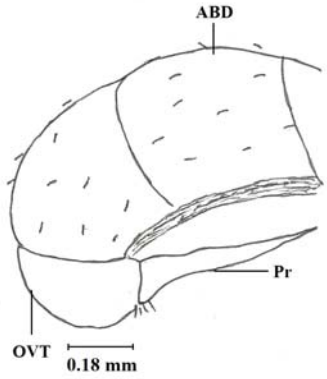
Abdomen: Shining black with sparse brownish dust. 1st abdominal segment with 3 stout black bristles on both sides. A bilateral rows of minute spars setae extend downward dorsolaterally and in between is bare. Ovipositor with black base, globose in shape, Piercer brownish yellow slender reaching upto the margin of 4th segment. It is slightly straight and its tip is slightly curved upwards (Fig. 3).

Body length: 2mm; wings: 3mm.

Specimen examined: *Holotype*: Female, Pokhara (Fish Tail Hotel Garden), Nepal, 28. iii.2015, Coll. Shailendra Kumar Amogh. The specimen will be







1. Wing. 2. Antenna. 3. Female genitalia

Figs.1-3. *Pipunculus* (*Cephalops*) *pokharensis*, sp.nov.

deposited at Natural History Museum, Kathmandu, Nepal.

Etymology: The species named after its type locality.

Remarks: The new species is closely related to *Pipunculus* (*Cephalops*) *deminitens* Hardy, 1966. However, it differs in having; (1.) Smaller body, (2.) Propleural fan with 4-5 bristles, (3.) 1st abdominal segment with 3 stout black bristles on both sides, and (4.) Piercer of ovipositor reaches upto 4th abdominal segment.

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BIOLOGY OF *PARACOCCUS MARGINATUS* ON PARTHENIUM HYSTEROPHORUS

LANEESHA, M., K. SHANKARGANESH*, SACHIN S. SUROSHE AND BISHWAJEET PAUL

Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi 110012
**ICAR-CICR, Regional Station, Coimbatore 641003*
**Email:shankarento@gmail.com (corresponding author)*

ABSTRACT

The biology of *Paracoccus marginatus* William and Granara De Willink (Pseudococcidae: Hemiptera) when reared on *Parthenium histerophorus* L. revealed that its incubation period varied from 2 to 5 days and females had three nymphal instars. The first instar nymphal stage lasted for 6.44 days, and for second and third instars it was 6.30 and 5.72 days, respectively. The nymphs took 19 to 24 days in case of females (mean of 21.67 days). In case of male it was four nymphal instars with two nymphal instars besides an additional pre-pupal and pupal stages; first and second instar lasted for 6.44 and 7.01 days, respectively. For both male and female, the developmental time was accounted separately from second instar onwards. Crawlers developing into male differentiated in second instar, and it was indicated by change in colour from greenish yellow to slight pink. These took 17 to 22 days for developing (mean 19.3 days), due to additional pupal stage. The adult longevity in male ranged 2 to 4 (2.58 ± 0.39) days. The total developmental period in female was from 41 to 65 (61.5 ± 3.26) days, while in male it was 24 to 35 (31.3 ± 5.87) days. The morphometrics of egg, nymphal instars, pupae and adults for both male and female had also been studied. The eggs were greenish yellow to green and are laid in an egg sac which is 2-3 times bigger than the body length and entirely covered with white cottony wax secretion produced by female.

Key words: *Paracoccus marginatus*, *Parthenium histerophorus*, egg, nymphs, crawlers, pupa, prepupa, male, female, longevity

The papaya mealybug, *Paracoccus marginatus* William and Granara De Willink is a soft, tiny yellow coloured pseudococcid. It is an invasive pest, damaging more than 60 plants including field as well as horticultural crops. It had been reported from more than 29 countries in Asia, Africa, North America, South America and Oceana regions (Williams and Granara De Willink, 1992; Meyerdirk *et al.*, 2004; Muniappan *et al.*, 2008; Chen *et al*., 2011). New Mexico is believed to be the native of this pest, where it has not attained an economic pest status owing to the suppression by the multiple primary parasitoids (Muniappan *et al*., 2009). During 2008, *P. marginatus* was reported as a serious threat to many cash and horticultural crops in India. Understanding its bionomics would help in predicting development, abundance and distribution over a region. Keeping these in view, the present study evaluated its biology and morphometrics on *Parthenium hysterophorus* L. at constant temperature.

MATERIALS AND METHODS

Biology and morphometrics of papaya mealybug *P. marginatus* were evaluated in the Biocontrol Laboratory, Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi. Specimens used were confirmed for species identity confirmation with morphological characters (Miller and Miller, 2002). The host plant used was tender stem cuttings of *Parthenium hysterophorus,* as it is known as a crucial off season host and amenable to rear mealybug under laboratory conditions (Suroshe *et al*., 2016).

The culture was maintained in the laboratory on sprouted potato tubers as given in Sankar (2012). Potatoes were soaked in 2% formalin for about 10 - 20 min., then rinsed with fresh water, air dried and kept for sprouting in a dark room. The sprouted tubers (5 - 6) were kept in each plastic jar. Newly emerged crawlers from other maintained colonies or gravid females collected from field were released on these potato sprouts with a camel hair brush, for each sprouted potato @ 3 to 5 ovisacs depending on the size of the potato. The jars were covered with clean muslin cloth and tied with the rubber band firmly to prevent the escape of mealybugs, and maintained at 27 ± 2^{0}C and 65 ± 5% RH. New potatoes were added roughly every week and old ones removed after the mealybug had settled on the new sprouts.

Succulent stem cuttings (5-7cm long) of *Parthenium* were collected from the field, these thoroughly washed and air dried, before sterilising with 70% ethyl alcohol wipings. Each cutting was placed in glass vials (7 ×1.5 cm size) plugged with porous paraffin wax. Both ends of stems were dipped in molten wax to reduce evaporation loss. These cuttings were used for biological study of mealybugs reared at 25 ^{0}C.

Crawlers (n=10) collected from a single female were placed on the *Parthenium* stem cuttings with the help of a camel hair brush (No.000). Incubation period was studied separately by keeping 10 eggs per stem cuttings with five replications. Vials were checked daily for hatching and for presence of exuviae. The number of days to hatch, survival of each instar, and number of emerged adults was recorded. The sex of mealybug was determined during the latter part of the second instar when males change their colour from yellow to pink. The developmental time of males and females was counted, and 50 vials (replicates) each with 10 crawlers were used. All experiments were carried out in the BOD maintained at 25^{0}C. Newly emerged premated females were used for monitoring the preoviposition and oviposition periods. Each female was placed on *Parthenium* stem cuttings, kept inside the vials, with each provided with 2-3 newly emerged males to ensure mating. Generation period (egg to oviposition period) was worked out from the same data.

A separate monitoring of male and female from the day of adult emergence until the death, provided the details regarding adult longevity. Thirty individuals of both male and female (10 males and 20 females) were kept as replicates. For determining fecundity, total number of eggs laid by each female was counted (% replicates). Sex ratio was worked out by counting the total number of male and female emerged from five ovisacs.

Life stages (eggs, first, second and third instars of males and females, fourth instar males, males and females) were separated from the rearing colony kept at 25^{0}C and morphometrics (length and width) measured under a stereozoom microscope (Leica®) with image analyzer facility. Five specimens of each of all stages of male and female from host plant were taken and a total of 55 specimens were sampled. All measured specimens were preserved in ethyl alcohol (70 %) for further reference.

RESULTS AND DISCUSSION

The morphometrics of egg, nymphal instars, pupae and adults for both male and female of *P. marginatus* are given in Table 1. The biological attributes viz., developmental periods of egg, nymphal instars, pupae, adult for both male and female, pre-oviposition, oviposition, fecundity and post-oviposition period are given in Table 2. Biology studies revealed that eggs are greenish yellow to green colored and are laid in an egg sac which is 2-3 times bigger than the body length and entirely covered with white cottony wax secretion produced by female. The incubation period varied from 2 to 5 days in both female and male.

Similar biology observations had been made earlier by Miller and Miller (2002), Walker *et al*., (2008), Muniappan *et al.* (2008) and Veeresh Kumar *et al.* (2014) who concluded that the egg-laying was usually in a small

Table 1. Morphometrics of life stages of *P. marginatus* on parthenium (at 25^{0}C)

Life stages	Length (mm)	Width (mm)
Egg	0.35± 0.01 (0.34-0.37)	0.15 ± 0.01 (0.15-0.17)
I instar	0.40 ± 0.02 (0.37-0.43)	0.21 ± 0.02 (0.19-0.23)
II instar	0.73 ± 0.02 (0.37-0.43)	0.43 ± 0.01 (0.41-0.44)
III instar (Pre-pupa for ♂)	0.91 ± 0.02 (0.89-0.95)	0.45 ± 0.01 (0.43-0.47)
IV instar (Pupa)	0.93 ± 0.01 (0.92-0.95)	0.38 ± 0.02 (0.36-0.42)
Adult male	0.95 ± 0.02 (0.93-0.96)	0.24 ± 0.04 (0.22-0.26)
II instar	0.70 ± 0.03 (0.65-0.73)	0.35 ± 0.02 (0.33-0.37)
III instar	1.01 ± 0.13 (0.92-1.20)	0.50 ± 0.03 (0.48-0.56)
Adult female	42 ± 0.02 (2.40-2.46)	1.40 ± 0.02 (1.38-1.43)

Mean ± SD (Range) for and ; n=5

Table 2. Life cycle of *P. marginatus* on parthenium

Biological attributes	Developmental period (days)	
	Female	Male
Life cycle		
Egg	3.41 ± 0.37 (2-5)	3.41 ± 0.37 (2-5)
I instar	6.44 ± 0.40 (4-8)	6.44 ± 0.40 (4-8)
II instar	6.30 ± 0.30 (4-8)	7.01 ± 0.48 (6-9)
III instar (Pre-pupa for ♂)	5.72 ± 0.42 (4-9)	2.86 ± 0.30 (2-4)
IV instar (Pupa)	-	3.51 ± 0.37 (2-5)
Pupal duration	-	4.46 ± 0.63 (4-6)
Life cycle Duration	21.87 ± 0.75 (19-23)	23.23 ± 0.99 (21-25)
dult longevity	19.63 ± 0.85 (16-21)	2.58 ± 0.39 (2-4)
Pre-ovipositional	10.006 ± 0.32 (9-11)	-
Ovipositional	10.00 ± 0.70 (8-13)	-
Generation time	39.64 ± 4.95 (32-45)	-
Life span	61.5 ± 3.26 (41-65)	31.3 ± 5.87 (24-35)
Fecundity	299.40 ± 5.41 (260-315)	-
Sex ratio	2.628	1

Mean ± SD (Range); n=10

white ovisac and egg hatching occurred in about 10 days. Females developed after three nymphal instars. The time taken for completing first instar nymphal stage was same for both female and male (6.44 days); and for second and third instars it was observed to be 6.30 and 5.72 days, respectively. The total lifecycle of female ranged from 19 to 24 days, with a mean of 21.67 days. The results obtained are in line with findings of Muniappan *et al*. (2008).

Male developed after four instars including additional pre-pupal and pupal stage. The mean developmental period of first and second instar was 6.44 and 7.01 days, respectively. Crawlers destined to become male changed colour from greenish yellow to slight pink in second instar, with the third nymphal instar considered as pre-pupal stage. At the end of this stage, males produced silken puparia over their bodies. Duration of pre-pupal period ranged from 2 to 4 days, (mean 2.86 days), and pupal stage for 2 to 5 days (mean 3.51 days). The total life span of male ranged from 17 to 22 days (mean 19.3 days).

These results corroborate with those of Muniappan *et al*. (2008), with slight variations in the developmental time (might be due to differences in temperature and relative humidity) and host. Results from present study also confirm those of Amarasekare et al. (2008), who reported the mealybug was able to complete its development between 18 to 35^{0}C without any failure. Walker *et al*. (2008) observed three nymphal instars besides pupa and a winged adult stage.

In the present study, pre-oviposition period varied from 9 to 11 days (mean 10.0± 0.32 days), whereas oviposition period was from 8 to 13 days (mean 10.0 ± 0.70 days). These observations agree with those of Muniappan *et al*. (2008) and Veeresh Kumar *et al.* (2014). Fecundity of female varied from 260 to 350 eggs (mean 299.40 ± 5.41 eggs), which agrees with observations of Amarasekare *et al.* (2008) and Walker *et al*. (2008) but in contrast with those of Veeresh Kumar *et al*. (2014), who reported a fecundity of 248 to 967eggs.

The longevity of male lasted 2 to 4 (2.58 ± 0.39) and female lived longer (16 to 21, 19.63 ± 0.85 days). These observation are in line with Amarasekare *et al*. (2008). The sex ratio was 2.62: 1 (female: male). The total developmental period for female varied from 41 to 65 (61.5 ± 3.26) days, and for male development from 24 to 35 (31.3 ± 5.87) days. These agree with those given in Walker *et al*. (2008) and Veeresh Kumar *et al*. (2014).

Parthenium is one of the most important invasive weed invading most Indian states, it plays a crucial role in off season survival and spread of *P. marginatus* throughout India. This study provides a detailed information of its stage wise biology and morphometrics, and might enable better understanding of its incidence, survival and spread.

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BIOCHEMICAL CHANGES IN SPIRALLING WHITEFLY AFFECTED CASSAVA LEAVES AND ITS IMPACT ON ERI SILKWORM *SAMIA CYNTHIA RICINI* BOISDUVAL

N. SAKTHIVEL

Regional Sericultural Research Station, Central Silk Board
Government of India, Salem 636003
Email: sakthivelcsb@hotmail.com

ABSTRACT

Changes in the biochemical constituents including nutritional and anti-nutritional values of the cassava varieties H226 and MVD1 infested by spiralling whitefly, *Aleurodicus dispersus* Russell and its influence on economic traits of eri silkworm *Samia cynthia ricini* Boisduval were studied. The moisture, crude protein, total carbohydrate, nitrogen, phosphorus, potassium and total minerals, tannins and HCN of leaves of both varieties were drastically reduced following infestation. The larvae fed with infested leaves from both varieties showed significant adverse effect on economic traits *i.e.* increase in total larval period and reduction in other traits namely larval weight, effective rate of rearing, cocoon yield, shell yield, shell ratio, fecundity and hatchability compared to those of healthy leaves recording lower larval duration and higher values of other corresponding traits. For all parameters adverse effect was more pronounced in the lot fed with infested MVD1 leaf than the variety H226.

Key words: *Manihot esculenta*, *Aleurodicus dispersus*, biochemical contents, moisture, protein, carbohydrate, N, P, K, minerals, tannin, HCN, eri silkworm, economic traits.

Eri silkworm, *Samia cynthia ricini* Boisduval is polyphagous in nature and feeds on number of plant species. Castor (*Ricinus communis* L.) and Kesseru (*Heteropanax fragrans* Seem.) are primary food plants and mainly exploited for eri silk production. There are several secondary host plants *viz.*, cassava (*Manihot esculenta* Crantz), Barpat (*Ailanthus grandis* Prain), Barkesseru (*Ailanthus excels* Roxb.), Payam (*Evodia flaxinifolia* Hook.) which are used for rearing of eri silkworms during the scarcity of primary host plants. Rest of them are considered to be the tertiary in nature on which the eri silkworm could survive for some extend but not complete its life cycle and hence they are not viable for ericulture. Among the secondary hosts, cassava also found most suitable after castor for successful production eri cocoons (Devaiah et al., 1985; Sakthivel, 2012).

The cassava growers can divert a portion of foliage (25-30%) to rear eri silkworm and get additional income without affecting the tuber yield and starch content (Rao, 2003; Jayaraj et al., 2006; Sakthivel, 2012). The huge amount of foliage available at the time of tuber harvest could also be diverted for production of eri silk (Sakthivel, 2004). However, infestation of spiralling whitefly (*Aleurodicus dispersus* Russell), the major pest of this crop often affects the leaf availability besides deleterious effect on leaf quality which causes adverse impact on eri silk production. Therefore, an attempt has been made in this study to find out the biochemical changes in spiralling whitefly infested cassava leaves and the extent of adverse effect of feeding these affected leaves on economic traits of eri silkworm.

MATERIALS AND METHODS

The ruling cassava varieties *viz*. H226 and MVD1 maintained under recommended agronomic practices (George et al., 2000) were earmarked and maintained with two sets of conditions viz. protected and unprotected (Bandyopadhyay et al., 2001). In unprotected plots no plant protection measures were taken up thereby allowing the natural infestation of spiralling whitefly and in the protected plots dimethoate (0.05%) + neem oil (3%) was sprayed (Palanisamy et al., 1995) followed by spray of forcible jet of water in weekly interval (Sakthivel et al., 2011) to maintain the plants free from the pest and sooty moulds till completion of rearing. The healthy and infested cassava leaves were harvested separately from randomly selected 15 plants each in protected and unprotected plots, respectively per variety. The biochemical contents viz. total carbohydrate (Dubois et al.,1956), crude protein, nitrogen, phosphorus, potassium and total minerals (Jackson, 1973), total tannins (Anonymous, 1984) and hydrocyanic acid (Bradbury

et al., 1991) were determined as per the standard chemical analytical methods.

The experiment on eri silkworm was initiated 25 days after spray of insecticides in the protected plots. Eri silkworms were mass reared up to second stage (chawki) using healthy tender leaves and then the larvae were divided into two lots, each having 1000 larvae replicated 10 times @ 100 larvae / replication. First lot was fed with healthy leaves harvested from the protected plots while another was fed with spiralling whitefly infested leaves harvested from unprotected plots, throughout the remaining rearing period *i.e.* till larval maturation. The economic traits of silkworms viz., larval duration (days), mature larval weight (g), effective rate of rearing (%), cocoon yield (kg / 100 dfls), shell yield (kg/100Dfls), single cocoon weight (g), single shell weight (g), Silk (%), fecundity (no.) and Hatching (%) were recorded.

RESULTS AND DISCUSSION

There was significant reduction in all biochemical parameters due to whitefly infestation in both varieties studied *i.e.* H226 and MVD1. The levels of moisture (66.38 & 70.50%), crude protein (21.93 & 23.32) nitrogen (3.51 & 3.73%), phosphorus (0.33& 0.36%), potassium (0.55 & 0.61%) and total minerals (8.93 & 9.06 %) and anti-nutrients *viz.* tannins (2.25 & 2.68 %) and HCN (320 & 319 mg/kg) were very much reduced in the infested leaves when compared to the corresponding values in healthy leaves *i.e.* whitefly free leaves (75.38 & 77.15%, 27.00 & 29.55 %, 4.32 & 4.73 %, 0.39 & 0.42 %, 0.91 & 0.93 %, 11.98 & 13.25%) anti-nutrients 3.05& 3.18% & 335 & 328 mg/kg) in the two varieties, respectively. However, the carbohydrates content was increased marginally (33.78 & 35 %) in the infested leaves compared to corresponding values (32.49 & 33.26) of healthy leaf of H226 and MVD1varieties respectively. The results revealed that the adverse effect on leaf quality in variety H226 was higher than that of MVD1 (Table 1).

The larvae fed with infested leaves from both H226 and MVD1 varieties showed significant adverse effect on economic traits *i.e.* increase in total larval period (29:16 & 28: 00 D:H), and reduction in other traits namely larval weight (5.28 & 5.72 g), ERR (73.86 & 81.15%), cocoon yield (41.607 & 49.500 kg/100 dfls), shell yield (4.467 & 5.819 kg/100 dfls), shell ratio (10.73 & 11.75 %), fecundity (268.58 & 275.23) and hatchability (82.28 & 85.09 %) respectively compared to those of healthy leaves recording lower larval duration (26:08 & 26:08 D:H) and higher values of other corresponding traits 6.63 & 6.84 g, 97.32 & 98.09 %, 73.770 & 75.342 kg/100 dfls, 11.379 & 11.949 kg/100 dfls, 15.42 & 15.86 %, 357.56 & 363.16 and 97.35 & 97.66%) respectively. For all parameters adverse effect was more pronounced in the lot fed with whitefly affected H226 leaf compared to the variety MVD1 (Table 2).

Marked reductions in values of nutrients viz., moisture content, crude protein, nitrogen, phosphorus, potassium and total minerals were recorded in infested cassava leaves of both varieties. Similar observations had been reported by Narayanaswamy et al. (1999) in mulberry leaf affected by whitefly. However, there was

Table 1. Biochemical changes in the spiralling whitefly affected leaves of cassava varieties

Varieties		Moisture %	Crude Protein (%)	Total Carbo-hydrate (%)	Nitrogen N (%)	Phosphorus P (%)	Potassium K (%)	Total Minerals (%)	Total tannins (%)	HCN (mg/kg)
H226	SWFF	75.38 ± 3.33	27.00 ± 1.17	32.49 ± 1.36	4.32 ± 0.16	0.39 ± 0.04	0.91 ± 0.02	11.98 ± 0.44	3.05 ± 0.09	335 ± 7.21
	SWFA	66.38* ± 2.98	21.93* ± 1.82	33.78* ± 1.77	3.51* ± 0.23	0.33* ± 0.02	0.55* ± 0.01	8.93* ± 0.56	2.25* ± 0.10	320* ± 11.25
MVD1	SWFF	77.15 ± 3.36	29.55 ± 1.23	33.26 ± 1.25	4.73 ± 0.19	0.42 ± 0.01	0.93 ± 0.02	13.25 ± 0.30	3.18 ± 0.07	328 ± 9.65
	SWFA	70.50* ± 3.12	23.32* ± 1.98	35.00* ± 2.01	3.73* ± 0.29	0.36* ± 0.02	0.61* ± 0.03	9.06* ± 0.48	2.68* ± 0.18	319* ± 13.77

SWFF=Spiralling whitefly free; SWFA=Spiralling whitefly affected; Values mean ± SD; *Significant at P< 0.05.

Table 2. Effect of feeding spiralling whitefly affected cassava leaves on economic traits of eri silkworm

Varieties		Larval period D:H	Matured larval weight (g)	ERR %	Cocoon yield (kg/100 dfls)	Shell yield (kg/100 Dfls)	SCW (g)	SSW (g)	Silk (%)	Fecundity (no.)	Hatching (%)
H226	SWFF	26:08	6.63 ± 0.23	97.32 ± 6.67	73.770 ± 2.96	11.379 ± 0.68	2.632 ± 0.17	0.406 ± 0.025	15.42 ± 0.42	357.56 ± 18.56	97.35 ± 0.27
	SWFA	29.16	5.28* ± 0.18	73.86* ± 4.78	41.607* ± 1.77	4.467* ± 0.36	1.956* ± 0.14	0.210* ± 0.042	10.73* ± 0.56	268.58* ± 22.13	82.28* ± 0.69
MVD1	SWFF	26:08	6.84 ± 0.29	98.09 ± 3.32	75.342 ± 4.03	11.949 ± 0.52	2.667 ± 0.08	0.423 ± 0.016	15.86 ± 0.25	363.16 ± 16.49	97.66 ± 0.36
	SWFA	28.00	5.72* ± 0.32	81.15* ± 3.66	49.500* ± 2.69	5.819* ± 0.33	2.118* ± 0.10	0.249* ± 0.029	11.75* ± 0.37	275.23* ± 12.64	85.09* ± 0.54

SWFF=Spiralling whitefly free; SWFA=Spiralling whitefly affected; Values mean ± SD; *Significant at P< 0.05.

slight increase in total carbohydrate content in the affected leaves of both the varieties studied compared to healthy leaves. This is supported by the observations of Narayanaswamy (2003) who recorded significant increase in sugar content of leaf roller affected mulberry leaves. Further, in the present study, the contents of tannins and HCN were also considerably reduced due to infestation. The spiralling whitefly is a phloem sap feeder and its direct consumption of nutrients carried in phloem and reduces productivity of the host plants by competing for available nutrients. *A. dispersus* also excretes honey dew which covers the surface if the leaves as a medium for growth of sooty mould. These interfere with photosynthetic process by not allowing enough light to reach the cytochrome tissues of the leaves (Bryne et al., 1990).

There were considerable reductions in all economic traits of eri silkworms fed with the cassava leaves affected by whitefly compared to unaffected leaves. Qadri et al. (2010) found drastic reduction in economic parameters of mulberry silkworm recording up to 48.09% cocoon yield loss when fed with infested mulberry leaves. Similar adverse effect on economic traits of mulberry silkworm fed with papaya mealybug affected mulberry leaves had been also reported (Sakthivel et al., 2011). Deterioration in cassava leaf quality due to reduction in nutrient values on whitefly incidence could be main attribute for the adverse effects on economic traits of eri silkworm which resulted in poor cocoon yield. Similarly, reduction in the nutritional components of food plants of silkworm due to different pests and its adverse effects on the economic characters of cocoon and reproductive performance had been reported by various workers (Kumar et al., 1992; Veeranna, 1997; Singh et al., 2002; Etebari and Bizhannia, 2006; Sakthivel and Qadri, 2010b). Increased larval duration and adverse effect on economic characters of tasar silkworm, *Antheraea mylitta* Drury fed with gall infested host leaves were also reported by Kishore et al. (1997).

The highest damage in economic parameters of silkworm was reported due to the corresponding loss in nutritional values with increase in pest population (Narayanaswamy et al., 1999; Bandyopadhyay et al., 2002). Nutrient levels of leaves play a vital role in the robust growth of silkworm larvae, cocoon production and reproductive performance (Takano and Arai, 1978). All nutrients in a balanced proportion are necessary for the healthy growth of silkworm whereas the protein content of the leaves influence greatly on silk yield. Fukuda et al. (1959) and Takeuchi (1960) had emphasized the role of soluble and crude protein contents in silkworm nutrition. This confirms the findings of present study that significant decline in nutritional values in pests affected cassava leaves has led to the adverse effect on economic traits and poor cocoon yield. The present study suggests that planning suitable IPM for this pest and avoiding cultivation of susceptible cassava varieties in spiralling whitefly prone zone could help to avoid loss in eri silk production.

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BIOEFFICACY OF PESTICIDES AGAINST GREEN APPLE APHID *APHIS POMI* DE GEER AND BIOSAFETY TO NATURAL ENEMIES IN APPLE ORCHARDS

AKHTAR ALI KHAN* AND SHAZIA RIYAZ

Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar 190025
**Email:akhtaralikhan47@rediffmail.com*

ABSTRACT

Field experiments were carried out to evaluate the bioefficacy of pesticides against green apple aphid (*Aphis pomi*) and biosafety to their natural enemies during 2014. Three pesticides viz., imidacloprid (17.8SL) @0.17, 0.28, and 0.58ml/L. dimethoate 30EC @1.0, 1.5 and 2.0ml/L; thioclopid (21.7SC) @0.1ml, 0.2ml and 0.4ml/L; cypermethrin (25EC) @1.0, 1.5, and 2.0ml/L; chlorpyriphos (20EC) @1ml, 1.5ml and 2 ml/L of water were compared with the treated check (dichlorvas 76 EC) @ 1ml/l of water, along with untreated control. Imidacloprid 17.8SL @0.28ml/L was the most effective with highest reduction in aphid incidence (87.16%) and natural enemies showing 62.85% change, and caused less effect of parasitisation. Thus it has only slight harmful insecticidal effect on the non target organisms (as per the recommendations of International Organisation of Biological Control) as compared to other evaluated pesticides. Thus, it can be considered as a potential pesticide for the management of green apple aphid in apple orchards.

Key words: Apple orchard, *Aphis pomi*, insecticides, bioefficacy, biosafety, imidachloprid, non target effect, coccinellids, syrphid, *Chrysoperla*

In Kashmir, the most common aphid species in apple orchard is the green apple aphid, *Aphis pomi* De Geer (Homoptera: Aphididae) (Shah, 2015; Khan, 2015). It is an economically important pest of apple throughout the world (Foottit *et al*., 2009). Severe infestation can also cause curling, stunting and weakening of terminals and increase risk of winter mortality. A common strategy to control this pest in conventional apple orchards in Kashmir is the use of one or more application of insecticides. But wide spectrum insecticides upsets natural biodiversity and affects population abundance of predators (Khan, 2009; 2012; Shah and Khan, 2014). In today's context conservation of natural enemies is very important deploying safer pesticides in horticulture ecosystem. The present study evaluates the possibility of effective control of *A. pomi* on apple trees by minimal treatment with insecticide achieving biosafety to the natural enemy populations in apple orchard of Kashmir.

MATERIALS AND METHODS

Field experiment was carried out to evaluate some pesticides against green apple aphid and their natural enemies during 2014. The treatments viz., imidacloprid (17.8SL) @0.17, 0.28 and 0.58ml/L of water; dimethoate 30EC @1.0, 1.5 and 2.0ml/L; thiocloprid (21.7SC) @0.1ml, 0.2ml and 0.4ml/L; cypermethrin (25EC)@ 1.0, 1.5, and 2.0ml/L; chlorpyriphos (20EC) @1ml, 1.5ml and 2 ml/L were compared with the treated check (dichlorvas 76 EC) @1ml/L along with untreated control. Each concentration was replicated 5 times, and 10 L spray volume was sprayed per tree. Pre- treatment count was taken one day before treatment and post treatment count after 1st, 7th and 15th days after treatment with random sampling of per twig with 10cm top of the twig. Similarly, the observations of natural enemies were also made before and after treatment. The experiment was laid out in randomized block design on variety "red delicious" of 15-20 years of uniform age. Mortality was worked out by computing the differences between pre and post treatment population of nymph, alate, and apterous stages and natural enemies applying Abbot's formula (1925). These data were subjected to ANOVA and critical difference at p= 0.05 was worked out.

RESULTS AND DISCUSSION

Bioefficacy against *Aphis pomi*: Data in Table 1 reveal that highest mortality of 90.52% was observed with imidacloprid (17.8SL) @0.56ml/L which was on par with imidacloprid (17.8SL) @ 0.28ml/L (87.16%); the least (67.72%) mortality was observed with

chlorpyriphos (20EC) @1.0ml/L. Maximum reduction in incidence of nymph (92.95%) was observed 1st day after treatment with imidacloprid (17.8SL) @0.56ml/L which was on par with its half dose; while the least reduction (59.92%) was with chlorpyriphos (20EC) @1.0ml/L. Similar trend was observed in case of alate aphids too; with apterous aphids too maximum reduction (86.20%) was observed with imidacloprid (17.8SL) @0.56ml/L and the least (50.00%) with cypermethrin (25EC) @1.0ml/L.

On seventh day after treatment, reduction in incidence of all stages of increased slightly and all pesticides were similar, and this was the case at 15th day after treatment; and highest mortality of nymph, alate, and apterous aphid was observed with imidacloprid (17.8SL) @0.56ml/L which was statistically on par with its half dose. Maximum cumulative mean reduction in incidence of nymph was obtained with imidacloprid (17.8SL) @0.28ml and 0.56ml/L, which was statistically on par with chlorpyriphos (20EC) @1.0ml/L.

In case of alate and apterous aphid, the highest cumulative mean reduction in incidence was observed again with imidacloprid (17.8SL) @0.56ml/L and @ 0.28ml/L. A common strategy to control *Aphis pomi* in apple orchids is based on one or more than one application of insecticides (Khan 2009; 2012). The toxicity of pesticides against *Aphis pomi* had been studied by few workers (Hardman *et al.*, 2003).

Biosafety to natural enemies: The evaluation of biosafety to coccinellids, syrphids and *Chrysoperla* larva and parasitisation revealed the following (Table 2): The population change in these was 79.21% with thiocloprid (21.7SC) @0.40ml/L which was statistically on par with imidacloprid (17.8SL) @0.56ml/L (75.00%), dimethoate 30EC @ 2.0ml/L (72.27%), cypermethrin (25EC) @ 2.0ml/L (71.90%) and chlorpyriphos (20EC) @ 2.0ml/L (71.32%) as compared to treated check (diclorovas) @1.0ml/L (57.38%). The least effect (3.4%) was observed with dimethoate 30EC@2.0ml/L followed by thiocloprid (27.7SC)@ 0.4ml/L (3.5%); impact of imidacloprid (17.8SL)@0.17,0.28 and 0.56ml/L was around 7.4%, 5.0% and 3.7%, respectively. These values are quite less as compared to higher concentration of other pesticides.

At 1st DAT, population change in coccinellids was the highest (66.66%) with imidacloprid (17.8SL) @0.56ml/L. Such change (>60%) had been reported at above the recommended dose of imidacloprid on aphid predators (Suganthy, 2003). The maximum population change in syrphid larvae (68.88%) was observed with chlorpyriphos (20EC)@ 2.0ml/L which was at par with others, while the least change (40.00%) was with imidacloprid (17.8SL) @0.17ml, and cypermethrin (25EC) @1.0ml/L. Thioclorpid (21.7SL) @ 0.4ml/L and cypermethrin (25EC) @ 2.0ml/L caused maximum reduction in parasitization. Khan (2009) observed in his study on the relative toxicity/ safety of pesticides to coccinellids observed the slightly harmful mortality rate of thiocloprid. Patil and Lingappa (2001) and Preetha *et al* (2009) reported that the higher concentration of imidacloprid as toxic to *Chrysoperla* larvae which is similar to the present observations.

The least population change in natural enemies was observed with chlorpyriphos (20EC) @1.0 ml, found on par with imidacloprid (17.8SL) @0.17ml/L. At 15th day after treatment, maximum population change in coccinellids, syrphid and *Chrysoperla* larva were 87.5%, 83.30% and 100% with thiocloprid (21.7SL) @0.4ml/L and the minimum with imidacloprid (17.8SL) @0.17ml/L found at par with chlorpyriphos (20EC) @1.0ml/L. Cumulative mean of population change in coccinellids was the highest (77.77%) with higher concentration of imidacloprid (17.8SL)@0.56ml/L observed at par with thiocloprid (21.7SL) @ 0.4ml/L (75.00%); with syrphid larvae it was 78.30% with thioclorpid (21.7SL) @ 0.4ml/L observed at par with dimethoate (30EC) @2.0ml/L.

With regard to *Chrysoperla* larvae, maximum change (74.00%) was observed with the higher concentration of dimethoate (30EC) @2.0ml/L, cypermethrin 25 EC@2.0ml/L, and thiocloprid (21.7SL) @ 0.4ml/L; and maximum change in population (87.00%) was observed with thiocloprid (21.7 SC) @ 0.0.4ml/L. The least cumulative population change in coccinellids (52.22%) and *Chrysoperla* larvae (50.00%) was observed with cypermethrin 25 EC@1.0ml/L while in case of syrphid larvae it was 50.00% observed with imidaclorpid (17.8SL) @ 0.17ml/L.

The insecticidal effect on non target organism are categorised as per the recommendations of International Organisation of Biological Control West Palaearctic Regional Section working group (Hassan, 1989; Nasreen *et al*., 2000) as harmless, slightly harmful, moderately harmful and harmful, when tested at field

Table 1. Bioefficacy of pesticides against green apple aphid *Aphis pomi* in Kashmir

Treatment	Conc. ml/L	Pre-treatment count (population/ 10cm of twigs)			Total	Post treatment count (Mean population/ 10cm of twigs)									Cumulative Mean			Total (Mean % reduction)
						1DAT			7DAT			15DAT						
		N	A	Ap		N	A	Ap	N	A	Ap	N	A	Ap	N	A	Ap	
	0.17ml	47.6	15.4	16.6	79.6	7.5	4.2	5.6	5.8	3.6	4.6	4.2	2.4	3.0	5.83	3.4	4.4	13.63
						(84.24)	(72.72)	(66.26)	(87.81)	(76.62)	(72.28)	(91.17)	(84.41)	(81.92)	(87.74)	(77.91)	(73.48)	(79.71)
Imidacloprid (17.8 SL)	0.28 ml	37.2	17.4	15.2	69.8	4.2	3.4	3.0	3.6	2.2	2.0	2.8	2.0	1.6	3.53	2.53	2.2	8.26
						(88.87)	(80.45)	(80.26)	(90.32)	(87.35)	(86.84)	(92.47)	(88.50)	(89.47)	(90.55)	(85.43)	(85.52)	(87.16)
	0.56ml	56.8	13.8	17.4	88.0	4.0	2.6	2.4	3.2	1.8	1.6	2.0	1.0	1.2	3.06	1.8	1.73	6.59
						(92.95)	(81.15)	(86.20)	(94.36)	(86.95)	(90.80)	(96.47)	(92.75)	(93.10)	(94.59)	(86.95)	(90.03)	(90.52)
	1ml	53.6	14.2	13.6	81.4	14.2	6.6	6.4	10.6	4.8	4.2	7.8	3.6	3.8	10.86	5.0	4.8	20.66
						(73.50)	(53.52)	(52.94)	(80.22)	(66.19)	(69.11)	(85.44)	(74.64)	(72.05)	(79.72)	(64.78)	(64.70)	(69.73)
Dimethoate (30 EC)	1.5ml	46.2	16.4	17.4	80.0	11.6	6.2	6.0	8.4	5.0	4.4	5.8	3.4	3.2	8.6	4.86	4.53	17.99
						(74.89)	(62.19)	(65.51)	(81.81)	(69.51)	(74.71)	(87.56)	(79.26)	(81.60)	(81.38)	(70.32)	(73.94)	(75.21)
	2ml	38.6	15.2	16.8	70.6	9.4	4.6	5.0	5.6	3.2	3.6	4.8	2.8	1.8	6.6	3.53	3.46	13.59
						(75.64)	(69.73)	(70.23)	(85.49)	(78.94)	(78.57)	(87.56)	(81.57)	(89.28)	(82.89)	(76.74)	(79.36)	(79.66)
	0.1ml	35.2	14.4	13.6	63.2	9.2	5.2	4.8	6.8	4.0	4.2	5.4	3.4	3.0	7.13	4.2	4.0	15.33
						(73.86)	(63.88)	(64.70)	(80.68)	(72.22)	(69.11)	(84.65)	(78.94)	(77.94)	(79.73)	(71.68)	(70.58)	(73.99)
Thiocloprid 21.7SC	0.2ml	36.4	15.2	14.6	66.2	7.2	5.4	4.8	6.4	3.6	3.2	5.2	3.2	2.4	6.20	4.06	3.4	13.66
						(78.02)	(64.47)	(67.12)	(82.41)	(76.31)	(78.08)	(85.71)	(87.50)	(83.56)	(82.04)	(76.09)	(76.25)	(78.12)
	0.4ml	43.6	14.4	12.4	70.4	4.2	3.6	4.0	3.0	2.4	2.4	2.6	1.6	2.0	3.26	2.6	2.66	8.52
						(90.36)	(75.00)	(67.74)	(93.11)	(83.33)	(79.03)	(94.03)	(88.88)	(83.87)	(92.50)	(82.40)	(76.88)	(83.92)
	1ml	37.6	13.8	11.6	63.0	9.6	5.2	5.8	7.4	4.0	4.2	5.2	3.2	3.8	7.4	4.13	4.6	16.13
						(74.46)	(62.31)	(50.00)	(80.31)	(71.01)	(63.79)	(86.17)	(76.81)	(67.24)	(80.31)	(70.04)	(60.34)	(70.23)
Cypermethrin (25EC)	1.5ml	48.4	15.6	13.4	77.4	11.4	4.2	5.6	8.6	3.2	4.8	6.4	2.2	3.0	8.8	3.2	4.46	16.46
						(76.44)	(73.07)	(58.20)	(82.23)	(79.48)	(64.17)	(86.77)	(85.89)	(77.61)	(81.81)	(79.48)	(66.66)	(75.98)
	2ml	42.8	13.4	11.8	68.0	9.6	3.6	4.2	7.4	2.2	3.0	5.4	1.6	2.4	7.46	1.26	3.2	11.92
						(77.57)	(73.13)	(64.40)	(82.71)	(83.58)	(74.57)	(87.38)	(88.80)	(79.66)	(82.55)	(81.83)	(72.87)	(79.08)
	1ml	51.4	15.8	13.4	80.6	20.6	6.4	5.4	16.4	5.2	4.6	12.2	3.6	3.2	16.4	5.06	4.4	25.86
						(59.92)	(59.49)	(59.70)	(68.09)	(67.08)	(65.67)	(76.26)	(77.21)	(76.11)	(68.09)	(67.92)	(67.16)	(67.72)
Chlorpyriphos (20EC)	1.5ml	50.0	16.4	17.2	83.6	15.2	6.6	6.6	11.4	4.8	5.8	8.8	3.4	3.6	11.8	4.93	5.33	22.06
						(69.60)	(59.75)	(61.62)	(77.20)	(70.73)	(66.27)	(82.40)	(79.26)	(79.06)	(76.40)	(69.91)	(68.98)	(71.76)
	2ml	54.2	14.4	16.4	85.0	12.2	5.4	6.0	9.0	4.2	5.0	7.6	2.8	3.0	9.6	4.13	4.66	18.39
						(77.49)	(62.50)	(63.41)	(83.39)	(70.83)	(69.51)	(85.97)	(80.55)	(81.70)	(82.28)	(71.29)	(71.54)	(75.03)
Treated check (Dichlorvas 76EC)	1ml/L	47.4	12.8	14.6	74.8	13.6	6.2	5.2	8.6	4.6	4.8	6.6	3.0	3.2	9.6	4.6	4.4	18.6
						(71.30)	(51.56)	(64.38)	(81.85)	(64.06)	(67.12)	(86.07)	(76.56)	(78.08)	(79.74)	(64.06)	(69.86)	(71.22)
Control	Use water only	36.2	12.6	13.4	62.2	37.2	12.8	13.6	38.2	13.0	14.2	38.4	13.2	14.4	37.9	13.0	14.06	64.96
						(-2.76)	(-1.59)	(-1.49)	(-5.52)	(-3.17)	(-5.97)	(-6.07)	(-4.76)	(-7.46)	(-4.69)	(-3.17)	(-4.92)	(-4.43)
CD(P=0.05)		4.21	1.67	1.45	3.94	2.01	2.11	1.01	1.18	0.97	0.76	1.06	0.47	0.55	-	-	-	-

Mean of 5 replications; DAT= days after treatment; Figure in parentheses indicates mean % reduction in population, N= nymph, Al= Alate, Ap= Apterus, DAT= days after treatment

Table 2. Biosafety of pesticides to natural enemies of green apple aphid in Kashmir

Treatment	Conc. (ml/L)	*Pre-treatment count			Total	P (%)	*Post treatment count (Mean population DAT)												Cumulative mean			Total (Mean % reduction)	Mean (% P)
							1				7				15								
		C.	S.	Ch.			C.	S.	Ch.	P (%)	C.	S.	Ch.	P (%)	C.	S.	Ch.	P (%)	C.	S.	Ch.		
Imidacloprid (17.8 SL)	0.17 ml	1.4	1.2	1.0	3.6	10.2	0.8 (42.85)	0.8 (40.00)	0.6 (40.0)	8.6	0.6 (57.14)	0.6 (50.00)	0.5 (50.00)	7.2	0.4 (57.14)	0.4 (66.60)	0.4 (60.00)	6.4	0.60 (57.14)	0.6 (50.00)	0.5 (50.00)	1.70 (52.77)	7.4
	0.28 ml	1.6	1.4	1.2	4.2	9.6	0.8 (50.0)	0.6 (57.14)	0.7 (41.66)	6.4	0.6 (62.25)	0.4 (71.40)	0.5 (58.30)	5.2	0.4 (75.00)	0.3 (78.6)	0.4 (66.60)	3.4	0.60 (62.50)	0.43 (69.28)	0.53 (55.83)	1.56 (62.85)	5.0
	0.56 ml	1.8	1.2	1.0	4.0	11.2	0.6 (66.66)	0.4 (66.67)	0.4 (60.00)	5.4	0.4 (77.77)	0.3 (75.00)	0.3 (70.00)	3.2	0.2 (88.88)	0.2 (83.30)	0.2 (80.00)	2.6	0.40 (77.77)	0.30 (75.00)	0.30 (70.00)	1.00 (75.00)	3.7
	1.0 ml	1.4	1.0	1.2	3.6	8.4	0.8 (42.8)	0.5 (50.0)	0.8 (33.30)	6.4	0.6 (57.14)	0.4 (60.00)	0.6 (50.00)	5.2	0.4 (71.44)	0.4 (60.00)	0.4 (66.66)	3.8	0.60 (57.14)	0.46 (54.00)	0.60 (50.00)	1.66 (55.55)	5.1
Diamethoate (30 EC)	1.5 ml	1.6	1.2	1.0	3.8	9.8	0.9 (43.70)	0.5 (58.3)	0.5 (50.0)	6.6	0.6 (62.25)	0.4 (60.60)	0.4 (60.00)	5.4	0.4 (75.00)	0.3 (75.00)	0.4 (60.00)	4.0	0.63 (60.60)	0.40 (60.60)	0.43 (57.00)	1.46 (59.40)	5.3
	2.0 ml	1.8	1.6	1.0	4.4	10.4	0.8 (55.50)	0.6 (66.60)	0.4 (60.00)	5.2	0.5 (72.22)	0.4 (77.70)	0.2 (80.00)	4.4	0.4 (77.77)	0.2 (88.80)	0.2 (80.00)	3.6	0.56 (68.80)	0.40 (77.70)	0.26 (74.00)	1.22 (72.27)	3.4
Thiocloprid (21.7SC)	0.1 ml	1.6	1.2	0.8	3.6	8.8	0.8 (50.00)	0.6 (50.00)	0.4 (50.00)	5.6	0.6 (62.50)	0.4 (66.66)	0.4 (50.00)	4.2	0.6 (62.50)	0.4 (66.66)	0.2 (75.00)	3.8	0.66 (58.75)	0.46 (61.66)	0.26 (67.50)	1.38 (61.66)	4.5
	0.2 ml	1.4	1.0	1.0	3.4	7.8	0.6 (57.14)	0.4 (60.00)	0.4 (60.00)	4.2	0.4 (71.42)	0.4 (60.00)	0.2 (80.00)	3.8	0.4 (71.42)	0.2 (80.00)	0.2 (80.00)	2.8	0.46 (67.14)	0.33 (67.00)	0.26 (74.00)	1.05 (69.12)	3.6
	0.4 ml	1.6	1.2	1.0	3.8	9.4	0.6 (62.50)	0.4 (66.66)	0.2 (80.00)	5.0	0.4 (75.00)	0.2 (83.30)	0.2 (80.00)	3.2	0.2 (87.5)	0.2 (83.30)	0.0 (100.0)	2.4	0.40 (75.00)	0.26 (78.30)	0.13 (87.00)	0.79 (79.21)	3.5
	1.0 ml	1.8	1.0	0.8	3.6	8.8	1.2 (33.33)	0.6 (40.00)	0.4 (50.00)	6.2	0.8 (55.55)	0.4 (60.00)	0.4 (50.00)	4.0	0.6 (66.60)	0.3 (70.00)	0.2 (75.00)	3.4	0.86 (52.22)	0.43 (57.00)	0.33 (58.75)	1.62 (55.00)	4.5
Cypermethrin (25EC)	1.5 ml	2.0	1.4	1.0	4.4	8.6	1.0 (50.00)	0.6 (57.14)	0.5 (50.00)	5.2	0.8 (60.00)	0.4 (71.42)	0.4 (60.00)	4.0	0.6 (70.00)	0.4 (71.42)	0.2 (80.00)	3.2	0.80 (60.00)	0.46 (67.14)	0.36 (64.00)	1.62 (63.18)	4.1
	2.0 ml	2.2	1.0	1.0	4.2	9.6	1.0 (54.54)	0.4 (60.00)	0.4 (60.00)	4.2	0.6 (72.72)	0.2 (80.00)	0.2 (80.00)	3.8	0.4 (81.81)	0.2 (80.00)	0.2 (80.00)	3.4	0.66 (70.00)	0.26 (74.00)	0.26 (74.00)	1.18 (71.90)	3.8
	1.0 ml	1.8	1.4	1.2	4.4	9.4	1.0 (44.44)	0.8 (42.85)	0.8 (33.33)	5.6	0.8 (55.55)	0.6 (57.14)	0.6 (50.00)	4.2	0.6 (66.60)	0.4 (71.42)	0.4 (60.00)	3.8	0.80 (55.55)	0.60 (57.14)	0.60 (50.00)	2.00 (54.54)	4.5
Chlorpyriphos (20EC)	1.5 ml	1.8	1.4	1.0	4.2	8.8	0.8 (55.55)	0.6 (57.14)	0.4 (60.00)	5.0	0.6 (66.66)	0.4 (71.42)	0.3 (70.00)	3.8	0.4 (77.70)	0.4 (71.42)	0.2 (80.00)	2.8	0.60 (66.66)	0.46 (67.14)	0.30 (70.00)	1.36 (67.62)	3.9
	2.0 ml	2.0	1.0	0.8	3.8	10.6	0.8 (60.00)	0.4 (68.88)	0.3 (62.50)	5.4	0.6 (70.00)	0.2 (80.00)	0.2 (75.00)	2.8	0.4 (80.00)	0.2 (80.00)	0.2 (75.00)	2.6	0.60 (70.00)	0.26 (74.00)	0.23 (71.25)	1.09 (71.32)	3.6
Treated check (Dichlorvas 76EC)	1.0 ml	2.2	1.2	0.8	4.2	9.2	1.2 (45.45)	0.8 (33.33)	0.4 (50.00)	6.0	0.8 (63.63)	0.6 (50.00)	0.4 (50.00)	4.8	0.6 (72.70)	0.4 (66.60)	0.2 (75.00)	4.2	0.86 (60.90)	0.60 (50.00)	0.33 (58.75)	1.79 (57.38)	5.0
Control	Use water only	1.8	1.4	1.0	4.2	9.0	1.8 (0.0)	1.6 (-14.28)	1.2 (-20.0)	10.2	2.0 (-11.11)	1.4 (0.0)	1.0 (0.0)	11.0	2.2 (-22.20)	1.6 (-14.28)	1.2 (-20.00)	12.4	2.0 (-11.11)	1.53 (-9.28)	1.13 (-13.0)	4.66 (-10.95)	11.2
CD(P=0.05)		0.14	0.08	0.04	0.92	1.23	0.21	0.26	0.14	1.19	0.17	0.09	0.11	2.14	0.06	0.08	0.07	0.96	-	-	-	-	-

Mean of 5 replications; Figure in parentheses mean % reduction of natural enemies, C= Coccinellids, S= Syrphid fly larva, Ch. = Chrysoperla, P= parasitized aphid (mummified), DAT= days after treatment, * Natural enemies count on the basis of 10 twigs.

recommendation dose. In the present study all the evaluated insecticides were observed to be slightly harmful as regards rate of change in population of natural enemies. Imidacloprid 17.8SL@ 0.28ml/L exhibited best performance on the basis of safety of natural enemies, and rated as slightly harmful.

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POPULATION DYNAMICS OF GREEN APPLE APHID *APHIS POMI* DE GEER (HOMOPTERA: APHIDIDAE) AND ITS NATURAL ENEMIES IN APPLE ORCHARD OF KASHMIR

AKHTAR ALI KHAN* AND MOHD ABAS SHAH

Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir Shalimar, Srinagar 190025, Jammu and Kashmir
**Email:akhtaralikhan47@rediffmail.com*

ABSTRACT

Population dynamics of green apple aphid (*Aphis pomi*) in relation to the natural enemies and weather parameters was studied in three districts viz., Srinagar, Budgam, and Ganderbal of Kashmir during 2012-13 and 2013-14. The peak population of *A. pomi* was recorded as 39.5 and 37.0 aphids/ shoot in Srinagar; 42.6 and 47.0 aphids/shoot in Budgam and 41.3 and 54.8 aphids/shoot in Ganderbal at 2nd fortnight of June during 2012-13 and 2013-14, respectively with exception during 2013-14 in Ganderbal the peak was attained at 1st fortnight of July. The natural enemies include coccinellids, syrphid fly and Chrysoperla and were recorded highest in 1st fortnight of July except Srinagar was on16th June during both years. Highest % of parasitization was found on 2nd fortnight of July and ranged 14.2 to 15.2% and 13.4-15.6% during 2012-13 and 2013-14, respectively. The *A. pomi* overwintering nymphs was 0.3 and 0.5/10 buds and their mean maximum population was 0.66 and 1.0/ 10 buds on 2nd fortnight of December during 2012-13 and 2013-14, respectively in Srinagar and trend was also similar in other locations of Kashmir. The temperature played major role to buildup the population of aphid, its predators and parasitoids and after attaining peak population of natural enemies, the aphid population tends to decrease. Relative humidity had a positive influence along with temperature on aphid population and rainfall had negative influence.

Key words: *Aphis pomi*, abiotic and biotic factors, population dynamics, Ganderbal, Budgam, Srinagar, natural enemies, coccinellids, syrphid, Chrysoperla, parasitoids

Apple trees are infested with more than 15 aphid species (Blackman and Eastop, 1984) worldwide and in Jammu and Kashmir it is infested with more than 10 species (Shah, 2015; Khan, 2015). The most common ones are the green apple aphid, *Aphis pomi* De Geer, Spirea aphid, *Aphis spiraecola* (Patch), the rosy apple aphid, *Dysaphis pyri* (Boyer de Fonscolombe) and the woolly apple aphid, *Eriosoma lanigerum* (Hausmann) (Homoptera: Aphididae) and these are serious pests in apple orchard worldwide (Niemczyk, 1988; Perdikis *et al*., 2008). In Kashmir, *A. pomi* is regarded as the most injurious (Shah, 2015; Khan 2015). It is a holocyclic and monoecious aphid species that is widespread in the temperate region of Jammu and Kashmir (Shah, 2015). *Aphis pomi* causes the severe damage; reduce tree growth and non-structural carbohydrate concentration in young apple trees (van Emden and Harrington, 2007), decrease fruit production (Hamilton et al., 1986). Severe infestation can also cause curling, and production of honey dew which results in fruit discolouration (Blommers, 1994), stunting and weakening of terminals and increase risk of winter (Dixon, 1998). It is especially harmful in nurseries and young orchards, and characteristically infested apple trees over the May-June period (Milenkovic *et al*., 2013). Keeping in view its economic importance, and lack of sufficient work on the population dynamics, the present study evaluated its population dynamics.

MATERIALS AND METHODS

The field experiment was conducted in apple orchards of three districts viz., Srinagar, Budgam and Ganderbal during 2012-13 and 2013-14. The population dynamics was studied by taking samples from 10 randomly selected trees. The sampling unit was the upper part of a growing shoot, bearing six leaves. As first leaf was considered the last leaf which had not been completely unruffled and its length was about 2 cm. The examination of the first six leaves (about 10 cm of apex shoots/twigs) offers an adequate estimation of the population level, since according to Hull and Grimm (1983) >90% of the total aphid population collected from the top or lower part of the tree,

respectively, develop on those leaves. From each selected tree, 4 shoots one from each northern, southern, western and eastern side of the tree's periphery) at a height of 1.5 to 2.0 m were collected. The populations were estimated so, since Hull and Grimm (1983) concluded that "despite of some loss of prediction when sampling only the lower part of the tree to predict the density at the top or over the entire tree, this loss may be compensated for by the more convenient use of the sampler's time".

Sample was collected fortnightly from 1st May to 16th April 2012-13 and 2013-14, respectively. Each shoot was put separately in a polyethylene bag and brought to the laboratory. The observations were per 10 cm twig/shoot, with examinations usually completed in 48 hr and during this time the sample were kept at 5^{0}C. These samples were examined under a stereomicroscope and aphids collected were kept in vials filled with preserving fluid (2 part ethyl alcohol 90% and one part lactic acid 75% w/w) (Eastop and van Emen, 1972). Nymphs were separated in instars and adults in alate and apterous. Fortnightly observations were also made on the axils and base of the dormant buds under microscope to see the overwintering egg, nymph, alate and apterous stages. The data on temperature (maximum and minimum), relative humidity (morning and evening) and rainfall were obtained from meteorological section of the Division of Agronomy, Sher-e-Kashmir University of Agricultural sciences and Technology of Kashmir. Multiple and simple correlations of population with these weather factors were worked out.

Adults and grubs/larvae/maggots of coccinellids, *Chrysoperla* and syrphid flies were collected from aphid infested trees. Immature stages of these were reared in the laboratory by providing them sufficient aphids as daily feeding (Shah and Khan, 2014) till the adults emerged. Except syrphid adults, all natural enemies were collected on the basis of per 10 shoots (10 cm of each shoot). Similarly, the parasitoids were collected from the aphid mummies on the basis of per 10 shoots and brought to laboratory. The adults of the predators and parasitoids thus obtained were got identified. The intensity of parasitism was evaluated on the basis of the formula by Root and Shelsey (1969):

$$\text{Parasitism (\%)} = \frac{\text{Total aphid mummies}}{\text{Total live aphid-Total aphid mummies}} \times 100$$

RESULTS AND DISCUSSION

Aphis pomi

The population dynamics of *A.pomi* in relation to the biotic and abiotic factors is given in Table 1- 3 and Figs. 1- 3 (2012-13 and 2013-14). The first alate (4.3 / 10 cm of twig) of *A. pomi* appeared in the 1st week of April during first year. This continued to increase from 1st fortnight of May to 2nd fortnight of June during 2012-13. Thereafter, population generally decreased from 1st fortnight of July to 2nd fortnight of August. This decline could be attributed to increase in temperature and appreciable activity of biotic agents. Aheer *et al.* (2007) reported that temperature has a significant and positive role in fluctuating aphid density. The population of aphid showed little gain in September, and then overwintered from October to March. In successive fortnightly intervals, population buildup was observed on 2nd fortnight of June in district Budgam (42.6 aphids/10 cm of twig) including nymph, alate and apterous followed by district Ganderbal (41.3 aphids/10 cm of twig) and Srinagar (39.5 aphids/ 10 cm of twig) (Figs 1, 2 and 3). Weather parameters at this time were as maximum; 28.7^{0}C, min; 12.3^{0}C, rainfall; 1.60 mm, morning relative humidity (78.7%), evening relative humidity (43.9%) during 2012-13 (Table 1).

The first alate (5.6 /10 cm of twig) appeared in the 1st week of April during 2013-2014, and the population continued to increase from 1st fortnight of May to 1st fortnight of July as influenced by the weather factors. The population continued to increase from 1st fortnight of April to 1st fortnight of July, and then generally decreased from 2nd fortnight of July to 2nd fortnight of August, and this decline could be attributed to increase in temperature and appreciable activity of biotic agents. The population of aphid showed little gain in September and then overwintered from October to March. Population densities were higher in July (Kozar *et al.*, 1994).

In successive fortnightly interval, population buildup was observed on 1st fortnight of July in district Ganderbal (54.8 aphids/10 cm of twig) including nymph, alate and apterous ones. Weather parameters were: maximum temperature- 30.1^{0}C, minimum- 16.0^{0}C; rainfall- 51.0 mm; morning relative humidity 80.1%, evening relative humidity 48.4%. This was followed by district Budgam (47.0 aphids/10 cm of twig) and Srinagar (37.0 aphids/10 cm of twig) on 2nd

fortnight of June with weather parameters being: temperature maximum- 30.1^{0}C, and minimum- 16.0 ^{o}C; rainfall- 35.6mm; morning relative humidity- 76.5%, evening relative humidity- 46.1%, during 2013-14 (Table 2). This population dynamics could be compared with the *A.pomi* in apple orchards of Wisconsin, California and Nova Scotia and it showed a more or less similar fluctuation (Oatman and Legner, 1961; Westigard and Madsen, 1965; Braun, 1991; Stewart and Walde, 1997).

The data given in Table 1 and 2 reveal a positive significant correlation between population buildup with combined effect of temperature and relative humidity (R= 0.7301 and 0.7263) during 2012-13 and 2013-14. The independent effect of humidity (r= 0.7002 and 0.6945) and temperature (r=0.5610 and 0.5461) were also found positively correlated during both years. The rainfall showed negative influence on aphid population. Population of the pest started multiplying from the fundatrix with the commencement of the flow of sap in the host plant. Observations by Gupta and Thakur (1993) and Arora *et al.* (2009) corroborate the present findings since they had also visualized that egg hatching rate depend on the initiation of sap flow.

Observations on the overwintering stages from January to March (Figs. 1- 3) during 2012-13 and 2013-14 revealed that nymphs produced by late December overwintered in the axils and bases of dormant buds. The overwintering nymphs were more in January than in December, with mean minimum number being 0.3 and 0.5/ 10 buds and their mean maximum population was 0.66 and 1.0/ 10 buds on 2nd fortnight of December during 2012-13 and 2013-2014, respectively in Srinagar and trend was also similar in other locations. The pest remain under overwintering conditions from 2nd week of December till last week of January as earlier observed by Madahi and Sahragard (2012) and Malina *et al.* (2010).

Natural enemies

Coccinellids: These include *Harmonia dimidiata* (F.), *Adalia tetraspilota* (Hope), *Hippodamia veriegata* (Goeze), *Coccinella septumpunctata* (L.), *Adalia bipunctata* (Mulsant), *Menochilus sexmaculata* (F.), and *Oenopia conglobata* (L) (Table 3). Thalji (1981), Vo1icu *et al.* (1987), Verma and Singh (1989) and Khan *et al.* (2007; 2009) too reported these associations. The predation of this pest by various coccinellids had also been reported by Bhagatand Mir (1995) and Charkrabarti *et al.* (1995).

The population of coccinellids increased from 1st fortnight of May up to June last and then decreased and disappeared by November; it was lower in August, started to buildup from 1st fortnight of September but again decreased from 2nd fortnight of October with over wintering from November. The peak population was in the 1st fortnight of May in district Srinagar (3.0 coccinellids/10 cm of each 10 twig). The weather parameters were: temperature, maximum- 21.4 ^{0}C, and minimum- 7.92 ^{0}C; morning relative humidity (81.2%), evening relative humidity (53.5%), during 2012-13.

In 2013-14, the population increased from 1st fortnight of May and 16th June, and decreased gradually from 2nd fortnight of October, with overwintering from 16thNovember in Srinagar and Ganderbal and 1st November in Budgam. The peak population was observed in the 2nd fortnight of June when temperature maximum was 28.0 ^{0}C and minimum 15^{0}C; rainfall; 61.2 mm; and morning relative humidity (82.0%), evening relative humidity (56.7 %).

Chrysoperla zastrowi sillemi: During 2012-13 and 2013-14, the population trend observed was similar to that of coccinellids, with the peak being in the 1st/ 2nd fortnight of June or 1st fortnight of July. The weather parameters at this time were: temperature maximum- 26.6 to 30.7^{0}C, and minimum - 10.1 to 15.7^{0}C; rainfall- 17.4 mm and 2.0 mm; and morning relative humidity- 77.3 to 78.7 %, evening relative humidity- 53.7 to 6.1%. Some of these observations derive support from Mushtaq and Khan (2010).

Syrphid fly: *Eristalis aeneus* (Scopoli), *E. cerealis* (F.), *E. tenax* (L.), *Episyrphus balteatus* (Degeer), *Spheorophoria scripta (*L.), *Syrphus* sp. were observed. Their population showed variation between Srinagar, Budgam and Ganderbal during 2012-2013. The population was present on 1st fortnight of May and then it decreased upto1st fortnight of December, 2nd fortnight of October and 1st fortnight of November, respectively in three districts of Kashmir (Table 1, 2, 3; Figs. 1, 2, 3).

The population peaked in 1st fortnight of June in Srinagar and on 2nd fortnight of May in Budgam, on 2nd fortnight of June in Ganderbal in 2012-13. Weather parameters at this time were: temperature maximum- 20.1-28.7^{0}C, minimum- 9.9 - 12.3^{o}C; rainfall- 17.5 mm and 1.6 mm; and morning relative humidity- 75.9 to 78.7%, evening relative humidity- 39.6 to 43.9%) between 2nd fortnight of May to 2nd fortnight of June.

Table 1. Population dynamics of *Aphis pomi* in apple orchard (Kashmir, 2012-13)

Date of observation	Population dynamics in relation to natural enemies and weather factors									Weather Data				
	Srinagar		Budgam				Ganderbal							
	Aphid	Natural enemies	Aphid	Natural enemies			Natural enemies		Temp	RF	RH			
		Predators	P %		Predators	P%	Aphid	Predators	P%	Max	Min		Rh1	Rh2
1st May	28.0	4.4	4.5	36.9	2.1	1.6	32.9	4.3	3	21.4	7.92	17.9	81.2	53.5
16th May	36.6	3.9	6.5	34.9	3	4	33.3	3.2	6.4	20.1	9.9	17.5	75.9	39.6
1st June	33.9	4.4	6.6	36.6	3.6	4.6	40.5	4.6	9.8	26.6	10.1	17.4	77.3	56.1
16th June	39.5	4.5	9.6	42.6	4.6	6.9	41.3	5	11.3	28.7	12.3	1.6	78.7	43.9
1st July	32.2	2.9	13.4	36.5	4.1	11.3	38.6	3.9	12.2	30.7	15.7	2.0	71.0	37.0
16th July	31.2	2.6	14.2	26.8	4	14.2	23.9	2.6	15.2	29.6	15.9	22.0	81.6	55.3
1stAugust	9.5	0.9	10	13.5	1.5	9.5	18.6	0.6	9	31.8	16.7	38.2	76.8	45.9
16th August	6.5	0.3	11	13	0.6	8.2	7.6	1.2	10	26.9	17.4	28.4	54.4	65.6
1st Sept	27.6	1.9	7.2	28.3	2.2	6.6	32.9	1.6	4.8	31.8	17.8	2.8	79.8	48.7
16th Sept	34.3	3.5	9.8	23.9	3.6	7.2	29.3	2.6	5.4	25.6	16.0	37.5	91.4	70.1
1st Oct	24.3	3.5	7.6	20.3	1.9	5.2	23.5	2.9	3.7	25.8	9.84	12.4	89.2	60.3
16th Oct	23.3	2.5	8.8	27.9	1.9	11	21.2	4.2	4.5	23.9	5.68	0	86.7	44.2
1st Nov	14.0	0.3	8	11.5	0	6.4	7.8	0.3	3.2	17.4	6.0	8.90	87.9	63.6
16th Nov	12.0	0.6	6.8	6.9	0	8.5	10.9	0	4.3	20.1	0.2	0	85.8	56.7
1st Dec	2.2	0	7	0.9	0	6.5	2.99	0	6	15.1	-0.03	1.0	81.2	50.6
16th Dec	1.9	0	6	0	0	5.5	0.3	0	5	11.1	-0.25	11.8	86.4	62.6
1st Jan	0	0	0	0	0	0	0	0	0	7.5	-0.44	5.42	82.4	82.4
16th Jan	0	0	0	0	0	0	0	0	0	7.65	-3.10	6.60	91.9	74.3
1st Feb.	0	0	0	0	0	0	0	0	0	7.42	-1.33	89.4	92.2	70.1
16th Feb.	0	0	0	0	0	0	0	0	0	10.0	0.34	59.0	84.4	62.5
1st March	0	0	0	0	0	0	0	0	0	17.1	3.35	13.0	75.9	47.0
16th March	0	0	0	0	0	0	0	0	0	17.8	4.699	38.0	79.0	44.6
1st April	27.6	3.9	8.4	24.9	1.9	2.4	26.3	1.9	5.5	19.2	5.29	43.4	72.7	61.2
16th April	25.9	3.9	9.2	20	3.3	3.6	24.9	1.6	6.7	18.2	5.04	96.5	86.7	60.1

Where, Aphid population includes; Nymph, Apterous aphid and Alate aphids, P (%) =Mummified aphids; Predators includes; CL=Chrysoperla larvae, C = Coccinellids and S=Syrphid fly larvae. Temp. =Temperature, Max. = Maximum Temperature (^{0}C), Min. = Minimum Temperature (^{0}C), RF=Rainfall (mm), RH= Relative humidity (%), Rh1= Morning Relative humidity, Rh2= Evening Relative humidity. Population of *Aphis pomi* and natural enemies' mean of five replications and in each replication population recorded from per 10 cm of twigs/shoot for *Aphis pomi* and 10 twigs/shoots for natural enemies.

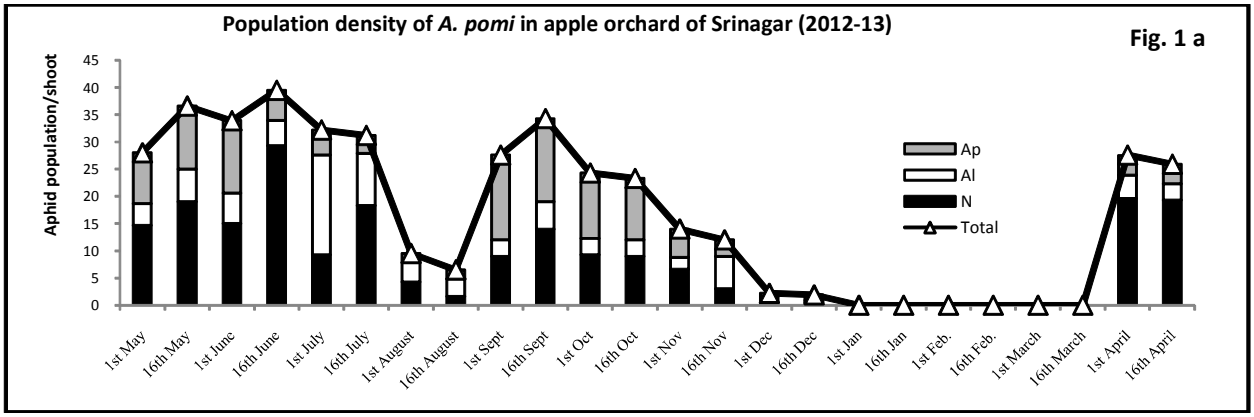
Multiple correlation coefficient (R_1)= 0.7301* (aphid), 0.6981 (predators) and 0.5107 (parasitoids); partial correlation coefficient (r)= 0.7002* (Temperature), 0.5610* (Humidity), 0.4723 (Rainfall); Coefficient of determination (R2)= 0.4933, Significant at p = 0.05.

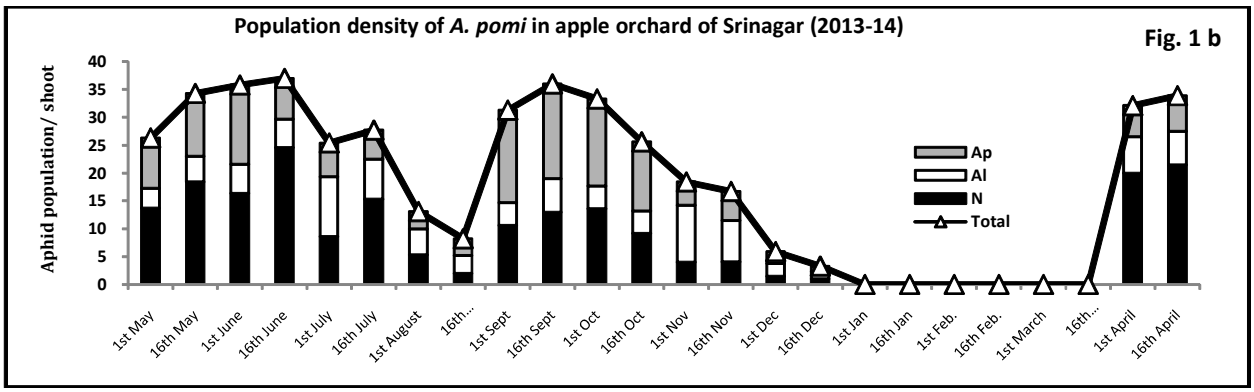
Table 2. Population dynamics of *Aphis pomi* in apple (Kashmir, 2013-14)

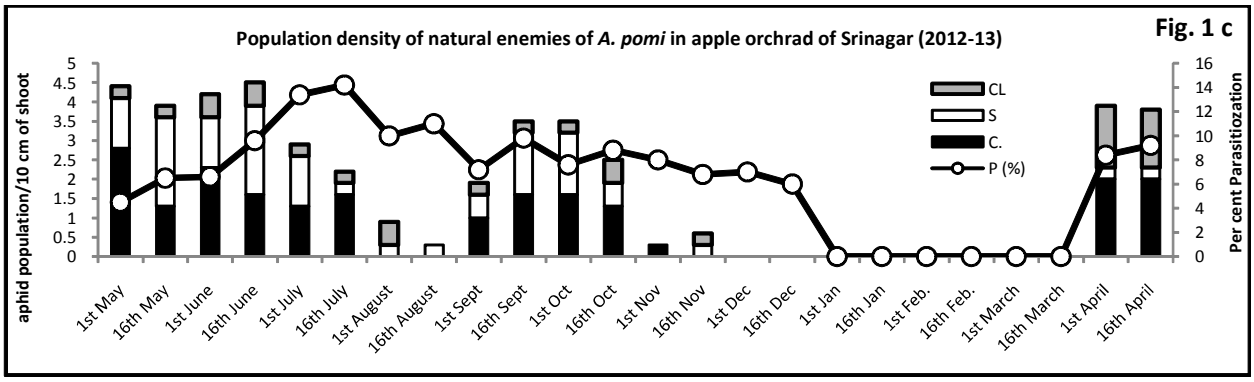
Date of observation	Population dynamics of *Aphis pomi* with relation to natural enemies and weather factor									Weather Data				
	Srinagar			Budgam			Ganderbal			Temp		RF	RH	
	Aphid	Natural enemies		Aphid	Natural enemies		Aphid	Natural enemies						
		Predators	P%		Predators	P%		Predators	P%	Max	Min		Rh1	Rh2
1st May	26.3	4.4	4.2	33.4	3.7	2	29.4	4.9	3.2	23.0	8.5	22.6	82.1	49.1
16th May	34.3	4.6	5.6	34.4	3.4	3.3	31.9	4.4	5.3	26.6	9.8	45.2	76.7	45.3
1st June	35.8	3.4	5.2	34.1	3.3	3.7	36	4.9	7.3	28.5	15.1	61.2	82.0	56.7
16th June	37.0	4.7	7.3	47	4.7	9.3	43.7	4.1	10.3	30.1	16.0	35.6	76.5	46.1
1st July	25.4	4	11.4	30.3	4	11.1	54.8	5.3	11.6	30.1	16.0	51.0	80.1	48.4
16th July	27.7	2.7	14.4	29.6	0.9	15.6	31	3.5	13.4	31.9	18.4	11.2	73.1	46.3
1stAugust	13.1	1.9	9.4	16.6	1.1	8.4	21.4	1.5	7.3	31.2	19.2	24.6	78.4	51.6
16th August	8.2	2.2	10.3	9.5	3.5	7.1	16.3	1.1	9.4	26.0	16.9	162.0	82.7	73.3
1st Sept	31.3	2.1	7.2	32.9	1.8	5.6	37	1.7	5.1	26.9	14.2	8.4	81.7	56.1
16th Sept	36.0	1.3	10	42.7	1.1	5	32.1	1.8	4.3	26.8	11.4	21.0	83.9	57.6
1st Oct	33.3	2.4	7.5	38.3	1.4	3.6	28.7	1.9	3.2	23.1	12.2	11.6	86.5	55.3
16th Oct	25.6	1.3	8.6	31.8	0.3	9.7	21.9	2.1	6.2	14.6	4.8	0	85.4	60.9
1st Nov	18.4	0.3	8	9.9	0	5.3	17.7	0.3	2.4	16.1	2.5	25.8	83.8	71.2
16th Nov	16.7	0.5	5.3	9.6	0	9.1	11.7	0	5	13.8	-1.8	0	86.8	55.4
1st Dec	5.9	0	6.4	1.6	0	6.2	6.2	0	5.5	12.6	-3.2	0	90.6	69.1
16th Dec	3.3	0	5	0.9	0	5.3	3.5	0	0	9.3	-1.2	12.6	87.6	71.9
1st Jan	0	0	0	0	0	0	0	0	0	4.5	-1.8	68.4	87.9	83.3
16th Jan	0	0	0	0	0	0	0	0	0	4.8	-1.7	95.2	90.2	75.5
1st Feb.	0	0	0	0	0	0	0	0	0	7.8	-1.9	32.5	89.7	64.8
16th Feb.	0	0	0	0	0	0	0	0	0	10.5	-1.7	30.0	86.3	57.1
1st March	0	0	0	0	0	0	0	0	0	9.3	1.5	116.4	83.2	68.4
16th March	0	0	0	0	0	0	0	0	0	12.7	5.0	76.8	86.7	64.6
1st April	32.1	4.1	10.3	29.6	2.1	1.5	27.2	1.2	2.3	15.8	5.6	86.8	80.0	62.8
16th April	33.9	4.3	10.5	27.3	3.2	2.6	26.7	1.3	3	19.7	6.7	38.0	76.9	59.2

Where, Aphid population includes; Nymph, Apterous aphid and Alate aphids, P (%) =Mummified aphids, Predators includes; CL=Chrysoperla larvae, C = Coccinellids and S=Syrphid fly larvae. Temp. =Temperature, Max. = Maximum Temperature (^{0}C), Min. = Minimum Temperature (^{0}C), RF=Rainfall (mm) RH= Relative humidity (%), Rh1= Morning Relative humidity, Rh2= Evening Relative humidity. Population of *Aphis pomi* and natural enemies' mean of five replications and in each replication population recorded from per 10 cm of twigs/shoot for *Aphis pomi* and 10 twigs/shoots for natural enemies.

Multiple correlation coefficient (R_1)= 0.7263* (aphid), 0.7124 (Predators) and 0.5124 (parasitoids); partial correlation coefficient (r)= 0.6945* (Temperature), 0.5461* (Humidity), 0.4643 (Rainfall); Coefficient of determination (R2)= 0.4968, Significant at p=0.05.







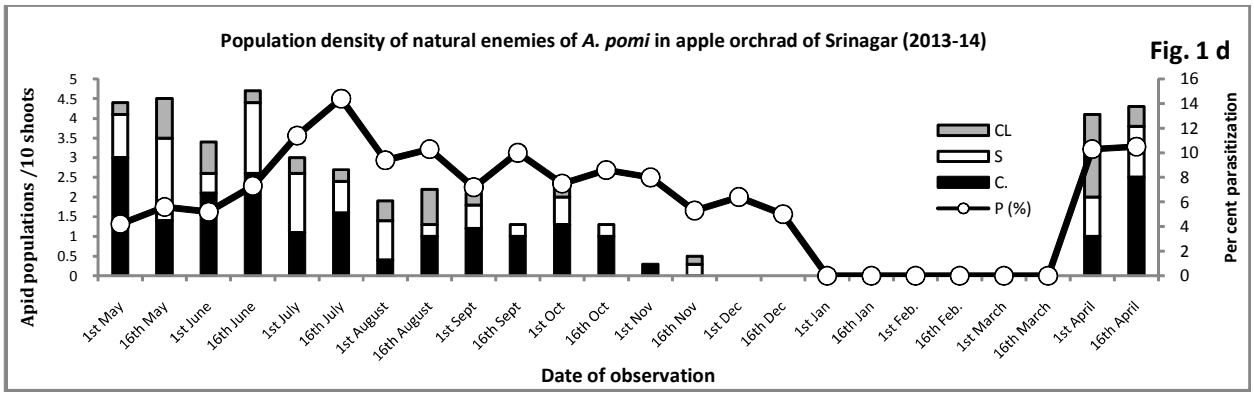
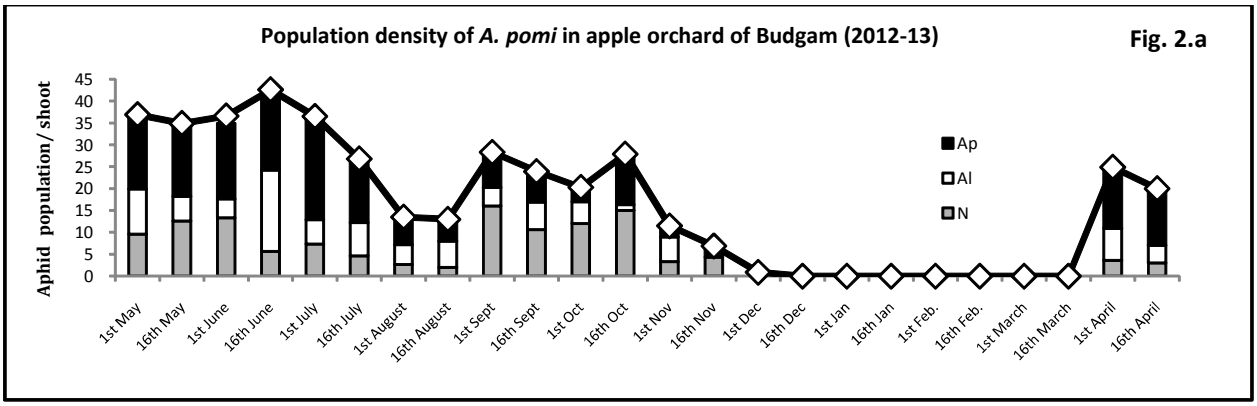
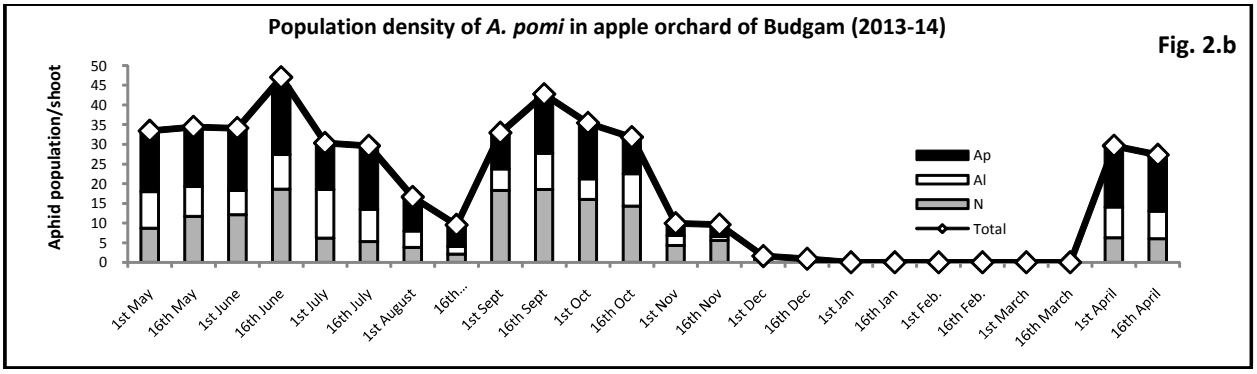
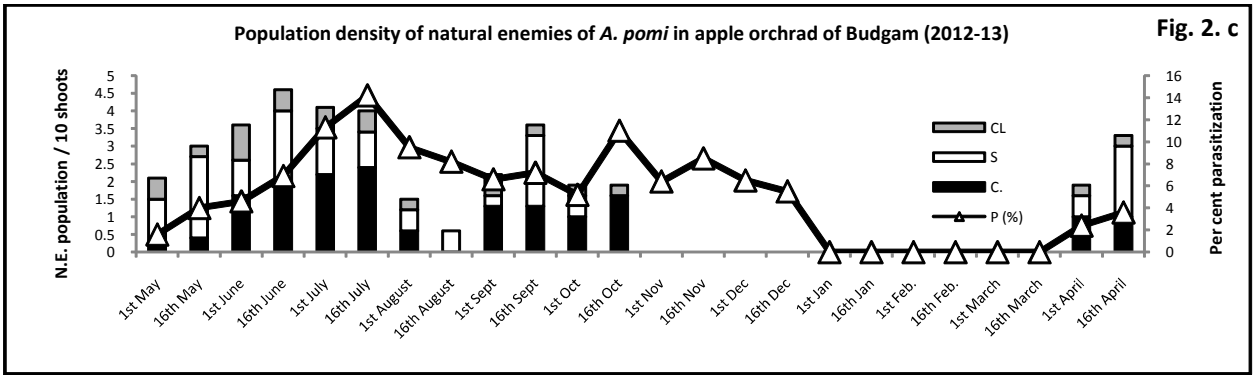


Fig. 1. Population density of *Aphis pomi* and its natural enemies in apple, Srinagar (2012-13 & 2013-14). Where, N = Nymph, AP = Apterous, Al = Alate, P (%) = Mummified aphids, CL= Chrysoperla larvae, C = Coccinellids, S = Syrphid fly.







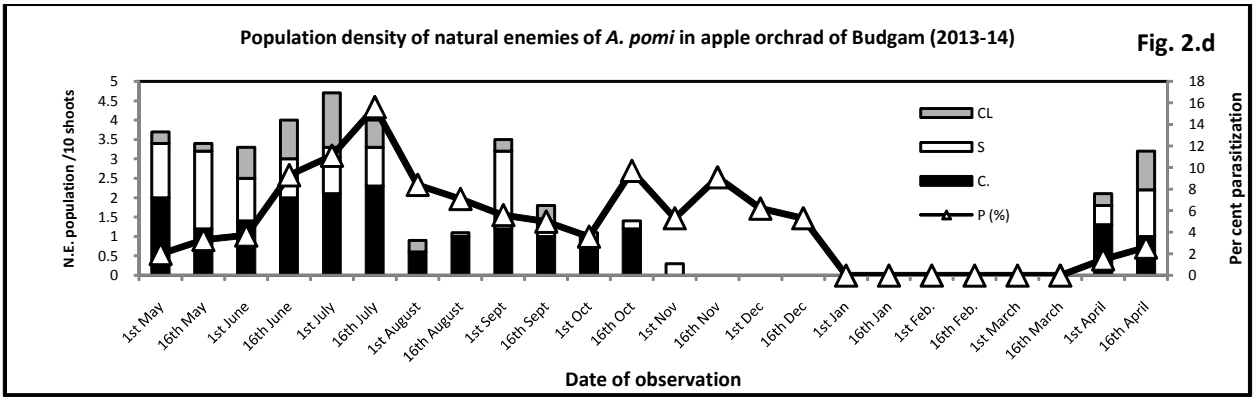


Fig. 2. Population density of *Aphis pomi* and its natural enemies in apple (Budgam, 2012-13 & 2013-14). Where, N = Nymph, AP = Apterous, Al = Alate, P (%) = Mummified aphids, CL = Chrysoperla larvae, C = Coccinellids, S = Syrphid fly

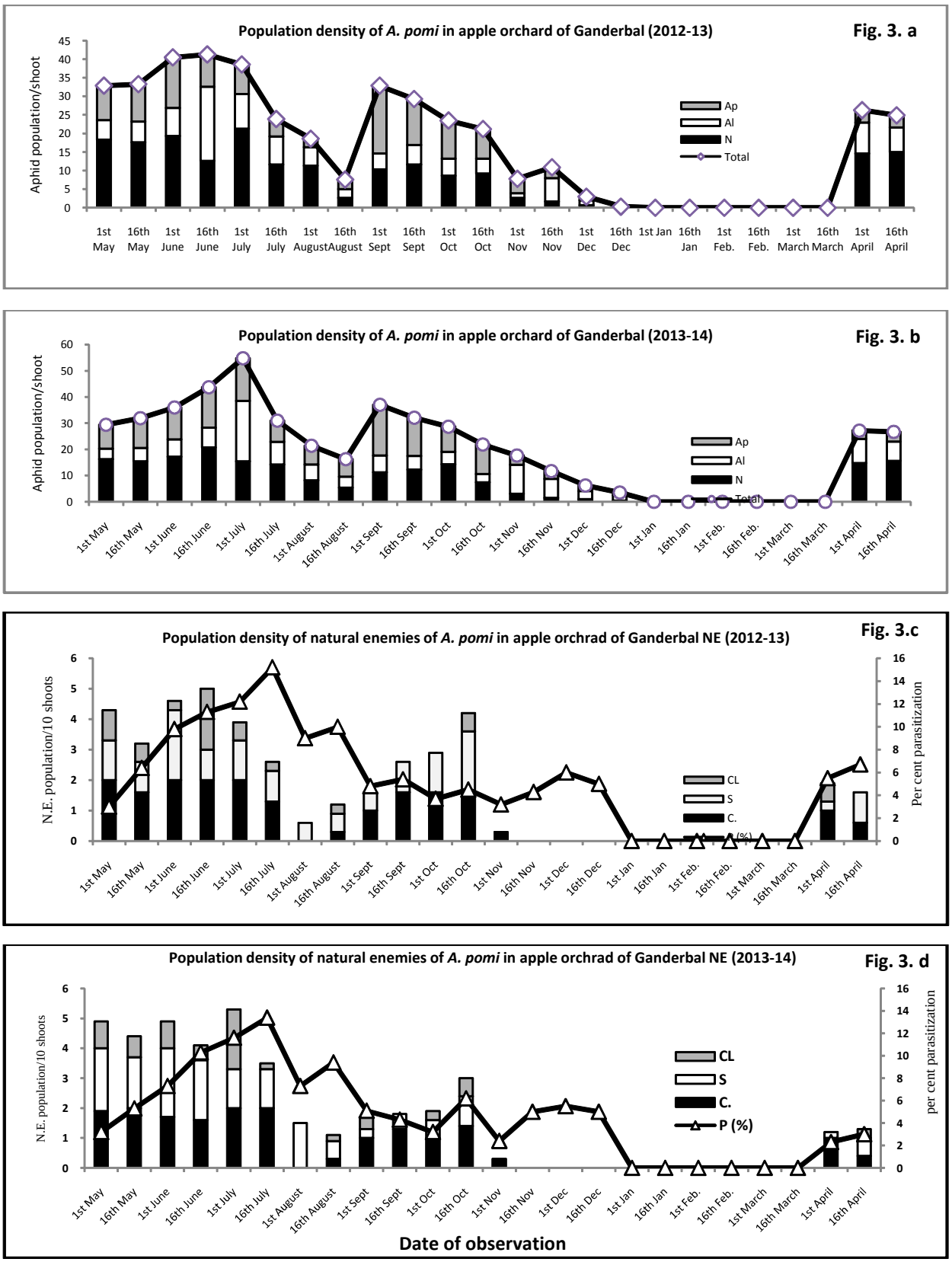


Fig. 3. Population density of *Aphis pomi* and its natural enemies (apple, Ganderbal, 2012-13 & 2013-14). Where, N = Nymph, AP = Apterous, Al = Alate, P (%) = Mummified aphids, CL = Chrysoperla larvae, C = Coccinellids, S = Syrphid fly.

Table. 3. Natural enemies complex of *A. pomi* (Kashmir, 2012-14)

Natural enemies	Order	family
A. Coccinellids		
Hormonia eucharis (Mulsant)	Coleoptera	Coccinellidae
Hormonia dimidiata (F.)	Coleoptera	Coccinellidae
Adalia tetraspilota(Hope)	Coleoptera	Coccinellidae
Hippodamia variegata (Goeze)	Coleoptera	Coccinellidae
Coccinella septumpuctata (L.)	Coleoptera	Coccinellidae
Adalia bipunctata (Mulsant)	Coleoptera	Coccinellidae
Menochilus sexmaculata (F.)	Coleoptera	Coccinellidae
Oenopia conglobata (L.)	Coleoptera	Coccinellidae
B. Chrysopids		
Chrysoperla zastrowi sillemi (E &P)	Neuroptera	Chrysopidae
C. Syrphids	Diptera	Syrphidae
Eristalis aeneus (Scopoli)	Diptera	Syrphidae
Eristalis cerealis (F.)	Diptera	Syrphidae
Eristalis tenax (L.)	Diptera	Syrphidae
Episyrphus balteatus (DeGeer)	Diptera	Syrphidae
Spheorophoria scripta (L.)	Diptera	Syrphidae
Syrphus sp.	Diptera	Syrphidae
D. Parasitoids		
Aphidius sp.	Hymenoptera	Braconidae
Ephedrus sp.	Hymenoptera	Braconidae
Toxares deltiger(Haliday)	Hymenoptera	Braconidae
Trioxys sp.	Hymenoptera	Braconidae

The population was observed in the 1st fortnight of May and then not increased gradually till 1st fortnight of July during 2013-14. It became lowest in August, built up again, but disappeared from November to March. The peak was during 2nd fortnight of June in Srinagar,1st fortnight of June in Budgam and 1st fortnight of July in Ganderbal. Bouchard *et al.* (1986) referred 60 predators and 60 parasitoids active against *A.pomi.* The occurrence of aphidophagous syrphids in apple orchids had been reported by S. Mayadunnage *et al.* (2009) and Khan *et al.* (2016).

Parasitism on *Aphis pomi:* The parasitoids collected include *Aphidius* sp., *Ephedrus* sp., *Toxares deltiger* (Haliday) and *Trioxys* sp. with these appearing in the samples collected in 1st fortnight of May. Their population increased gradually and then decreased after 2ndfortnight of July (Table 1-3; Figs. 1-3). No parasitism was observed in samples from 1st fortnight of January to March, due to decrease in temperature. The highest degree of parasitism was recorded from district Ganderbal (15.2%) in 2012-13, with weather parameters being: temperature maximum-29.6^{0}C, minimium-15.9^{0}C; rainfall-22.0 mm; and morning relative humidity-81.6%, evening relative humidity-55.3%.

In 2013-14, peak population of parasites was observed at Budgam (15.6%) in 2nd fortnight of July. Weather parameters at this time were: temperature maximum- 31.9^{0}C, minimum- 18.4 ^{0}CF; rainfall- 11.2 mm; and morning relative humidity- 73.1%, evening relative humidity- 46.3%. Bouchard *et al.* (1986) showed 60 predators and 60 parasitoids active against *A. pomi*.

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LEAFHOPPER FAUNA ASSOCIATED WITH RICE ECOSYSTEM IN THRISSUR DISTRICT, KERALA

NESMI ABDUL KHADER, T.K.* AND MAICYKUTTY P. MATHEW

Department of Agricultural Entomology
College of Horticulture, Kerala Agricultural University, Vellanikkara 680654
**Email: nesmishijad@gmail.com*

ABSTRACT

A study was undertaken in the Department of Agricultural Entomology, College of Horticulture, Vellanikkara during 2015-2016, to document the leafhopper fauna associated with rice ecosystem in Thrissur district of Kerala. Leafhoppers were collected from paddy fields of Vadakkanchery and Kole lands. Different parts of leafhoppers *viz.*, head, pronotum, scutellum, male genitalia, abdominal apodemes and female seventh sternum were studied in detail and illustrations were made. Results revealed nine species of leafhoppers associated with rice: *Cofana spectra* (Distant), *C. lineata* (Distant), *Nephotettix nigropictus* (Stal), *N. virescens* (Distant), *Exitianus indicus* (Distant), *Maiestas dorsalis* (Motschulsky), *Hecalus porrectus* (Walker), *H. lutescens* (Distant) and *Doratulina* sp. Occurrence of *H. lutescens* (Distant) in rice ecosystem is a new report for Kerala. *C. lineata* and *H. porrectus* are new records on rice in Kerala. A dichotomous taxonomic key to separate these nine species is also given.

Key words: Leafhoppers, rice, Kerala, Vadakkancherry, Kole, taxonomic characters, illustrations, taxonomic key, habitus images, new records, new reports

The leafhoppers are economically important as they suck sap from agriculturally important crops and some leafhoppers inject toxic saliva into plant tissues resulting in hopper burn symptoms. Some of the leafhopper species are known to act as vectors of plant pathogens *viz.*, viruses, phytoplasmas, spiroplasmas and bacteria.The leafhoppers are characterized by their two or more rows of spines on hind tibia and their pronotum not extending backwards over the abdomen. The characters of head, thorax, male and female genitalia, hind leg spinulation and venation of fore and hind wings are used for identifying subfamilies and tribes of the family Cicadellidae.

A number of leafhopper species infest rice crop. Correct identification of these notorious insect pests is very important for their proper management. A total of six species of leafhoppers were known from previous taxonomic studies on leafhopper fauna associated with the rice ecosystem of Kerala. Menon (1976) reported *Balclutha* sp. from Mannuthy. Abdulla (1984) reported four species of leafhoppers, *viz.*,*N. nigropictus*, *N. virescens*, *E. indicus* and *Maiestas dorsalis* from paddy fields of Thrissur district. Nair (1989) listed four species of leafhoppers from rice ecosystems of Kerala *viz., C. spectra, M. dorsalis, N. nigropictus* and *N. virescens.* Mathew (2004) in his book on "Biodiversity Documentation for Kerala" listed six species of leafhoppers from rice, namely, *C. spectra*, *Balclutha* sp., *N. nigropictus*, *N. virescens*, *E. indicus* and *M. dorsalis*. Thus only six leafhopper species had been known from rice in Kerala so far. However, Chowdhury et al. (2011) reported 19 species of leafhoppers in the subfamily Cicadellinae and Deltocephalinae, from rice ecosystems of Tripura. The leafhopper species associated with rice ecosystem in Thrissur District, Kerala is presented here.

MATERIALS AND METHODS

Extensive surveys were conducted in Kole lands of Thrissur district and paddy fields of Vadakkanchery for collecting leafhoppers associated with rice ecosystem. Leafhoppers were collected using a sweep net and aspirator. The collected specimens were oven dried (50-55^{0}C) and sorted out into glass vials with the help of a stereo zoom microscope (Bio Linkz, 45x). These were then mounted on triangular card points (3mm x 7mm) and labelled with collection data, including name of collector, date, host plant and location, before studying the general form and colouration, and dissection of abdomen. Dry mounts of wings were made by keeping both fore and hind wings in between two coverslips, which were then

kept between two gummed stickers with holes punched on it so that wings could be examined easily under microscope with transmitted light. Genitalia dissection was carried out as given by Knight (1965).

RESULTS AND DISCUSSION

A. List of species and their descriptions

Nine species of leafhoppers belonging to two subfamilies, *viz.,* Cicadellinae (Tribe: Cicadellini- 2 species) and Deltocephalinae (Chiasmini- 3 species, Deltocephalini- 1 species, Hecalini- 2 species and Stenometopiini- 1 species) were collected. Seven species of leafhoppers were collected from rice plants: *Cofana spectra* (Distant), *C. lineata* (Distant), *Nephotettix nigropictus* (Stal), *N. virescens* (Distant), *Exitianus indicus* (Distant), *Maiestas dorsalis* (Motschulsky) and *Hecalus porrectus* (Walker). Another two species, *viz., H. lutescens* (Distant) and a species of leafhopper in the genus *Doratulina* were collected from the weed *Eragrostis tenella* Linnaeus (Love grass) associated with rice ecosystem. Occurrence of *Hecalus lutescens* (Distant) is a new record for Kerala.

1. White jassid, *Cofana spectra* (Distant) (Figs. 1, 10 A)

Tettigoniella spectra Distant, 1908, Fauna of British India, Rhynchota, 4: 211

Cicadella spectra Distant, 1910, Insecta Trans.10: 234 (Praveen et al., 2014)

Tettigella spectra Evans, 1954, Memoires de I'Institut Scientifique de Madagascar. Serie A: Biologie Animale 4: 87-137

Cofana spectra Young, 1979, Proc. Entomol. Soc. Wash. 81(1): 1-21

This species of leafhopper is comparatively bigger and was collected from all the locations surveyed and during all growth stages of rice plants.

Characters: Leafhopper white with a flavous tint; vertex with four large black spots, two central, one at base and apex, other two on lateral margins near basal angles of face; muscle impressions distinct in vertex.

Male genitalia: Pygofer oval in shape, pygoferal processes absent; male subgenital plate triangular and with uniseriate row of macrosetae; style short, apex truncate; connective short and triangular; aedeagus 'U' shaped with dorsal apodemes well developed, shaft cylindrical, without processes.

Seventh sternum of female: Hind margin of female seventh sternum convex.

Measurements of ♂ and (♀) (mm): Total length including tegmen 7.21 (8.52), head, width 1.47 (1.49), vertex, width 1.21 (1.22), length 0.577 (0.578), pronotum, width 1.75 (1.76), length 0.93 (0.98), tegmen length, 6.1 (7.3), scutellum length, 0.55 (0.56)

Material examined: 4♂, 7♀, Kerala: Kanjani; sweep net ex. rice, 10.x.2015, coll. Khader, N. A.; 14♂, 18♀, Kerala: Vadakkanchery, Nettissery; sweep net, ex. rice, 22.x.2015, 25.x.2015, Khader, N. A. 10♂, 12♀, Kerala: Puzhakkal, sweep net, w2ex. rice, 23.x.2015, 11.xii.2015, Khader, N. A.

Remarks: Ayyar (1984) reported *C. spectra* as a pest of paddy in South India. Later in 1986, Rao reported occurrence of *C. spectra* in Silent Valley, Palakkad district, Kerala.

***2. Cofana lineata* (Distant)** (Figs. 2, 10B)

Kolla lineatus Distant, 1908, Fauna of British India, Rhynchota, 4: 224

Cofana lineata (Distant) Young, 1986, Taxonomic study of the Cicadellidae (Homoptera: Cicadellidae). Part 3. Old World Cicadellini. 1-639

This species of leafhopper was collected only from paddy fields of Vadakkanchery.

Characters: Anterior margin of head narrowly pointed; vertex with a black central discal spot; anterior portion of pronotum with five to six small brown spots arranged transversely; longitudinal brownish grey fascia present on pronotum; head with median pronotal black line which reach up to scutellum; wing veins and margins fuscous; three closed pre-apical cells.

Male genitalia: Pygofer trapezoidal with rounded caudo-dorsal margin, aedeagal shaft in lateral view, bulbous, apex slightly narrowed, not membranous, apodeme longer than shaft; genital plates with a number of macrosetae on lateral margin; abdominal apodemes slender, extending to mid length of fourth segment.

Seventh sternum of female: Hind margin of female seventh sternum convex.

Measurements of ♂ and (♀) (mm): Total length including tegmen, 5.19 (5.8), head, width 1.27 (1.28),

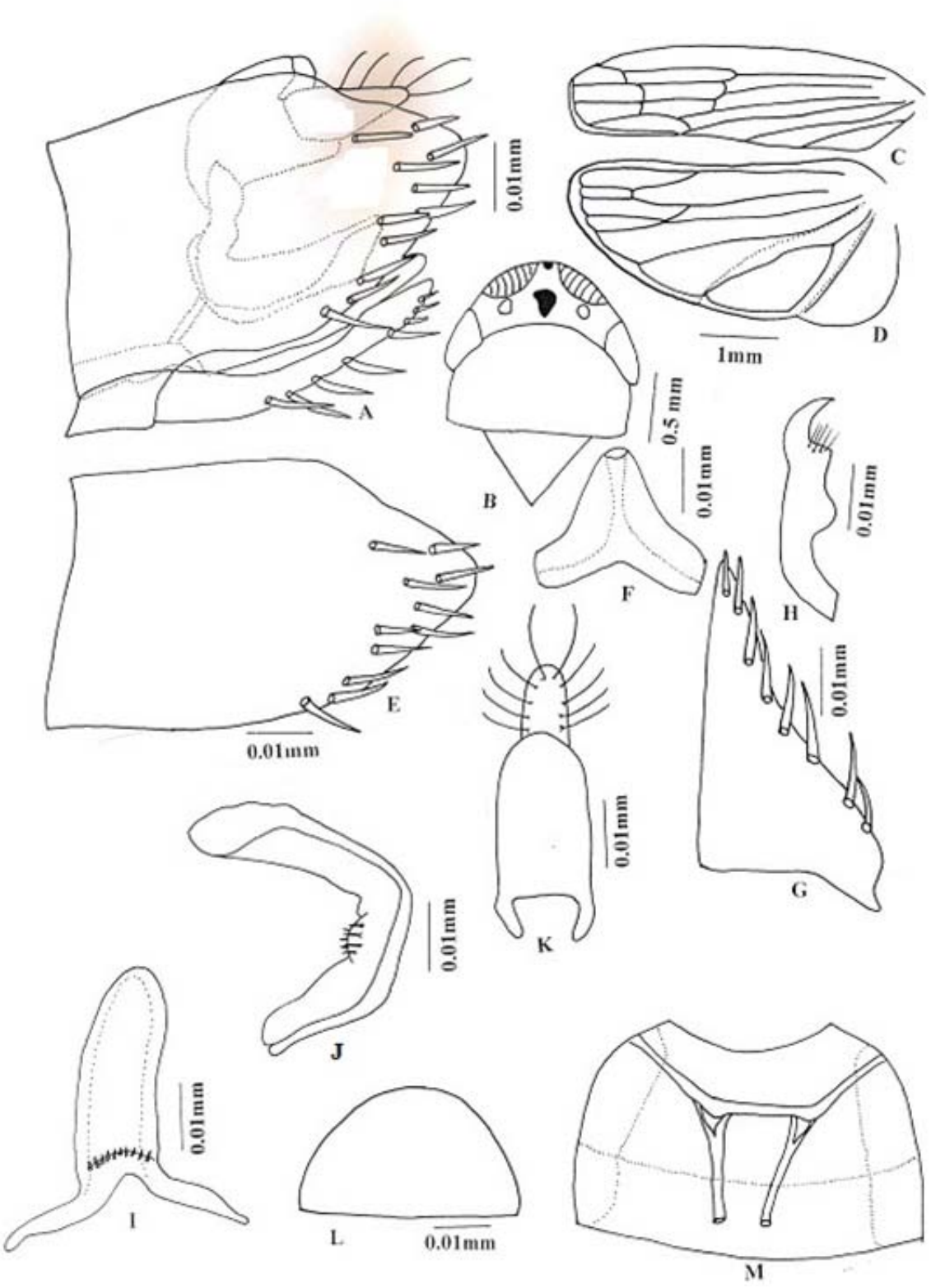

Fig. 1. *Cofana spectra* (Distant). A. genital capsule; B. head; C. fore wing; D. hind wing; E. pygofer; F. connective G. genital plate; H. genital style, lateral view; I. aedeagus, ventral view; J. aedeagus, lateral view; K. anal tube; L. female 7th sternum; M. abdominal apodemes.

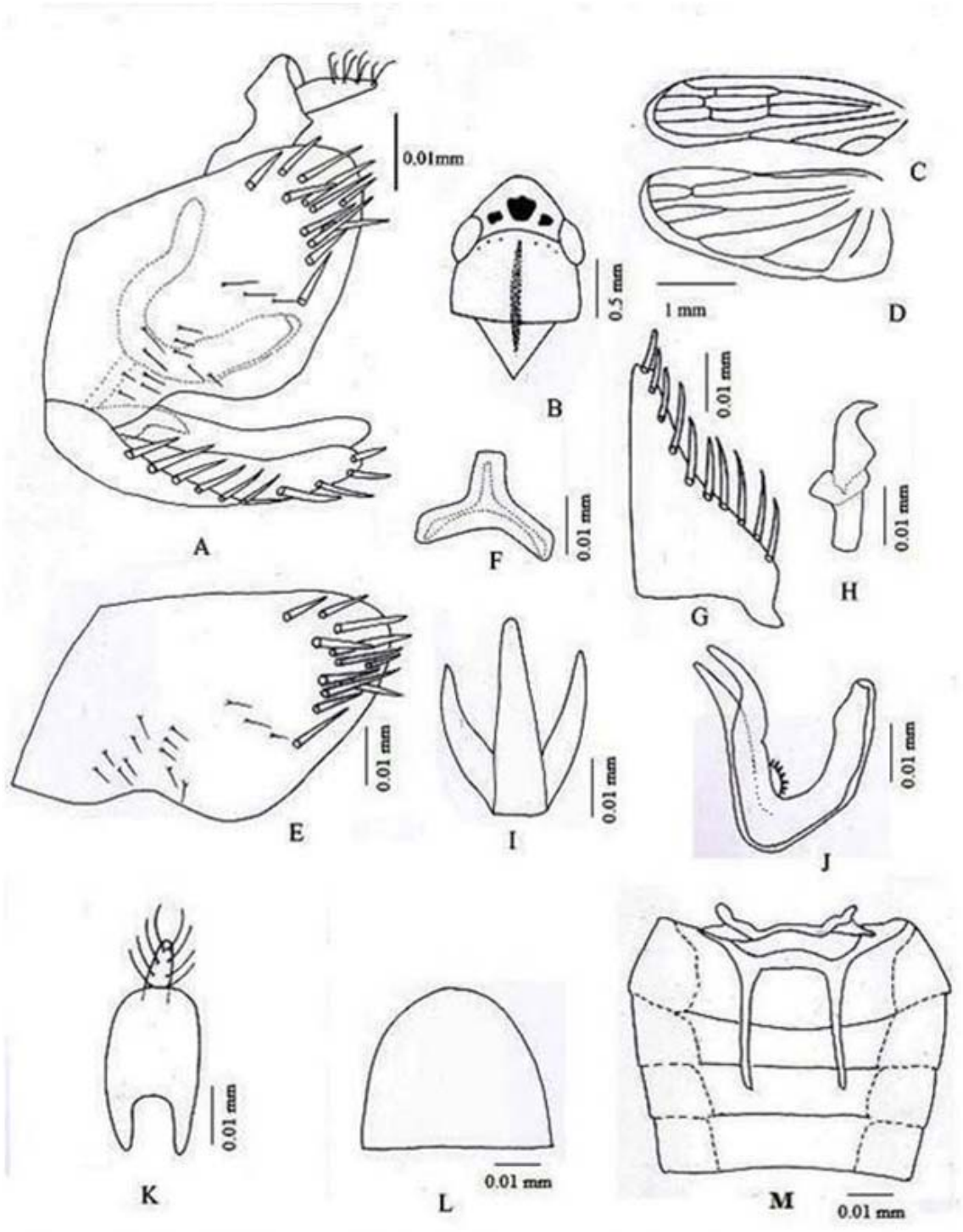

Fig. 2. *Cofana* lineata (Distant). A. genital capsule; B. head; C. fore wing; D. hind wing; E. pygofer; F. connective G. genital plate; H. genital style; I. aedeagus, ventral view; J. aedeagus, lateral view; K. anal tube; L. female 7th sternum; M. female 7th sternum

vertex, width 0.817 (0.817), length 0.691 (0.692), pronotum, width, 1.18 (1.19), length 0.853 (0.86), tegmen length, 4.76 (4.8), scutellum 0.549 (0.6).

Material examined: 1♀, 2♂ Kerala: Vadakkanchery, net sweeping; ex. rice, 22.x.2015, coll. Khader, N. A..

Remarks: *Cofana lineate* is smaller than *C. spectra* and these two species can be easily distinguished based on the markings on vertex and pronotum. This species was first reported from Kerala by Viraktamath (Mathew, 2004).

3. Rice green leafhopper, *Nephotettix nigropictus* (Stal) (Figs. 3, 10 C)

Thamnotettix nigropicta Stal, 1870a, Kongl.Svenska.Vetensk.Akad.Handl. 9 (1):740

Nephotettix apicalis sensu Distant, 1908, The fauna of British India: 360

Nephotettix apicalis sensu Ishihara and Kawasae,1968, Appl. Ent. Zool. 3(3): 119-123

Nephotettix nigropictus (Stal) Ghauri, 1971, Bull. ent. Res. 60 (3): 491

Nephotettix nigropictus is a medium sized leafhopper species. It was collected from all the locations surveyed and during all the growth stages of rice plant.

Characters: Leafhopper green; vertex with submarginal black band extending beyond ocelli to inner margin of eyes; pronotum with anterior margin black; vertex with anterior margin not rounded, a little longer medially than next to eye; forewing green with anterior black margin along commissure; discal black spot touching the claval suture in male; apical third of tegmina black, light brown in female.

Male genitalia: Pygofer with one long spine and three to four small spines, pygofer in lateral aspect with caudal margin rounded, with small lobe posteroventrally; genital plate almost triangular, short, uniseriate row of setae located submarginally; connective 'Y' shaped with arms not usually close to each other; style with apical process somewhat straight, elongate, apical margin oblique; aedeagus with shaft in ventral aspect almost straight, in lateral aspect long tube like, broad over basal two-thirds, narrowed apically with notch at apex, extreme apex somewhat swollen; dorsal carinae concave in lateral aspect with about seven pairs of spines on mid-length of shaft to near swollen apex.

Female seventh sternum: Hind margin with a notch

Measurements of ♂ and (♀) (mm): Total length including tegmen 4.3 (4.6), head, width 1.26 (1.26), vertex, width 0.721 (0.722), length 0.341(0.342), pronotum, width 1.34 (1.35), length 0.391 (0.392), tegmen length, 3.71(3.74), scutellum length, 0.44 (0.46).

Material examined: 12♂, 10♀, Kerala: Kanjani; net sweeping; ex. rice, 10.x.2015, 11.x.2015;coll. Khader, N. A.; 2♂, 4♀, Kerala: Vadakkanchery; net sweeping; ex. rice, 22.x.2015, 25.x.2015, 26.x.2015;coll. Khader, N. A.; 3♂, 6♀, Kerala: Puzhakkal, net sweeping; ex. rice, 23.x.2015, 11.xii.2015, 12.xii.2015, coll. Khader, N. A..

Remarks: Abdulla (1984) reported the occurrence of *N. nigropictus* in paddy fields of Palakkad and Thrissur district.

4. *Nephotettix virescens* (Distant) (Figs. 4, 10 D)

Selenocephalus virescens Distant, 1908, Fauna of British India, Rhynchota, 4: 291

Cicada bipunctata Fabricius, 1803, Reichard, Brunsvigae 10: 78

Nephotettix impicticeps Ishihara, 1964, Trans. Shikoku Ent. Soc. 8(2): 39-44

Nephotettix virescens (Distant) Ghauri, 1971, Bull. ent. Res. 60 (3): 484

This species of leafhopper was also collected from all the locations surveyed and during all the growth stages of rice plants.

Characters: General colour light yellowish green to green; vertex and pronotum light yellowish green, immaculate; completely unmarked vertex with a distinct transverse furrow and sloping raised submarginal area anteriorly delimited by a fine ridge, vertex much longer medially than next to eye; tegmina in males with discal spot not reaching claval suture; apical third of tegmen black.

Male genitalia: Pygofer with one long spine and three to four small spines, pygofer in lateral aspect with the caudal margin somewhat rounded; genital plate

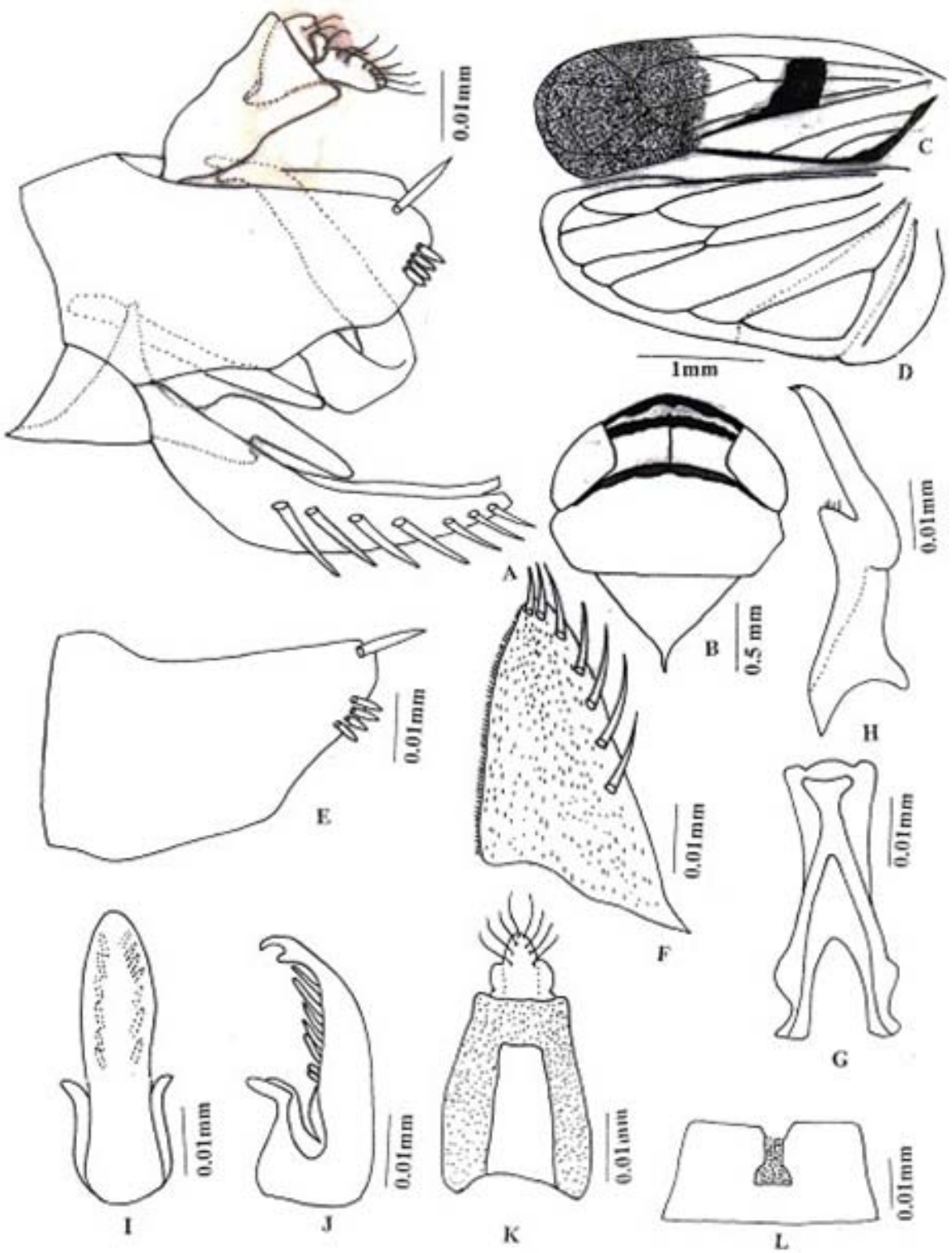

Fig. 3. *Nephotettix nigropictus* (Stal). A. genital capsule; B. head; C. fore wing; D. hind wing; E. pygofer; F. genital plate G. connective; H. genital style; I. aedeagus, ventral view; J. aedeagus, lateral view; K. anal tube; L. female 7th sternum.

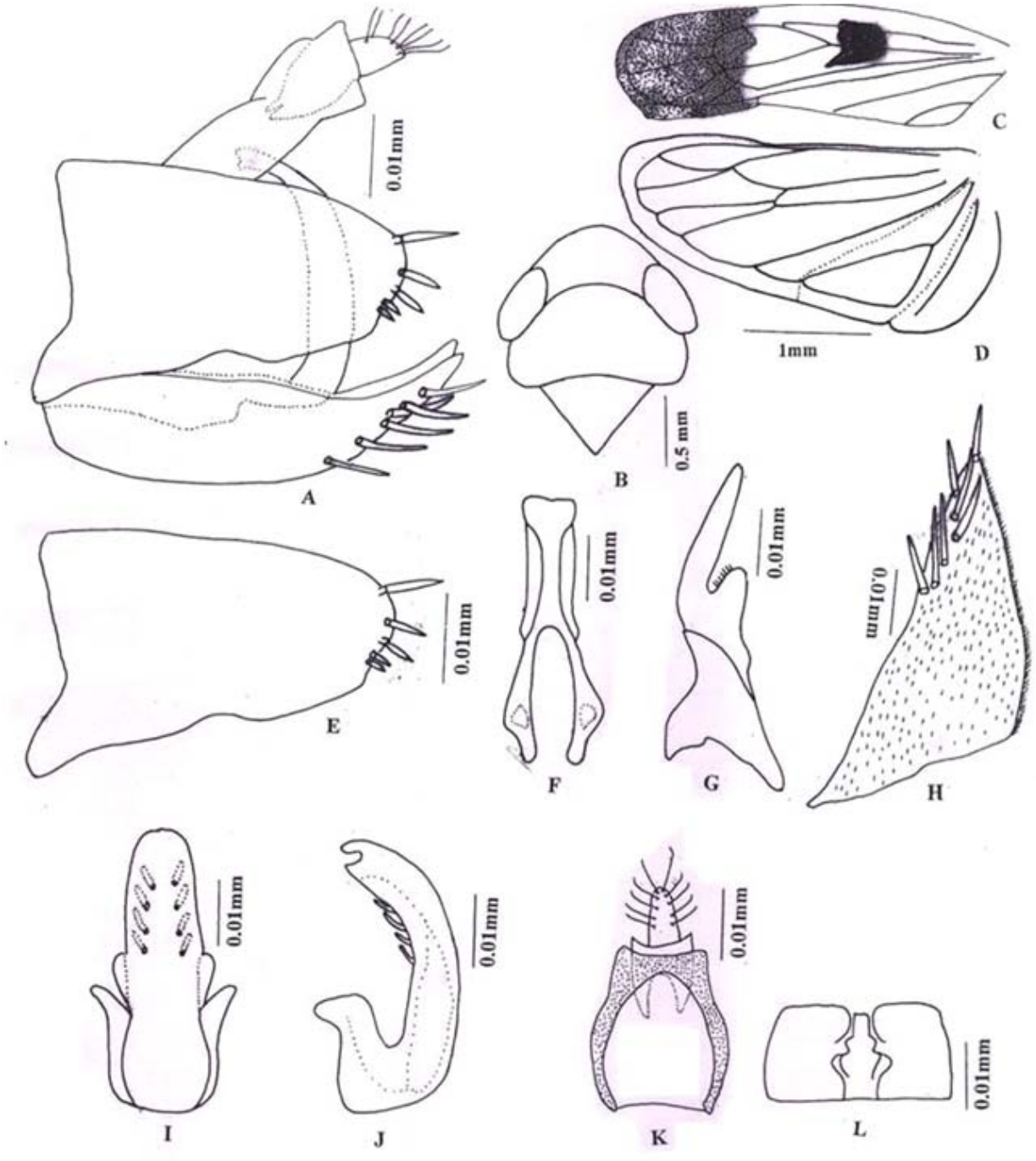

Fig. 4. *Nephotettix virescens* (Distant). A. genital capsule; B. head; C. fore wing; D. hind wing; E. pygofer; F. connective; G. genital plate; H. genital style; I. aedeagus, ventral view; J. aedeagus, lateral view; K. anal tube; L. female 7th sternum.

narrow at apex and somewhat produced with uniseriate row of spines sub marginally; connective 'Y' shaped with arms close to each other; aedeagal shaft in ventral aspect more or less constricted at mid length, tube like in lateral aspect, median paraphyses short, dorsal surface with two longitudinal row of four spines near mid length of shaft.

Female seventh sternum: Hind margin with a notch

Measurements of ♂ and (♀) (mm): Total length including tegmen 4.38 (4.72), head, width 1.12 (1.2), vertex, width 0.670 (0.68), length 0.401(0.42), pronotum, width 1.24 (1.26), length 0.502 (0.51), tegmen length, 3.66 (3.72), scutellum length, 0.536 (0.536).

Material examined: 3♂, 6♀, Kerala: Kanjani; net sweeping; ex. rice, 10.x.2015, 11.x.2015, coll. Khader, N. A.; 6♂, 10♀, Kerala: Vadakkanchery; net sweeping; ex. rice, 22.x.2015, 25.x.2015, 26.x.201, coll. Khader, N. A.; 6♂, 12♀, Kerala: Puzhakkal; net sweeping; ex. rice, 23.x.2015, 11.xii.2015, 12.xii.2015, coll. Khader, N. A.; 4♂, 8♀, Kerala: Nettissery: net sweeping; ex. rice, 26.x.2015, 28.xii.2015, coll. Khader, N. A..

Remarks: The leafhoppers, *N. nigropictus* and *N. virescens* showed variations in the number of spines in the aedeagal shaft and in the shape of central discal spot in tegmina and in *N. nigropictus* a sub marginal black band is present on vertex which is absent in *N. virescens*.This species was first reported from Kerala by Abdulla in 1984.

5. *Exitianus indicus* (Distant) (Figs. 5, 10 E)

Athysanus indicus Distant, 1908, Fauna of Br. India, Rhynchota 4: 344

Athysanus atkinsoni Distant, 1908, Fauna of Br. India, Rhynchota 4: 345

Phrynomorphus fusconervosus Distant, 1918, Fauna of Br. India, Rhynchota 7: 51

Exitianus indicus (Distant), Ross, 1968, Bull. Br. Mus. Nat. Hist., (Ent) 22:12

Exitianus indicus is a medium sized leafhopper which is very common in rice fields.

Characters: Brown; single arcuate dark line on crown; pronotum with black spots near crown; triangular faint spots present on scutellum; forewing with faint veins, three ante-apical cells.

Male genitalia: Pygofer with two spines at apex, one spine shorter and thicker than the other; six to eight macrosetae present on genital plate; anal tube chitinous; aedeagus sturdy, aedeagal shaft consists of a pair of process in its middle; aedeagus is pointed laterally, gonopore present on dorsal side; connective 'Y' shaped; apophysis of style pointed but not drawn into a spine.

Measurements of ♂ and (♀) (mm): Total length including tegmen 3.86 (3.98), head, width 1.31 (1.32), vertex, width 0.832 (0.833), length 0.293 (0.294), pronotum, width 1.17 (1.172), length 0.512 (0.513), tegmen length, 2.99 (3.31), scutellum length, 0.481(0.482).

Material examined: 1♂, 2♀, Kerala: Kanjani; net sweeping; ex. rice, 10.x.2015, 11.x.2015, coll. Khader, N. A.; 2♀, Kerala: Vadakkanchery: net sweeping ex. rice, 22.x.2015, 25.x.2015, 26.x.2015, coll. Khader, N. A., 1♂, 2♀, Kerala: Puzhakkal: net sweeping; ex. rice, 23.x.2015, 11.xii.2015, 12.xii.2015, coll. Khader, N. A.

Remarks: This species can be easily distinguished from its closely related species *E. nanus* in the number of spines on pygofer, the number of spines on the pygofer of *E. nanus* is four whereas in *E. indicus* it is two. Abdulla (1984) reported the occurrence of *E. indicus* from paddy fields of Palakkad and Thrissur district.

6. *Zigzag leafhopper, Maiestas dorsalis* (Motschulsky) (Figs. 6, 10 F)

Deltocephalus dorsalis Motschulsky, 1859, Etud. Entomol. 8: 25-118; 114

Deltocephalus dorsalis Distant, 1908, Fauna Br. India.Rhynchota 4: 380

Inazuma dorsalis (Motschulsky), Ishihara, 1953, Scientific Reports of the Matsuyama Agricultural College 11: 48

Recilia dorsalis (Motschulsky), Nielson 1968, Taxonomic relationships of leafhopper vectors of plant pathogens: 315

Recilia (Inazuma) dorsalis (Motschulsky), Kwon & Lee, 1979, Nature and Life 9 (2): 80

Maiestas dorsalis (Motschulsky), Webb & Viraktamath, 2009, Zootaxa 2163: 16

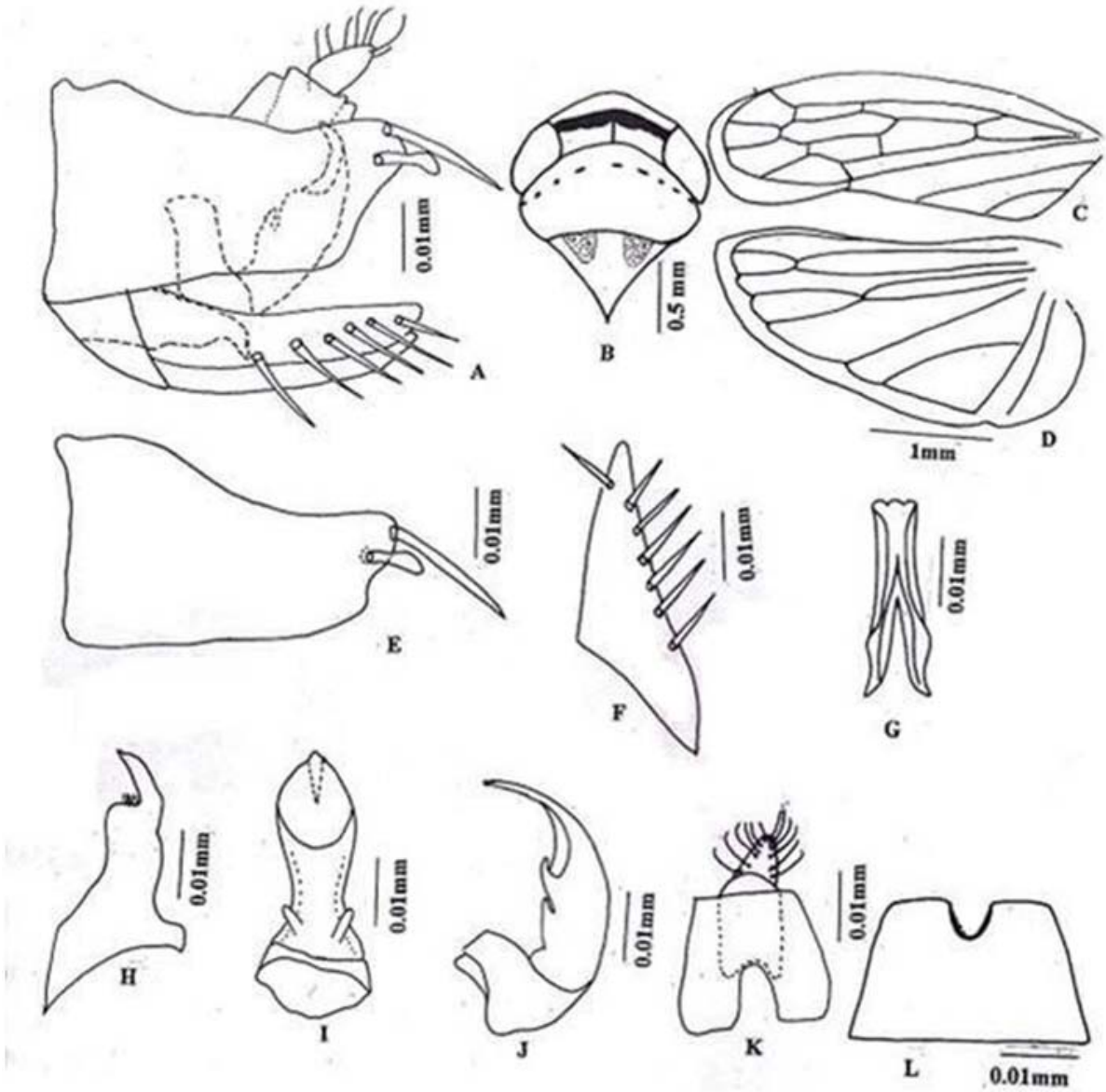

Fig. 5. *Exitianus indicus* (Distant). A. genital capsule; B. head; C. fore wing; D. hind wing; E. pygofer; F. genital plate; G. connective; H. genital style; I. aedeagus, ventral view; J. aedeagus, lateral view; K. anal tube; L. female 7th sternum.

This is a medium sized leafhopper species which is very common in paddy fields of Kerala, known as *Recilia dorsalis* earlier.

Morphological characters: Whitish leafhopper with brown zigzag markings on forewing; vertex ochraceous with a short pale brownish fascia and two short submarginal fasciae; eyes red in colour; ocelli placed on lateral margins, nearer to eyes than to apex; face broader than long; lora short, convex not reaching apex of clypellus; frontoclypeus marked with or without lateral brownish striations; scutellum small, as long as vertex, pale patches at basal angles, small brown streak on each lateral margin.

Male genitalia: Pygofer large, large setae arising from mid-dorsal region; genital plates are large and narrowed to apical region, number of setae present on lateral margin; connective 'Y' shaped, arms fused, base of the connective fused to base of the aedeagus and have the connective parallel sided throughout, aedeagal shaft long and dagger like; style large, inner limb with small curve at apex, pre-apical lobe small, apophyses long, narrow at apex.

Female seventh sternum: Short, posterior margin truncate.

Measurements of ♂ and (♀) (mm): Total length

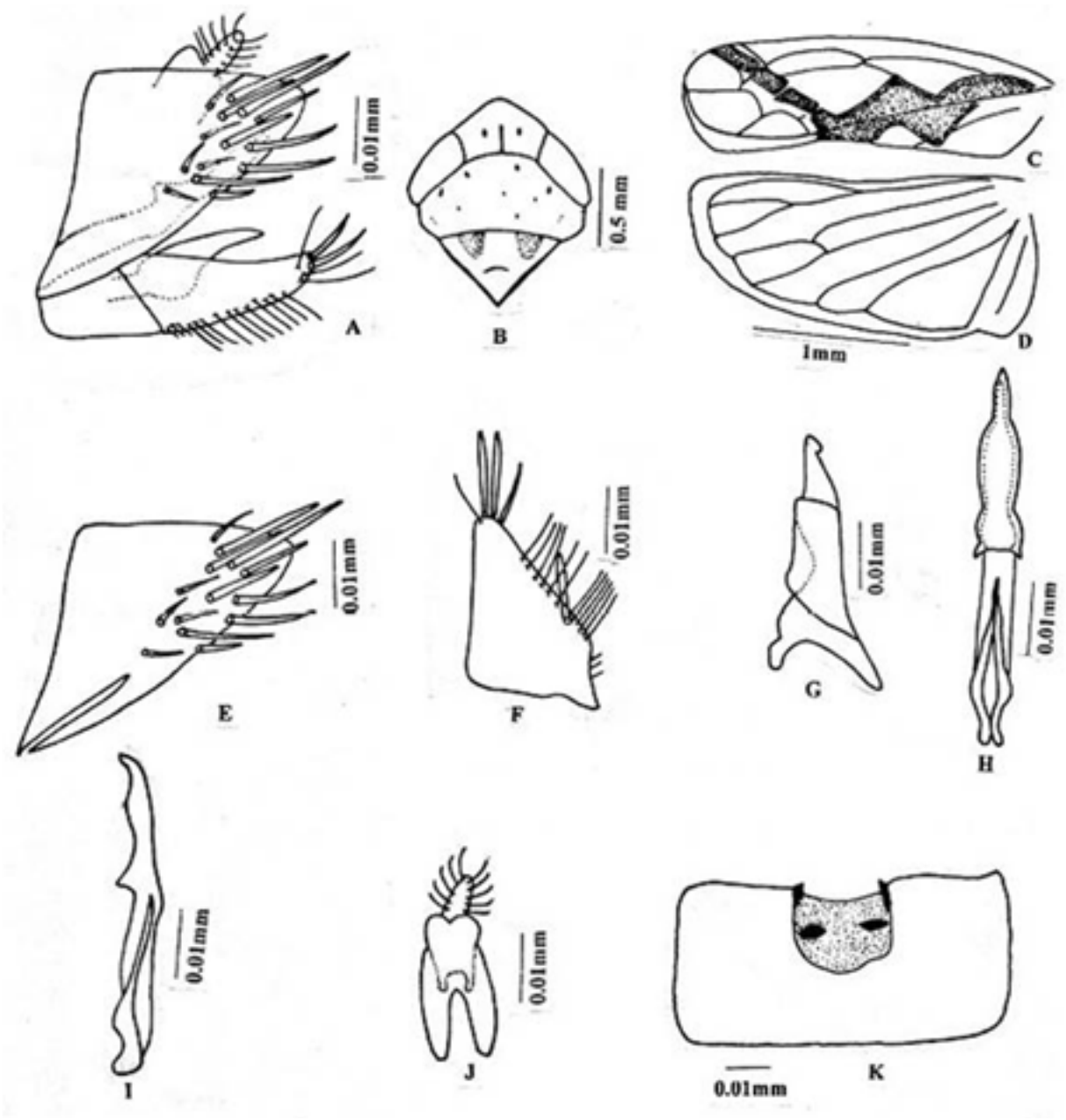

Fig. 6. *Maiestas dorsalis* (Motschulsky). A. genital capsule; B. head; C. fore wing; D. hind wing; E. pygofer; F. genital plate; G. genital plate; H. aedeagus and connective, ventral view; I. aedeagus and connective, lateral view; J. anal tube; K. female 7th sternum.

including tegmen 3.57 (3.59), head, width 0.944 (0.944), vertex, width 0.455 (0.456), length 0.386 (0.386), pronotum, width 0.924 (0.294), length 0.521 (0.522), tegmen length, 2.87 (0.288), scutellum length, 0.415 (0.416).

Material examined: 2♀, Kerala: Kanjani: net sweeping; ex. rice, 17.x.2015, coll. Khader, N. A.; 2♂, 4♀, Kerala: Vadakkanchery: net sweeping: ex. rice, 22.x.2015, coll. Khader, N. A.

Remarks: *M. dorsalis* can be easily identified based on the brownish zigzag marking on the tegmen. This species was first reported from Kerala by Abdulla (1984) from paddy fields of Palakkad and Thrissur district.

7. *Hecalus porrectus* (Walker) (Figs. 7, 10 G)

Acocephalus porrectus Walker, 1858, Supplementary list of specimens of homopterous insects in the collection of British Museum: 232

Platymetopius lineolatus Motschulsky, 1859, Etud.Ent. 8: 114

Hecalus kirschbaumii Stal, 1870b, K. SvenskaVetensk-Akad.Ofv.Forh. 27: 737

Thomsoniella kirschbaumii Signoret, 1879, Soc. Entomol. De France Ann. 9: 280

Platymetopus lineolatus Kirby, 1891, Linn. Soc. Lond. Zool. 24: 173

Thomsoniella porrecta Melichar, 1903,Verlag Von Felix L. Dames : 172

Thomsonia lineolatus Kirkaldy, 1906, Pl. Assoc. Div. Entomol. Bul. 1: 316

Thomsoniella viridis Distant, 1908, Fauna of British India, Rhynchota, 4: 280, synonymised by Morrison, 1973

Thomsoniella albomaculata Distant, 1908, Fauna of British India, Rhynchota, 4: 280

Thomsonia porrecta Esaki and Ito, 1954, Japan Society for Promotion of Science:80

Parabolocratus merino Capco, 1959, Philippine J. Sci. 88:333, synonymised by Morrison 1973.

Thomsoniella lineolata Metcalf, 1967, Agr. Res. Serv. US. Dep. Agr.: 1721

Hecalus porrectus (Walker) Morrison, 1973, Pacific Ins. 15: 421

Morphological characters: Adults, green; orange coloured longitudinal lines present on vertex and pronotum, four in number, three in scutellum; margin of vertex with transverse sub marginal fuscous line; male abdomen dark brown dorsally and mid ventrally, laterally yellow green; tegmen of male green with apical 1/3 brown, white spots in apical and anteapical cells; brown spot near clavus, three additional brown spots on apical margin; female forewings are entirely light green, dark spot at end of clavus, two additional brown spots on apical margin, hind wing hyaline.

Male genitalia: Posterior half of pygofer heavily setose, somewhat rounded, transverse brown band dorsally; genital plates dorsoventrally flattened, tapering apically, setae present on lateral side; style triangular with a thumb like projection; connective inverted 'V' in shape; aedeagus with a pair of terminal processes tapering apically, gonopore subapical, dorsal apodeme reduced.

Measurements of male (mm): Total length including tegmen 4.66, head, width 1.23, vertex, width 0.926, length 0.503, pronotum, width 1.33, length 0.633, tegmen length, 3.48, scutellum length, 0.721

Material examined: 2♂, Kerala: Kanjani: net sweeping; ex. rice, 17.x.2015, coll. Khader, N. A.; 1♂, Kerala: Vadakkanchery: net sweeping; ex. rice, 22.x.2015, coll. Khader, N. A..

Remarks: This species was reported from Silent Valley of Palakkad district by Rao (1986).

8. *Hecalus lutescens* (Distant) (Figs. 8, 10 H)

Parabolocratus lutescens Distant, 1918, Fauna of British India series 7: 31

Hecalus lutescens Morrison, 1973, Pacific Ins. 15: 419

This species of leafhopper was collected from the weed *Eragrostis tenella,* which is a rice associated weed.

Morphological characters: Leafhopper, pale yellow in colour, head and thorax pale yellow dorsally; fore wing pale yellow in colour; hind wing hyaline.

Male genitalia: Genital plates dorsoventrally flattened with five macrosetae on lateral margin; pygofersetose in posterior half and pointed apically; connective inverted 'Y' shaped; style triangular in shape, sharp thumb like projection present in style; aedeagus with two terminal projections curving dorsally, shaft laterally compressed, mid dorsal lateral expansion, gonopore apical, dorsal apodeme finger like with median bulge.

Measurements of ♂ and (♀) (mm): Total length including tegmen 5.18 (5.99), head width 1.40 (1.8), vertex, width 1.10 (1.3), length 0.687 (0.72), pronotum, width 0.70 (0.73), length 1.51 (2.1), tegmen length, 3.97 (4.3), scutellum length 0.782 (0.79).

Material examined: 2♂, 2♀, Kerala: Kanjani: net sweeping: ex. *Eragrostis tenella* L. 17.x.2015, coll. Khader, N. A.; 2♂, 2♀, Kerala: Vadakkanchery: net sweeping: ex. *E. tenella*. 22.x.2015, coll. Khader, N. A..

Remarks: Morrison (1973) reported occurrence

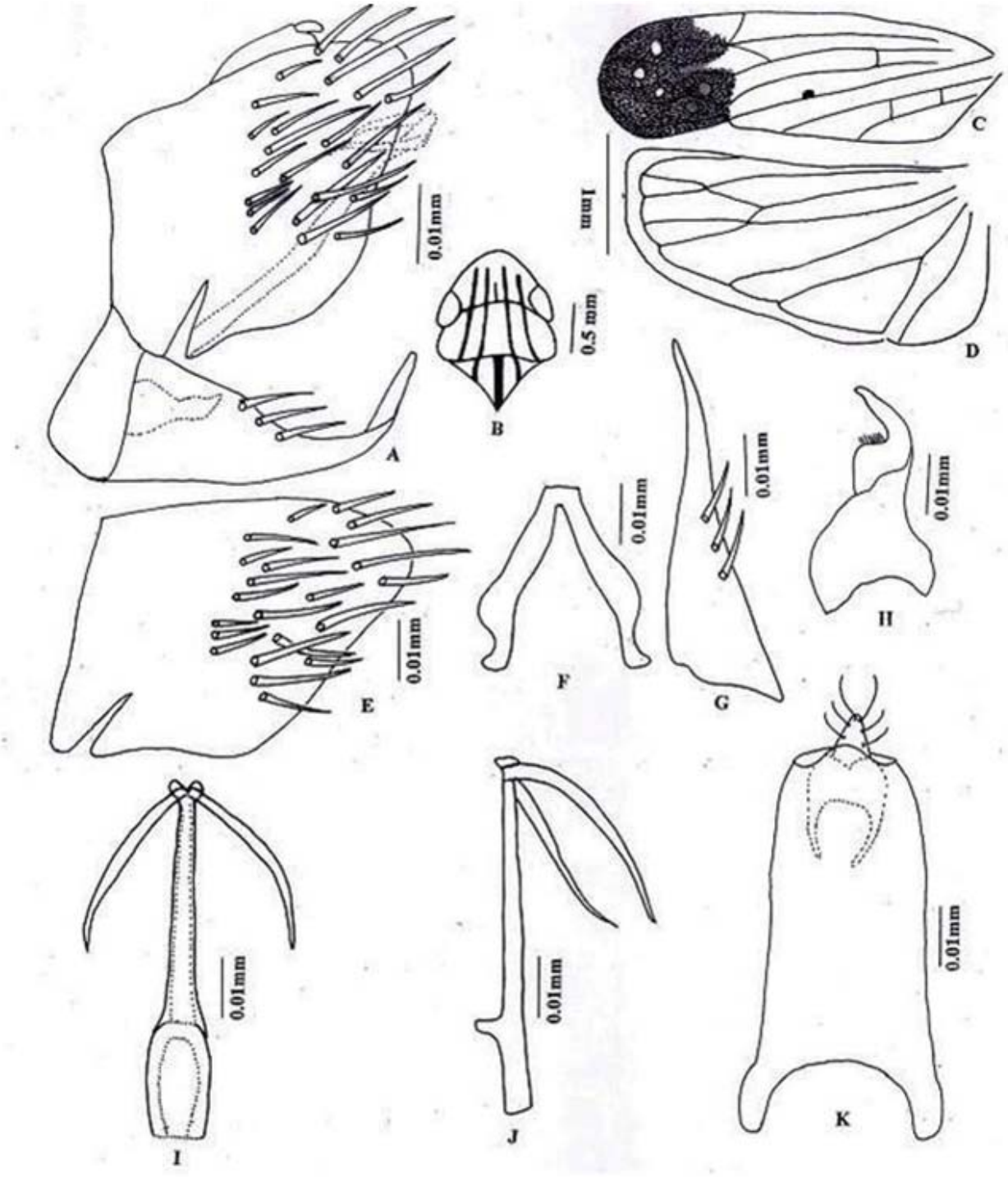

Fig. 7. *Hecalus porectus* (Walker). A. genital capsule; B. head; C. fore wing; D. hind wing; E. pygofer; F. connective; G. genital plate; H. genital style; I. aedeagus, ventral view; J. aedeagus, lateral view; K. anal tube.

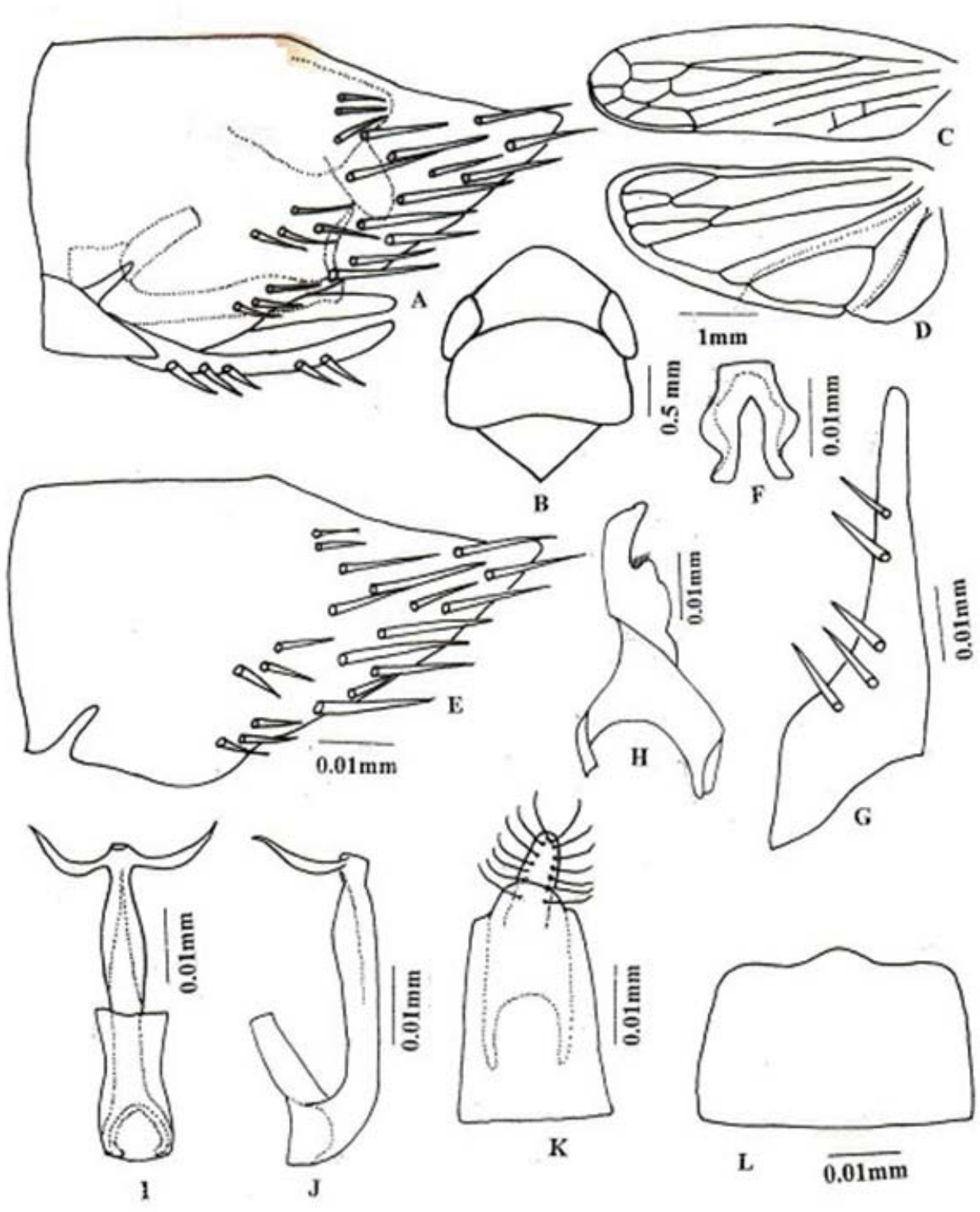

Fig. 8. *Hecalus lutescens* (Distant). A. genital capsule; B. head; C. fore wing; D. hind wing; E. pygofer; F. connective G. genital plate; H. genital style; I. aedeagus, ventral view; J. aedeagus, lateral view; K. anal tube; L. female 7th sternum.

of *H. lutescens* from India. This species is a new record for Kerala.

9. *Doratulina* sp. (Figs. 9, 10 I)

This species of leafhoppers are relatively small in size. This species was collected from the rice associated weed *E. tenella.*

Morphological characters: Pale yellowish; head triangularly produced.

Male genitalia: Pygofer large, triangular in shape, obscure small denticle on the posterior rounded margin; valve triangular; genital plate small with six macrosetae on caudal end; connective 'Y' shaped, arms well separated; style long, narrow with the apophysis turned laterad; aedeagus with well-developed dorsal apodeme, shaft long, slender, strongly recurved and attenuated to form long undulating filamentous structure reaching back beyond the basal attachment of aedeagus.

Measurements of ♂ and (♀) (mm): Total length including tegmen 2.6 (2.72), head width 0.82 (0.82), vertex width 0.418 (0.419), length 0.574 (0.575), pronotum width 0.845(0.846), length 0.453 (0.453), tegmen length, 2.1 (2.3), scutellum length 0.37 (0.38).

Material examined: 1♂, 38♀, Kerala: Kanjani; net sweeping; ex.*Eragrostis tenella* L., 17.x.2015, coll. Khader, N. A.;1♂, 20♀, Kerala: Vadakkanchery: net sweeping; ex. *E. tenella*, 22.x.2015, coll. Khader, N. A.; 1♂, 22♀, Kerala: Nettissery: net sweeping; ex. *E. tenella*, 11.xii.2015, coll. Khader, N. A.;12♀, 1♂, Kerala: Vadakkanchery; net sweeping; ex. *E. tenella*, 2.xi.2015, coll. Khader, N. A..

The present study revealed the presence of nine species of leafhoppers associated with rice ecosystem in the Thrissur District of Kerala, India. *Hecalus lutescens* is being reported as a new record for Kerala.

Earlier studies showed that *Balclutha* sp. was reported from Mannuthy by Menon (1976). Abdulla (1984) conducted taxonomic studies on the leaf and plant hoppers of paddy in Palakkad and Thrissur district of Kerala and observed four species of leafhoppers, *viz., N. nigropictus*, *N. virescens*, *E. indicus* and *Recilia dorsalis*. These four species were collected from paddy fields of Thrissur district during the present study also. In addition to this, three more species, namely, *C. spectra, C. lineata* and *H. porrectus* were also collected during this study.

Nair (1989) recorded four species of leafhoppers from rice ecosystems of Kerala *viz., C. spectra, M. dorsalis, N. nigropictus* and *N. virescens.* All these four species were collected from rice ecosystem during the present study also. In addition to these, three more species, namely, *H. porrectus, E. indicus* and *C. lineate* were added to the leafhopper fauna of rice from Kerala.

Mathew (2004) in his book on "Biodiversity Documentation for Kerala" listed six species of leafhoppers from rice. These include *C. spectra*, *Balclutha* sp., *N. nigropictus*, *N. virescens*, *E. indicus* and *M. dorsalis*. Among these, all other species except *Balclutha* sp. were collected from paddy fields of Thrissur district during the present study.

Chowdhury et al. (2011) reported 19 species of leafhoppers in the subfamily Cicadellinae and Deltocephalinae, from rice ecosystems of Tripura. Out of these 19 species, six species, *viz.,C. spectra*, *N. nigropictus*, *N. virescens*, *E. indicus,M. dorsalis* and *H. porrectus* were collected during the present study also.

Occurrence of *H. lutescens* (Distant) in rice ecosystem is a new report for Kerala. *Cofana lineata* and *H. porrectus* are new records on rice in Kerala.

The present study reported three more species of leafhoppers associated with rice ecosystem. The two species, namely, *C. lineata* and *H. porrectus* were previously reported from Kerala by Mathew (2004) without host plants, probably collected from light traps. This shows that systematic survey all over Kerala might yield more leafhopper species.

B. Key to the species from rice ecosystems of Thrissur district, Kerala

1. Lateral facial sutures extending over margin and well on to crown, almost reaching ocelli which are large and remote from eye; lateral margin of pronotum with a weak keel……...**Cicadellinae: Cicadellini**……..……..……2

   Lateral facial sutures not or briefly extending on to crown; ocelli more central in position; lateral margin of pronotum widely and sharply keele.....**Deltocephalinae**…...……..3

2. Vertex with a black central discal spot; longitudinal brownish grey fascia present on pronotum (A1);

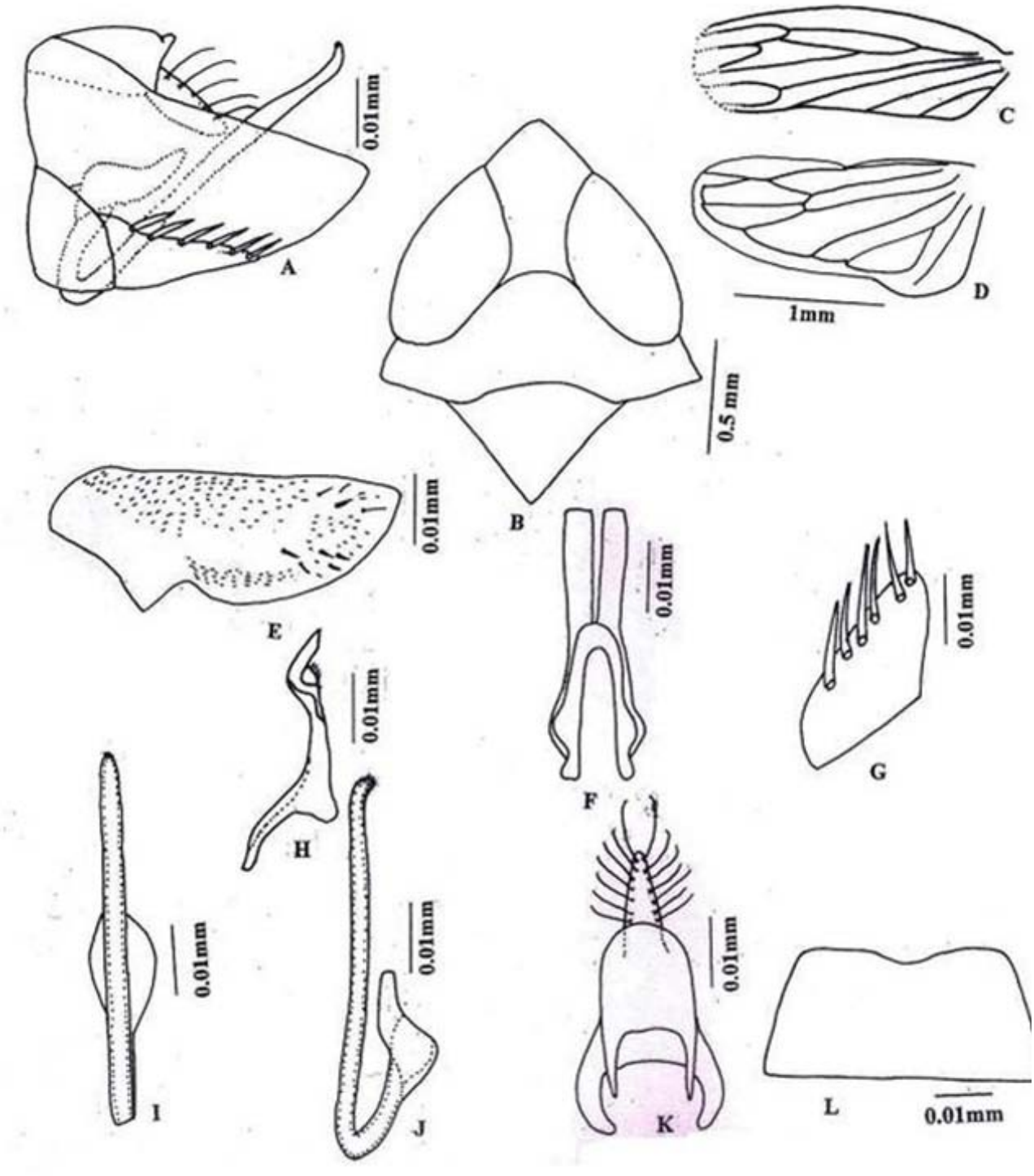

Fig. 9. *Doratulina* sp.. A. genital capsule; B. head; C. fore wing; D. hind wing; E. pygofer; F. connective G. genital plate; H. genital style; I. aedeagus, ventral view; J. aedeagus, lateral view; K. anal tube; L. female 7th sternum;

A. *Cofana spectra* B. *Cofana lineata* C. *Nephotettix nigropictus* D. *Nephotettix virescens*

E. *Exitianus indicus* F. *Maiestas dorsalis* G. *Hecalus porrectus* H. *Hecalus lutescens* I. *Doratulina* sp

Fig. 10 (A-I): Leafhoppers collected from rice ecosystem

aedeagal shaft in lateral view bulbous, apex slightly narrowed, apodemelonger than shaft ……***Cofana lineata*** **(Distant)**

Vertex with four large black spots; pronotum without brownish grey fascia; aedeagus with dorsal apodemes well developed, shaft cylindrical ……***Cofana spectra*** **(Distant)**

3. Male genitalia with connective fused with aedeagus (A3)…..**Deltocephalini**...……..***Maiestas dorsalis*** **(Motschulsky)**

Male genitalia with connective articulated with aedeagus……...…4

4. Macropterous to brachypterous, if macropterous, forewing appendix small and not extending around apex; aedeagus not movably hinged; ovipositor length variable……5

- Macropterous to brachypterous, if macropterous, forewing appendix large, extending around forewing apex; aedeagus movably hinged between base and apex or with hinged ventral appendage; ovipositor extending well beyond pygofer apex……..**Chiasmini**.....7

5. Crown narrow, width between eyes about same as or less than median width of eye; crown completely shagreen to base; pronotum lateral margin not carinate; male pygofer declivous directed postero ventrally with few macrosetae; ovipositor extending far beyond pygofer; first valvulae with distinctly delimited ventroapical sculptured area; second valvulae without teeth……**Stenometopiini**…….. …..…..***Doratulina*** **sp.**

Crown not narrow, crown texture usually glabrous or striate posteriorly; pronotum lateral margin carinate; male pygofer shape variable; ovipositor not protruding far beyond pygofer apex; second valvulae with teeth……**Hecalini**……6

6. Posterior half of pygofer heavily setose and pointed apically; aedeagus with two terminal projections curved dorsally, shaft laterally compressed with mid-dorsal lateral expansion (A4); pale yellow in colour……***Hecalus lutescens*** **(Distant)**

Four longitudinal orange coloured lines on vertex and pronotum (A6); posterior half of pygofer heavily setose but not pointed (A5); aedeagus with a pair of terminal process, sub equal, tapering apically, shaft without mid-dorsal lateral expansion; green in colour ……...***Hecalus porrectus*** **(Walker)**

7. Predominantly green species with apex of tegmen black…….....……8

Not with above combination of characters, usually brown in colour……...***Exitianu sindicus*** **(Distant)**

8. Tegmina in males with discal black spot touching the claval suture; vertex with a submarginal black band (A7); connective 'Y' shaped with arms not usually close to each other; about seven pairs of spines on mid-length of shaft to near swollen apex (A8)…….***Nephotettix nigropictus*** **(Stal)**

Tegmina in males with discal black spot not reaching claval suture; vertex completely unmarked (A9); connective 'Y' shaped with arms close to each other; with two longitudinal rows of four spines near mid length of aedeagal shaft (A10). ……***Nephotettix virescens*** **(Distant)**

9. Predominantly green species with apex of tegmen black……..….8

- Not with above combination of characters, usually brown in colour…....***Exitianus indicus*** **(Distant)**

10. Tegmina in males with discal black spot touching the claval suture; vertex with a submarginal black band (A7); connective 'Y' shaped with arms not usually close to each other; about seven pairs of spines on mid-length of shaft to near swollen apex (A8)……..***Nephotettix nigropictus*** **(Stal)**

Tegmina in males with discal black spot not reaching claval suture; vertex completely unmarked (A9); connective 'Y' shaped with arms close to each other; with two longitudinal rows of four spines near mid length of aedeagal shaft (A10). …… .....……***Nephotettix virescens*** **(Distant)**

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RECORDS OF *RHINYPTIA* SPP. (SCARABAEIDAE) FROM MAHARASHTRA

S. M. DADMAL AND SUVARNA KHADAKKAR*

Department of Entomology, Dr Panjabrao Deshmukh Krushi Vidyapeeth, Akola 444104
**Email: suvarnask17@gmail.com (corresponding author)*

ABSTRACT

Survey conducted on scarabaeids in Maharashtra during 2012-13 led to collection of beetles belonging to the genus *Rhinyptia*. These were studied along with previously preserved specimens for their taxonomic characters. This led to identification of *Rhinyptia indica* and *R. nigrifrons* along with an indetermined species. The manuscript include illustrations of salient morphological characters including male genitalia.

Key words: White grubs, Scarabaeidae, Rutelinae, *Rhinyptia indica, R. nigrifrons*, redescriptions, male genitalia

The species of the subfamily Rutelinae of Scarabaeidae can be distinguished by the unequal claws, with larger one being either cleft at the tip or not cleft, lobed beneath, or distorted in shape (Arrow, 1917). Adults are usually 10-16 mm long, dull brown, or yellowish, or in shades of green, darker, and some with stripes. Of these, the members of the genus *Rhinyptia* are easily recognizable by its clypeus anteriorly extending into a rostrum and strongly recurved. Arrow (1917) gave a detailed account of its species from the erstwhile British India, while Machatschke (1971) added some more details. The larval stage of *Rhinyptia* spp. are pests and had been known to occur throughout India on *bajra* (Singh *et al*., 1970; Pal, 1974; Pal and Sharma, 1974; Yadava *et al*., 1975) or pearl millet (Mitharwal *et al*., 2007) and ramie (Pandit, 1995). The present study provides details of occurrence of its three species from Maharashtra along with redescriptions.

MATERIALS AND METHODS

Field surveys were done in various agroclimatic zones of Maharashtra during 2012-2013 by the Department of Entomology, Dr. PDKV, Akola. The specimens were collected by hand picking and with light traps, and processed and labeled. These specimens were compared with the available *Rhinyptia* specimens in the NPIB- ICAR Lab of Department of Entomology, Dr. PDKV, Akola, and the morphological characters including genitalia illustrated.

RESULTS AND DISCUSSION

Redescriptions

1. Rhinyptia indica Burmeister

Ochraceous yellow, ovate, shining, body glabrous on the dorsum, provided with elongate, yellowish setae on the sides and on the vertex (Fig. 1A). Forehead dark brown, clypeus anteriorly extends into a rostrum, strongly recurved anteriorly, rounded at the ends laterally, with a strong mid carina, black. Vertex punctate, blackish. Eyes large and prominent. Antenna 9 segmented with a 3 segmented club, first segment elongated with fringes of hairs, second globular, third to fifth elongated, sixth rather small, globular, seventh to ninth form the club with scattered hairs; maxillary palp first segment elongated, rounded at the apex, second segment bears hairs along the apical margin. Mandibles with bifurcated tooth.

Pronotum uniformly and finely punctate, broadest at the centre and rounded towards the sides with hairs along the lateral margin, lateral margins smooth, scutellum finely punctured, flat, less narrowly angulate at the posterior end with smooth sides. (Fig. 1B,D). Foreleg with a much slender femur, foretibia tridentate, with a slightly elongate proximal tooth, forming acute angle with the middle tooth, inner foretibial spine placed above the basal tooth, a carina on the midline, feebly punctate, the inner claw bifurcated, outer simple (Fig. 1C,F); metatibia and hind tibia with three spiral rows of spines ventrally, dark brown, dorsally spines scattered and with a crown of short spines at the ventral end of tibia and apart from two terminal tibial spines, unequal in length, feebly pointed, two claws simple; and hind femur broader than long.

Elytra with four equidistant costae, punctate anteriorly, less densely punctate on the posterior half, with row of hairs along the lateral margin. Six visible ventral sclerites, ventral thoracic sclerites with setae

(Fig. 1E); with pygidium finely and uniformly punctate, relatively broader in males than in females, more sharply triangular in females.

Male genitalia with spiculum gastrale 'T' shaped, with two arms and two oval sclerites, one above each arm. Sclerites with a fringe of hairs distally (Fig. 1H). Aedegus with a phallobase and a compact tubular, fused paramera; distal tube elongate, 4x longer than phallobase, broad at the base, blunt and rounded and divided only at the tip, slightly narrow at the middle. Parameres with basal half slightly broader than anterior and bulged dorsally, fused ventrally, less sclerotised in the middle, gonopore placed at the tip and roughly triangular. The distal part of the tube darker along the edges, dorso-ventrally compressed, expanded by about ¼ the length to form a keel on either side, that end abruptly (Fig. 1 G,I).

Specimens examined: Maharashtra: Akola, 30.ix.2007 (5♂, 5♀), K D Bisane & P N Dawane.

Remarks: Differs from *R. nigrifrons* and *Rhinyptia* sp. (indet.) in the presence of a strong mid carina, black, elongated proximal tooth of foretibia with foretibial spine placed above the basal tooth, metatibia and hindtibia with 3 spiral rows of spines ventrally and presence of four equidistant costae on elytra. In male genitalia, distal tube 4x as long as phallobase, with a keel on either side on distal end.

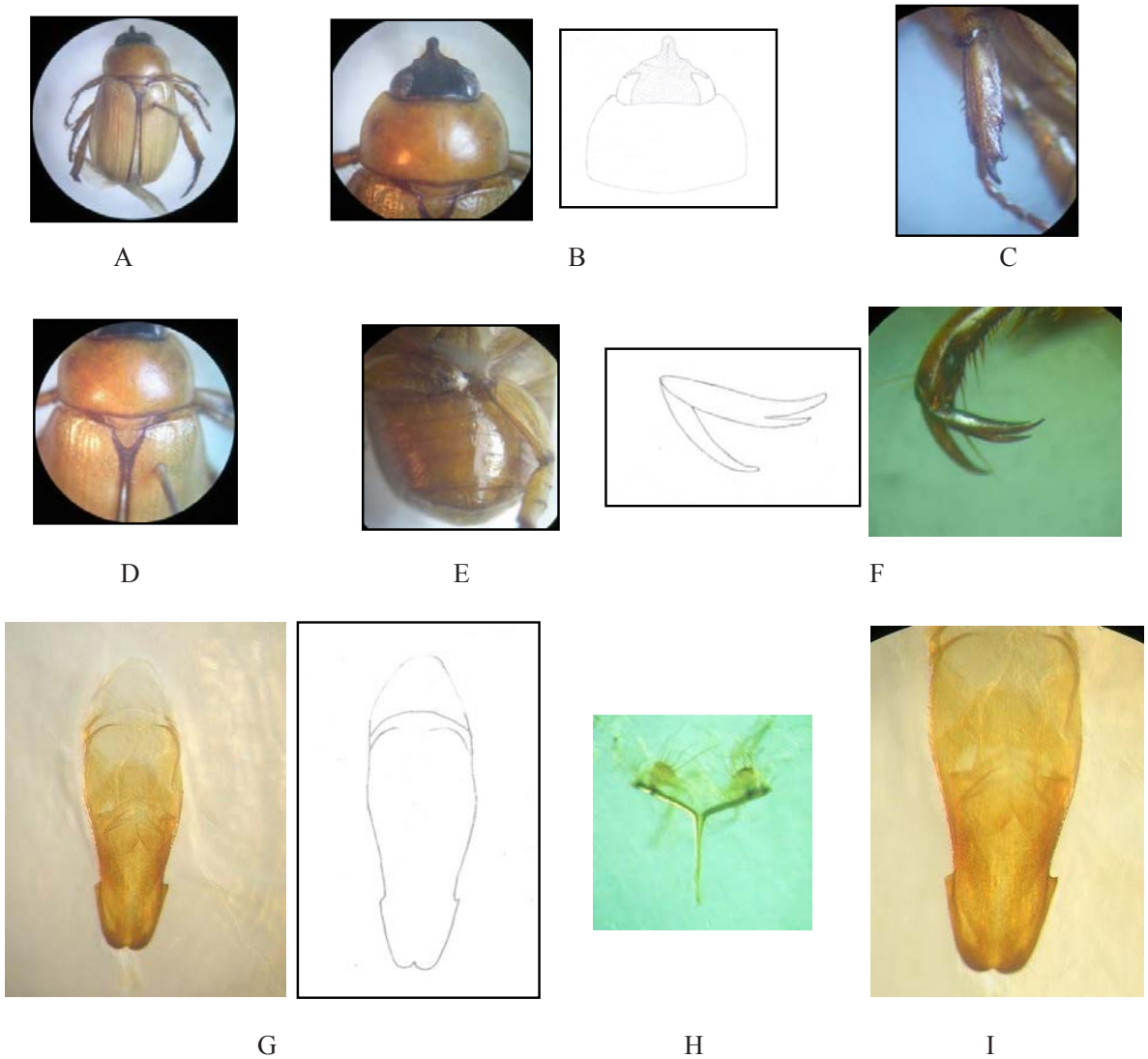

Fig. 1. Morphological and anatomical characteristics of *Rhinyptia indica* (♂): A-Dorsal view, B-Pronotum, C-Foretibia, D-Scutellum, E-Ventral sclerites, F-Hind tibial claw, G–Aedeagus: Dorsal view, H–Spiculum gastrale, I–Aedeagus(magnified)

2. Rhinyptia nigrifrons Kraatz

Colour pastel yellow, shining, ovate, and median suture not dark. Body glabrous on the dorsum with setae on vertex laterally. Clypeus anteriorly extends into a pale brownish rostrum, strongly recurved and narrowed anteriorly with a strong mid carina extending from middle of the forehead between the eyes towards entire length of the rostrum (Fig. 2A). Vertex feebly punctate. Clypeus feebly punctate. Eyes large and prominent. Antenna 9 segmented with 3 segmented club, first segment elongated, second globular, third to fifth elongated, sixth very small, globular, seventh to ninth form the club. Maxillary palp first segment elongated, rounded at the apex, second segment bears hairs along the apical margin. Mandibles with bifurcated tooth.

Pronotum uniformly and feebly punctate. Scutellum punctate only at the anterior margin. Median suture pale brown. Foreleg with a slender femur; tarsi yellowish; tibia tridentate, with a blunt proximal tooth, inner foretibial spine placed at same length as that of the basal tooth (Fig. 2D), and feebly punctate; inner claw forked, outer simple. Middle and hind tibia with two spiral rows of spines (Fig. 2E), spines smaller, dark brown, with sparse short spines at the ventral

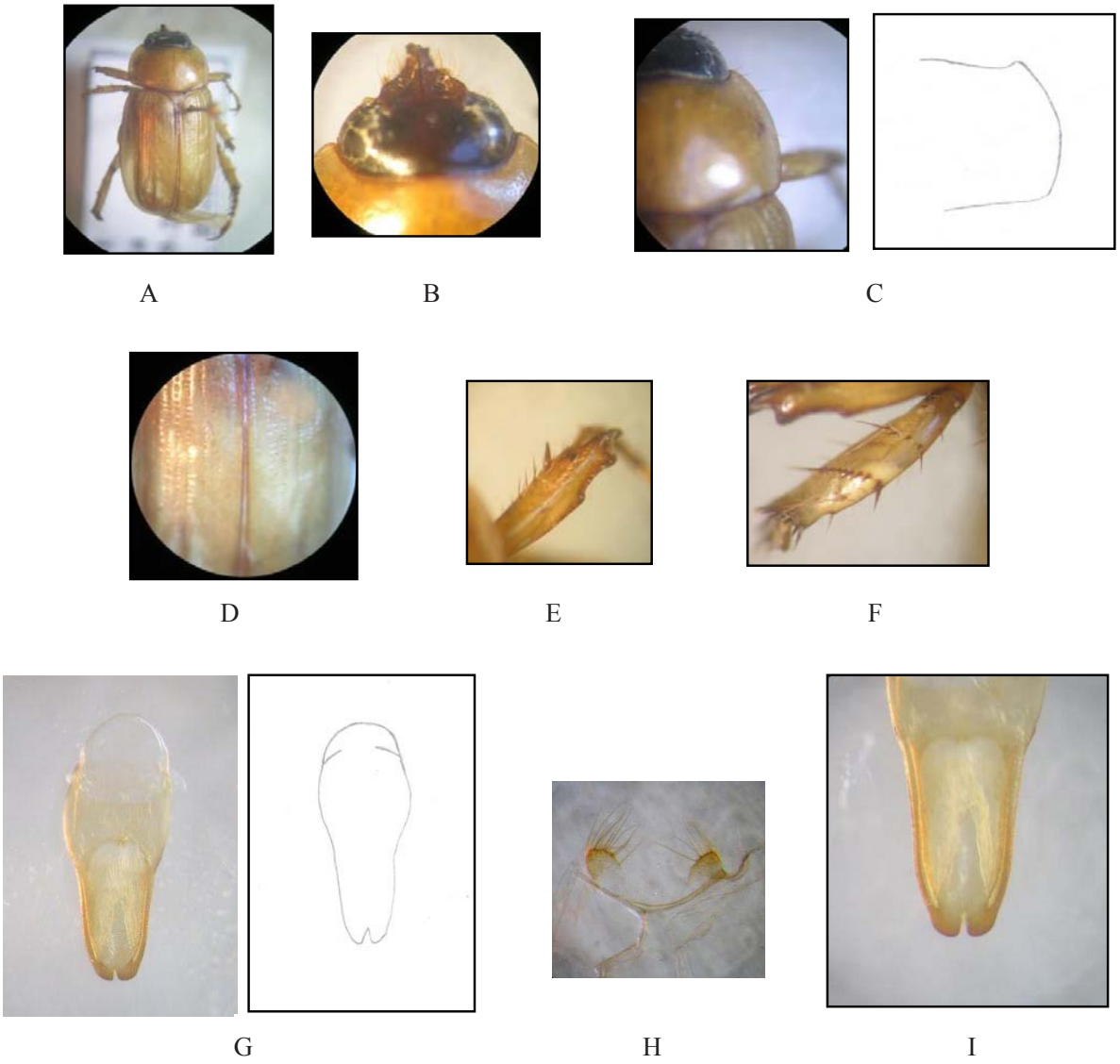

Fig. 2. Morphological and anatomical characteristics of *Rhinyptia nigrifrons* (♂): A-Dorsal view, B–Clypeus, C-Pronotum, lateral view, D-Elytra, E-Foretibia, F-Hindtibia, G–Aedeagus, Dorsal view, H–Spiculum gastrale, I–Aedeagus (magnified)

end of tibia; tibial spurs unequal in length, feebly pointed (Fig. 2F), two metatibial and hindtibial claws simple. Hind tibial spine elongated and pointed in males while blunt and stout in females.

Elytra with three costae, middle costae broad, feebly punctate; glabrous laterally. Six visible ventral sclerites (Fig. 2G), ventral thoracic sclerites with setae. Pygidium finely and uniformely punctuate (Fig. 2H).

Male genitalia with phallobase broad at base, parameres fused ventrally, less sclerotised in middle than the edges, elongate, 3x longer than phallobase, broad at the base, blunt, rounded, narrowed and divided

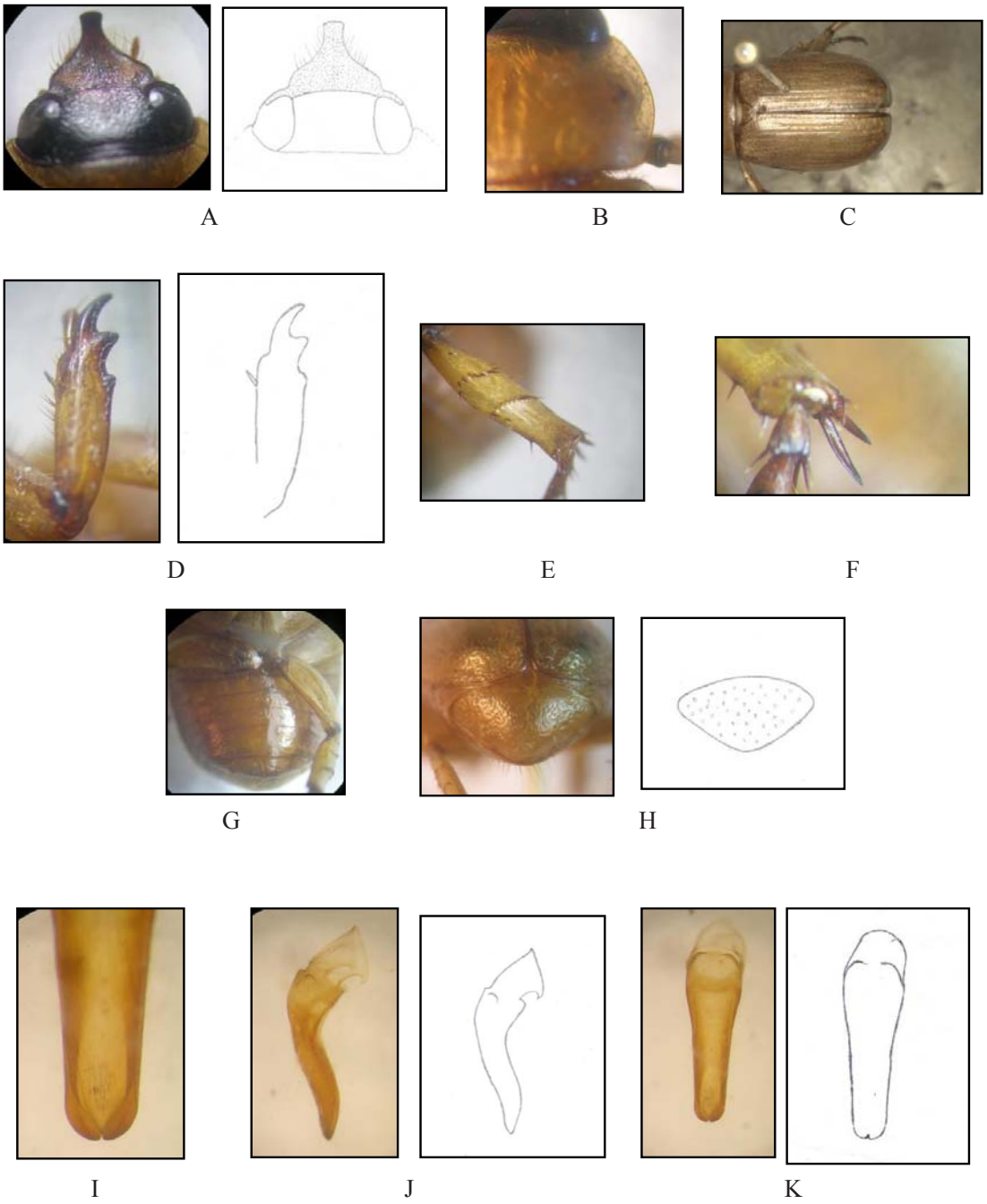

Fig. 3. Morphological and anatomical characteristics of *Rhinyptia* sp. indet. (♂): A-Forehead, B-Pronotum, C-Elytra, D-Foretibia, E-Hindtibia, F-Hind tibial spines, G–Ventral sclerites, H-Pygidium, I–Aedeagus, J-Aedeagus, Lateral view, K-Aedeagus, Dorsal view

only at the tip (Fig. 2I). Gonopore placed at the tip, less elongated, small. Distal part of the tube shows two tips of parameres prominently.

Specimens examined: Maharashtra: Akola, 30. ix.07 (1♂, 1♀), K D Bisane.

Remarks: Differs from *R. indica* and *Rhinyptia* sp. (indet.) in the absence of mid carina, blunt proximal tooth of foretibia, foretibial spine placed at the same length of the basal tooth, metatibia and hindtibia with 2 spiral rows of spines ventrally and presence of 3 costae on elytra, and with middle costae broad; in male genitalia, distal tube stout, and significantly bifurcated on distal end.

3. Rhinyptia sp. (indetermined)

Colour plae golden yellow, shining, ovate. Body glabrous on the dorsum with setae on vertex laterally. Forehead pale brown, clypeus anteriorly extends into a rostrum strongly recurved and narrowed anteriorly with a strong mid carina extending from middle of the forehead between the eyes towards entire length of the rostrum (Fig. 3A). Vertex strongly punctate, blackish, pastel brown in middle. Eyes large and prominent. Antenna 9 segmented with 3 segmented club, first segment elongated, second globular, third to fifth elongated, sixth very small, globular, seventh to ninth form the club. Maxillary palp first segment elongated, rounded at the apex, second segment bears hairs along the apical margin. Mandibles with bifurcated tooth.

Pronotum uniformely and finely punctate, lateral margin smooth with 4 to 5 yellowish elongated setae laterally (Fig. 3B). Scutellum feebly punctated only at the anterior margin, flat, narrowly angulate posteriorly with smooth sides. Foreleg with a slender femur; tibia tridentate, with a elongate proximal tooth forming acute angle with the middle tooth, inner tibial spine placed at same length as that of the basal tooth (Fig. 3D); feebly punctate; inner claw forked, outer simple. Metatibia and hind tibia with two spiral rows of spines (Fig. 3E), spines smaller, dark brown and with sparse short spines at the ventral end of tibia; tibial spurs unequal in length, feebly pointed (Fig. 3F), and claws simple.

Elytra with three costae, middle costae broad, feebly punctate; glabrous laterally. Six visible ventral sclerites (Fig. 3G), ventral thoracic sclerites with setae. Pygidium finely and uniformly punctuate (Fig. 3H).

Male genitalia with phallobase broad at base. Parameres fused, elongate, 4x as long as phallobase, broad at the base, blunt, rounded, narrowed and divided only at the tip (Fig. 3I); ventrally fused, less sclerotised in middle than the edges. Gonopore placed at the tip, more elongated and oval. Distal part of the tube darker along the edges and dorsoventrally compressed.

Specimens examined: Maharashtra: Karjat (Kokan), 06.xii.12 (3♂, 1♀), S M Dadmal.

Remarks: Differs from *R. indica* and *R. nigrifrons* in elongated proximal tooth of foretibia forming acute angle with the middle tooth, foretibial spine placed at the same length of the basal tooth, metatibia and hindtibia with 2 spiral rows of spines ventrally and presence of 3 costae on elytra, middle costae broad. External male genitalia with distal tube elongated and slender, and 4x as long as phallobase.

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FIELD EFFICACY OF NEW INSECTICIDES AGAINST APPLE WOOLLY APHID *ERIOSOMA LANIGERUM* (HAUSMANN)

JOGINDER SINGH AND SUSHMA BHARDWAJ

Dr. Y. S. Parmar University of Horticulture and Forestry, Regional Horticultural Research and Training Station, Mashobra, Shimla, Himachal Pradesh 171007
Email: drjsverma@yahoo.com

ABSTRACT

The woolly aphid, *Eriosoma lanigerum* (Hausmann) (Aphididae: Homoptera) on apple, a key pest was studied in its aerial form for field efficacy of five insecticides namely spirotetramat (Movento150OD)- 0.009, 0.012, 0.015%, flupyradifurone (Sivanto 200SL)- 0.02, 0.03, 0.04%, thiamethoxam (Thomson 25WG)- 0.012, 0.025% and flonicamid (Ulala 50WG)- 0.20, 0.30, 0.40%. These were compared with chlorpyriphos (Dursban 20 EC) 0.04%. The field trial was conducted during October- November of 2015 in apple orchards at Regional Horticulture Research and Training Station, Mashobra. The results revealed that all the treatments were superior, and 21 days after spray, chlorpyriphos (0.04%) and thiamethoxam 25WG (0.025%) were the best with zero infestation; but these were statistically at par with flupyradifurone (0.03 and 0.04%. Spirotetramat was observed to be the least effective. All the insecticides proved safe as regards phytotoxic symptoms.

Key words: Apple woolly aphid, aerial form, spirotetramat, flupyradifurone, thiamethoxam, flonicamid, chlorpyriphos, phytotoxicity

Apple, the most important fruit crop in Himachal Pradesh is attacked by a large number of insect pests, of which the woolly aphid, *Eriosoma lanigerum* (Hausmann) is the key pest. Both adults and nymphs suck cell sap from aerial as well as subterranean parts in nurseries and in grown up trees, weakening the plants and affecting growth and yield. Its biology and movement behaviour had been studied (Bhardwaj *et al*., 1995). Studies indicated movement from root to shoot and shoot to root exhibited by the first instar aphids and maximum movement was recorded during mid June, followed by October. Its maximum population was observed during November-December (Thakur, 1970). Aphid overwinters as adult or nymph on rootstocks and crown in the soil (Kim *et al*., 2009).

A large number of contact or systemic insecticides like endosulfan, methyl parathion, fenitrothion, phosphamidon, dimethoate and chlorpyriphos had been recommended against aerial populations of this aphid (Thakur and Dogra, 1980). Some new molecules like neonicotinoids with mode of action differing from that of organophosphate and carbamates are now known to be effective against such sucking pests (Angelini and Lazzarini, 1997; Lacombe, 1999; Nakano et al., 1999). The present study, evaluates few new insecticide molecules against aerial forms of apple wooly aphid in Himachal Pradesh.

MATERIALS AND METHODS

Field trial was carried out in apple orchard at the Regional Horticultural Research and Training Station, Mashobra, Shimla. The trial was laid in randomized block design on 10-15 years old apple trees of variety 'Red Fuji'. The treatments included: spirotetramat 150 OD (0.009, 0.012, 0.015%), flupyradifurone 200 SL (0.02, 0.03,0.04%), thiamethoxam 25 WG (0.0125, 0.025%), flonicamid 50% WG (0.2, 0.3, 0.4%) and chlorpyriphos 20 EC (0.04%); these compared as foliar application against the aerial populations, at post harvest stage i.e. October- November, 2015. There were thirteen treatments including an untreated control, each treatment replicated thrice, with single tree as a replication. A total of 10 litres of spray fluid/ tree was used and the spray done with a high volume sprayer in the third week of October. The pretreatment counts on the number of aphid colonies on ten randomly selected twigs were recorded in each treatment before the spray, while posttreatment counts were taken after 3, 7, 14 and 21 days of the spray. Data was analyzed statistically after subjecting to suitable transformation. The plants were also observed for phytotoxicity symptoms after spray, if any.

RESULTS AND DISCUSSION

The results presented in Table 1 reveal that all treatments are superior, of which chlorpyriphos, flupyradifurone and thiamethoxam are the most effective. After three days after spray, flupyradifurone 0.03 and 0.04%, thiamethoxam 0.025% and chlorpyriphos 0.04% proved highly effective and statistically at par with each other; chlorpyriphos resulted in zero aphids even after 21st day of spray. Spirotetramat 0.009% and flonicamid 0.30 and 0.40% gave only control, while spirotetramat 0.012 and 0.015%, and flonicamid 0.20% were ineffective.

After 7 days after spray, there was slight increase in population in spirotetramat 0.009, 0.012 and 0.015% (4.53, 6.03 and 6.47 aphid colonies/ twig), flupyradifurone 0.02, 0.03 and 0.04% (1.57, 0.47 and 6.43 aphid colonies/ twig) and thiamethoxam (1.93 aphid colonies/ twig). Reduction in aphids was observed with thiamethoxam 0.025%, flonicamid 0.20, 0.30 and 0.40%. Flupyradifurone 0.03 and 0.04%, thiamethoxam 0.025% and chlorpyriphos 0.04% gave highly effective control. After 14 days after spray, flupyradifurone (0.03, 0.04%), thiamethoxam (0.025%) and chlorpyriphos (0.04%) proved effective

Table 1. Field efficacy of new insecticides against apple woolly aphid - aerial form

Treatments	Dose (% a.i.)	Mean no. of colonies/twig				
		Pre-count	3 DAT	7 DAT	14 DAT	21 DAT
Spirotetramat	0.009 (Movento 150 OD)	11.43 (3.52)^{bcdef}	4.33 (2.31)^{c}	4.53 (2.35)^{d}	6.07 (2.66)	6.17 (2.68)^{g}
Spirotetramat (Movento 150 OD)	0.012	11.83 (3.58)^{def}	5.43 (2.53)^{cd}	6.03 (2.65)^{e}	4.53 (2.35)^{c}	3.80 (2.19)^{f}
Spirotetramat (Movento 150 OD)	0.015	8.93 (3.15)^{ab}	5.73 (2.59)^{cd}	6.47 (2.72)^{e}	4.40 (2.32)^{c}	3.73 (2.15)^{f}
Flupyradifurone (Sivanto 200 SL)	0.02	12.20 (3.62)^{ef}	1.27 (1.51)^{b}	1.57 (1.60)^{b}	1.63 (1.62)^{b}	1.77 (1.66)^{e}
Flupyradifurone (Sivanto 200 SL)	0.03	9.90 (3.28)^{abcde}	0.37 (1.17)^{a}	0.47 (1.21)^{a}	0.27 (1.12)^{a}	0.23 (1.11)^{abc}
Flupyradifurone (Sivanto 200 SL)	0.04	11.10 (3.48)^{abcdef}	0.20 (1.10)^{a}	0.43 (1.19)^{a}	0.23 (1.11)^{a}	0.23 (1.10)^{ab}
Thiamethoxam (Thomson 25WG)	0.012	10.37 (3.37)^{abcdef}	1.53 (1.59)^{b}	1.93 (1.71)^{b}	1.07 (1.44)^{b}	0.87 (1.36)^{bcde}
Thiamethoxam (Thomson 25WG)	0.025	13.10 (3.75)^{f}	0.40 (1.18)^{a}	0.37 (1.16)^{a}	0.00 (1.00)^{a}	0.00 (1.00)^{a}
Flonicamid (Ulala 50% WG)	0.20	10.57 (3.40)^{abcdef}	6.37 (2.71)^{d}	4.50 (2.34)^{d}	3.03 (2.01)	1.53 (1.59)^{de}
Flonicamid (Ulala 50% WG)	0.30	6.27 (2.69)	4.87 (2.42)^{cd}	3.27 (2.06)^{c}	2.03 (1.73)	1.00 (1.42)^{cdef}
Flonicamid (Ulala 50% WG)	0.40	8.70 (3.11)^{a}	5.53 (2.55)^{cd}	2.27 (1.80)^{bc}	1.70 (1.64)^{b}	0.73 (1.31)^{bcd}
Chlorpyriphos (Dursban 20 EC)	0.04	9.37 (3.21)^{abcd}	0.00 (1.00)^{a}	0.00 (1.00)^{a}	0.00 (1.00)^{a}	0.00 (1.00)^{a}
Control	Water spray only	9.17 (3.18)^{abc}	10.27 (3.35)	10.53 (3.39)	8.73 (3.11)	6.63 (2.75)^{g}
C.D.(0.05)		0.38	0.29	0.27	0.21	0.27
SE(m)		0.13	0.10	0.09	0.07	0.09
C.V.		6.68	8.45	8.20	6.83	9.61

Figures in parentheses $\sqrt{n+1}$ transformed values; *Each replicate consisted of 10 twigs; *DAT=Days after treatment

followed by flupyradifurone (0.02%) and thiamethoxam (0.012%); and the rest were moderately effective.

After 21 days after spray, chlorpyriphos 20 EC (0.04%), thiamethoxam 25 WG (0.025%), flupyradifurone 200 SL (0.03 and 0.04%) proved highly effective and were found statistically at par with each other; these were followed by flonicamid 0.40%. Flupyradifurone (0.04 and 0.03%) and thiamethoxam (0.025%) resulted in 0.23, 0.23 and zero aphid per twig, respectively; spirotetramat in all doses was observed ineffective, along with flonicamid 0.30%. Also, a slight increase was observed with lower doses of flupyradifurone (0.02%) and spirotetramat (0.009%). All the insecticides were safe and no symptoms of phytotoxicity were observed.

Khajuria et al. (2010) revealed higher immediate toxicity of carbosulfan and chlorpyriphos against the aerial form of the woolly apple aphid in the Kullu valley of Himachal Pradesh; the superiority of chlorpyriphos over flupyradifurone (0.04 and 0.03%) and thiamethoxam (0.025%) are thus clear. These results also revealed that thiamethoxam and chlorpyriphos remained effective only for 14 days. Thus, it can be concluded that chlorpyriphos is the best against apple woolly aphid, followed by flupyradifurone and thiamethoxam.

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LIGHT TRAP AS A MONITORING TOOL FOR COMMON CUTWORM *SPODOPTERA LITURA* (F.) IN SOYBEAN

M. PUNITHAVALLI

ICAR- Indian Institute of Soybean Research, Indore 452001
Current address: ICAR- Sugarcane Breeding Institute, Coimbatore 641003
Email: punithaentomol@yahoo.co.in

ABSTRACT

The population dynamics of common cutworm *Spodoptera litura* (F.) (Lepidoptera: Noctuidae) captured by light trap in soybean was studied at the Directorate of Soybean Research, Indore during 2009- 2011. In soybean, *S. litura* adults were not captured by light trap until 30th standard week. Two peaks of sudden increase of moth catches were observed on 38th and 41st standard week in 2009; 37th and 41st standard week in 2010 and 37th and 39th standard week in 2011. Moths caught/ week usually began to decrease to <3 during post soybean season. Similarly, intensity of larval population was zero until 31st standard week, and thereafter a peak on 37th standard week was observed during 2009 and 2011 seasons, and 36th standard week in 2010; subsequently, this reduced to <2 on 41st standard week. The seasonal moth catches/light trap were significantly higher in season 2009 and 2011 compared to that in 2010. Likewise, intensity of larval population during 2010 and 2011 seasons were considerably lower than that of 2009. A significant positive correlation was observed between light trap catches vs. larval population during crop season.

Key words: *Spodoptera litura*, soybean, monitoring, light trap, larva, moth catches, correlation, crop season, standard weeks

Soybean is a major rainy season crop in the rainfed agroecosystem of central and peninsular India. It was observed that its production drastically reduced over a decade due to extended association of various biotic, abiotic and socioeconomic factors (Bhatia et al., 2008). Of these biotic factors, insect pests are the major constraints and yield losses due to various insect pests had been estimated at approximately 26- 29% (Oerke, 2006). In recent years, the common cutworm, *Spodoptera litura* (F.) had been reported to be a primary pest by majority of the researchers in most soybean growing areas of the world. This pest attacks over 112 cultivated plants, of which 60 are from India (Garad et al., 1984). In the last 15 years, it has extended its host range to other crops such as cotton, mung bean, groundnut, brinjal, rice, cabbage and leafy vegetables, including soybean (Pogue, 2003). There was an outbreak of *S. litura* on soybean in the Kota region of Rajasthan. The pest also struck in epidemic form on soybean in Vidarbha region of Maharashtra in August 2008 and caused widespread losses (Dhaliwal and Koul, 2010).

Effective IPM depends on the early detection of insect pests before they reach damaging levels. Light trapping is an effective surveillance tool for the detection of new pests and monitoring existing pests, particularly night flying noctuid moths in the cropped areas. Besides, it provides information related to insect distribution, abundance, flight patterns and helps to decide the timing of the application of pesticides, biopesticides or the release of biocontrol agents (Camelo et al., 2011). The potential of light trap for monitoring key pests had been investigated in cereals crops (rice, maize, sorghum), pulses (chickpea, pigeonpea, lentil, green gram), vegetables (okra, cauliflower, cabbage, tomato, brinjal), horticultural crops (mango, ber, litchi, pomegranate) (Solsoloy et al., 2011). The present study includes three consecutive years data from 2009 to 2011 with the objective of determining occurrence of *S. litura* adults and their relationship with larval population in soybean fields.

MATERIALS AND METHODS

The study was conducted in the experimental farm at Directorate of Soybean Research, Indore from June - October, 2009 to 2011. The field was direct seeded with JS 335 using tractor mounted seed drill during late June to early July based on prevailing climatic condition. The study site was surrounded on one or more sides with uncultivated natural vegetation and

weeds, which provided *S. litura* an overwintering habitat. The crop was raised following regular agronomic practices without any plant protection measures, and harvested in late October. A light trap with a 125 watt mercury vapour lamp was installed @ one/ ha and the *S. litura* moth catches observed. Light trap was operated regularly at every evening and trapped adults collected daily at each morning. A plastic bag was placed inside the trap tied with rubber band having at the bottom, a cotton swab impregnated with dichlorvos to kill the captured moths. The captured moths were counted daily and calculated at weekly intervals.

The larval populations were monitored at weekly intervals from early vegetative stage (July) to harvesting stage (mid October). Soybean plants were sampled between 8.00 and 11.00 am as per the recommendation of the All India Coordinated Research Project on Soybean. About 25 randomly selected sampling units at one meter row intervals in the 1 ha fields were marked with wooden stakes. The "canopy-shake" sample method was followed with one shake sample consisting of a plastic sheet (45x 30 cm) placed with a wooden frame on the planting bed beneath the plant canopy and shaking five times the foliage approximately 0.5 m either side of the row on to the plastic sheet to dislodge the larvae for counting.

Data on mean light trap catches and larval population observed at weekly intervals were subjected to simple correlation coefficient analyses ($p > 0.05$) to bring out the relationship between them.

RESULTS AND DISCUSSION

The weekly mean light trap catches of *Spodoptera litura* adults over the growing season of soybean (2009- 2011) are presented in Fig. 1. Light trap catches were distributed almost in a similar pattern in all years, except those of season 2009 being evidently more. Despite the soybean season starting between 25 or 26 standard week, it was not until 30th standard week moth catches started to buildup, and these were less up to 32 standard week. Then began to increase gradually from 34th standard week, though marked increase was observed between37th to 41st standard weeks *i.e.*, mid-September to mid-October. Thereafter, moths caught/week decrease to fewer than 3 during post soybean season.

Two peaks of sudden increase of moths were recorded on 38th and 41st standard week in season 2009; 37th and 41st standard week in season 2010; and 37th and 39th standard week in season 2011. Such sudden increase might be possibly due to migration of adults from unsuitable areas and monocropping of soybean in the particular area (Ramesh Babu et al. (2015). The epidemic of *S. litura* on soybean in the Vidarbha region of Maharashtra during August- September was mainly due to favourable prevailing weather conditions particularly elevated temperature (Bambawale et al.,

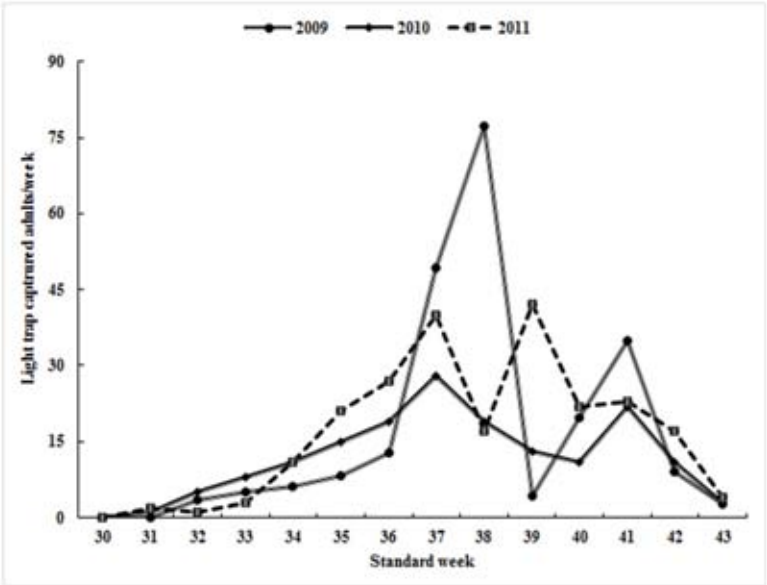

Fig. 1. Population dynamics of *S. litura* in soybean-moth catches in light trap (2009-2011)

2009). Results also clearly indicate that peak activity of adults normally corresponded with reproductive phases particularly pod formation stage of soybean. Similarly, Ramesh Babu et al. (2015) observed that moth population was active from August to mid-October and peak appearance was noticed during September-October.

Figure 2 shows the weekly mean distribution of larval population of *S. litura* in soybean during the cropping seasons 2009 to 2011. The intensity was conspicuously higher in the 2009 and 2011 seasons than in the 2010 season. Zero larval population was recorded until 31st standard week, and thereafter gradually increased with plant growth; and led to peak on 37th standard week in 2009 and 2011 and 36th standard week in 2010; thereafter decreased to <2 at the end of September i.e., 41st standard week during post soybean period in all years. In the study, larval population always occurred after the first appearance of moths in the light trap, and was observed steadily increasing in correspondence with trap catches except later stage of the crop; also peak in larval population coincided with the peak activity of moths at pod formation stages, during mid-September to late September.

Larval populations were maximum during September to October in soybean at Gujarat (Sojitra, 1990); Madhya Pradesh (Punithavalli et al., 2014); and Rajasthan (Ramesh Babu et al., 2015). Moreover, epidemics of *S. litura* led to >90% defoliation in sunflower as studied by Sujatha and Lakshminarayana (2007). Increase in larval population in September might be due to reproduction by earlier emerged overwintered moths, and or by migrating moths arriving to central India from northern India with infrequent weather fronts. Results evidently showed that the larval population steeply decreased towards the end of the season which could be possibly correlated to the maturity of the crop which led to termination of insects and/ or overwintering in weeds and alternative hosts.

The trend of moth catches in light trap was more or less similar in season 2009 and 2011, but differed significantly from season 2010 (Fig. 3); maximum was in 2009 (16.66 moths/light trap) and 2011 (16.43 moths/ light trap) compared to that of 2010 (11.86 moths/ light trap). Seasonal mean was lowest in season 2010, and this might be due to frequent rainy days accompanied with minimum temperature. Similarly, the larval populations were considerably more in 2009 (3.56 larvae/m row) compared to those of 2010 and 2011 (2.24 and 2.34 larvae/m row), and was observed coinciding with maximum moth catches. The year-to-year variation in the seasonal activity and abundance of *S. litura* moths and the larval population could be due to the response to climatic factors and their impact on migration, reproduction and other behaviour, as well as regional makeup and abundance of crops, crop planting and harvest cycles.

In the correlation study, significant positive correlation ($r^2 = 0.51$; $p < 0.05$) was found between pooled seasonal mean light trap catches with seasonal mean larval population (Fig. 4). Results indicate that the larval population gradually increased corresponding to the trap catches and thus positively coincided with broad reproductive phase of the crop. The present

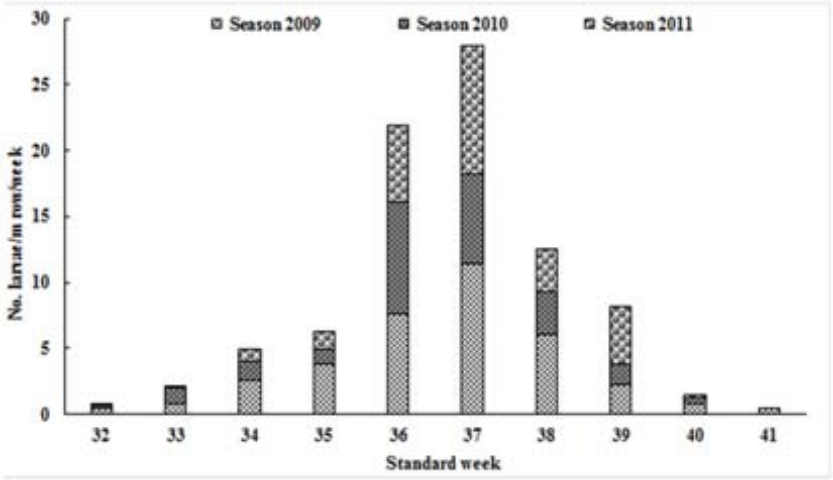

Fig. 2. Population dynamics of *S. litura* in soybean-larval population (2009-2011)

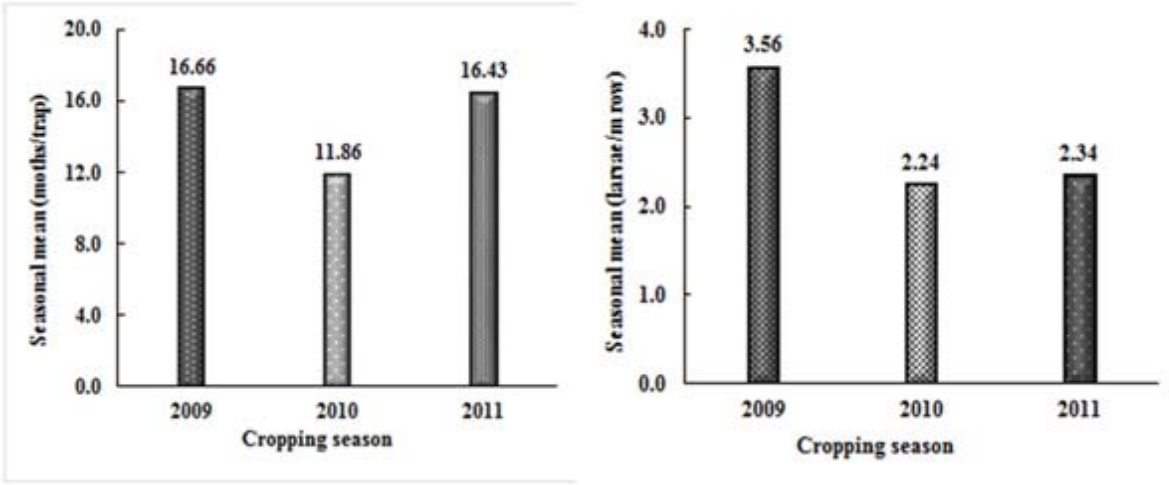

Fig. 3. Seasonal mean of *S. litura* moth catches and larval population in soybean (2009-2011)

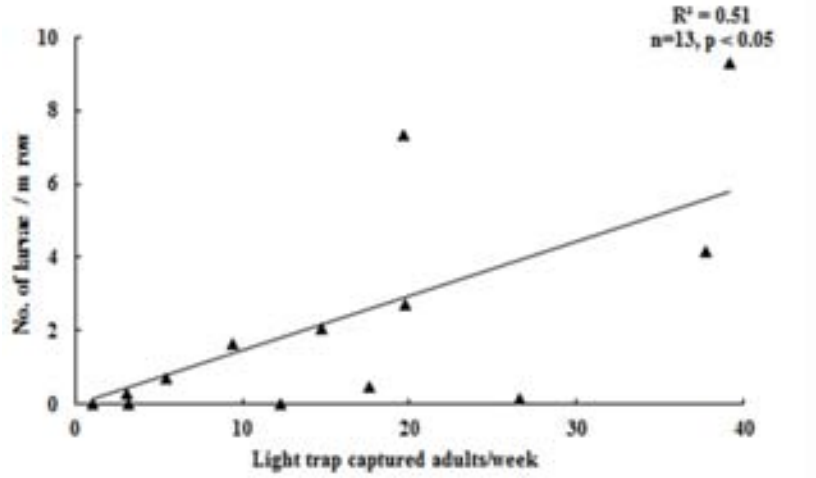

Fig. 4. Light trap moth catches vs. larval population in soybean (2009-2011)

study also establishes the utility of light trap as an indicator tool for monitoring of *S. litura* in soybean ecosystem. Besides, it could provide appropriate planning for the pest control strategy prior to its active feeding stage.

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ENDOPARASITOID: *BRACON LEFROYI* (DUDGEON AND GOUGH) OF PINK BOLLWORM *PECTINOPHORA GOSSYPIELLA* (SAUNDERS) ON COTTON

V. CHINNA BABU NAIK*, S. KRANTHI, SHRUTI GHARADE, SUJIT KUMBHARE, V.S. NAGRARE AND L. RONI KUMAR SINGH**

**Division of Crop Protection, ICAR-Central Institute for Cotton Research, Nagpur 440010*
***Division of Entomology, ICAR- Indian Agricultural Research Institute, New Delhi 110012*
**Email: chinnaenton@gmail.com (corresponding author)*

ABSTRACT

Pink bollworm *Pectinophora gossypiella* (Saunders) is a major insect pest of cotton in India. Neonates enter developing bolls and destroy seed as well as fibre forming tissue. Chemical control method is the dominant method against this pest. Excessive use of insecticides has resulted in tolerance in this pest against insecticides. Biocontrol agents are the key components of IPM that provide sound ecological foundation, while being safe. The present study on the endoparasitoid, *Bracon lefroyi* (Dudgeon and Gough) (Hymenoptera: Braconidae) reveals observations on its incidence in Indian locations. It was observed that this parasitoid exerts control of the pink bollworm in central and north India. The % parasitization was more in Sriganganagar (74.65 %) as compared to the other locations in 2015-2016. The incidence of the endoparasitoid was nil during 2014-2015 and 2013-2014 except Nagpur.

Key words: *Bracon lefroyi*, endoparasitoid, *Pectinophora gossypiella*, biocontrol agent, central and north India, parasitization, Sriganganagar, Nagpur.

The pink bollworm *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae) is a major pest of cotton, *Gossypium* spp. in India and in many other cotton producing areas of the world (Ingram, 1994; Mahfouz and El-Ela**,** 2011). Pink bollworm larvae feed on flower buds, flowers, bolls and the seeds within. Damage to the developing seeds results in boll rotting, premature or partial boll opening, reduction of staple length, strength, and causes staining of lint. It causes locule damage to an extent of 55% and reduction in seed cotton yield in the range of 35-90% (Chinna Babu Naik et al., 2014). In India among the bollworms, the pink bollworm assumed major pest status in recent past (Ghosh, 2001; Patil et al., 2003, Dhara Jothi et al., 2016).

Use of insecticides is the primary control measure that has been successful in limiting damage of pink bollworm in commercial cotton. However, use of insecticides increases chemical control costs, while causing secondary pest problems, environmental and social considerations. Ecologically oriented pink bollworm management strategies are necessary. Extensive research has indicated that monitoring and control measures such as, biological, cultural, behavioral, genetic and host plant resistance methods can be integrated for effective pink bollworm management. Biological control organisms are valuable. In the present study we found that *Bracon lefroyi* (Dudgeon and Gough) (Hymenoptera: Braconidae) caused natural mortality of pink bollworm in the field.

MATERIALS AND METHODS

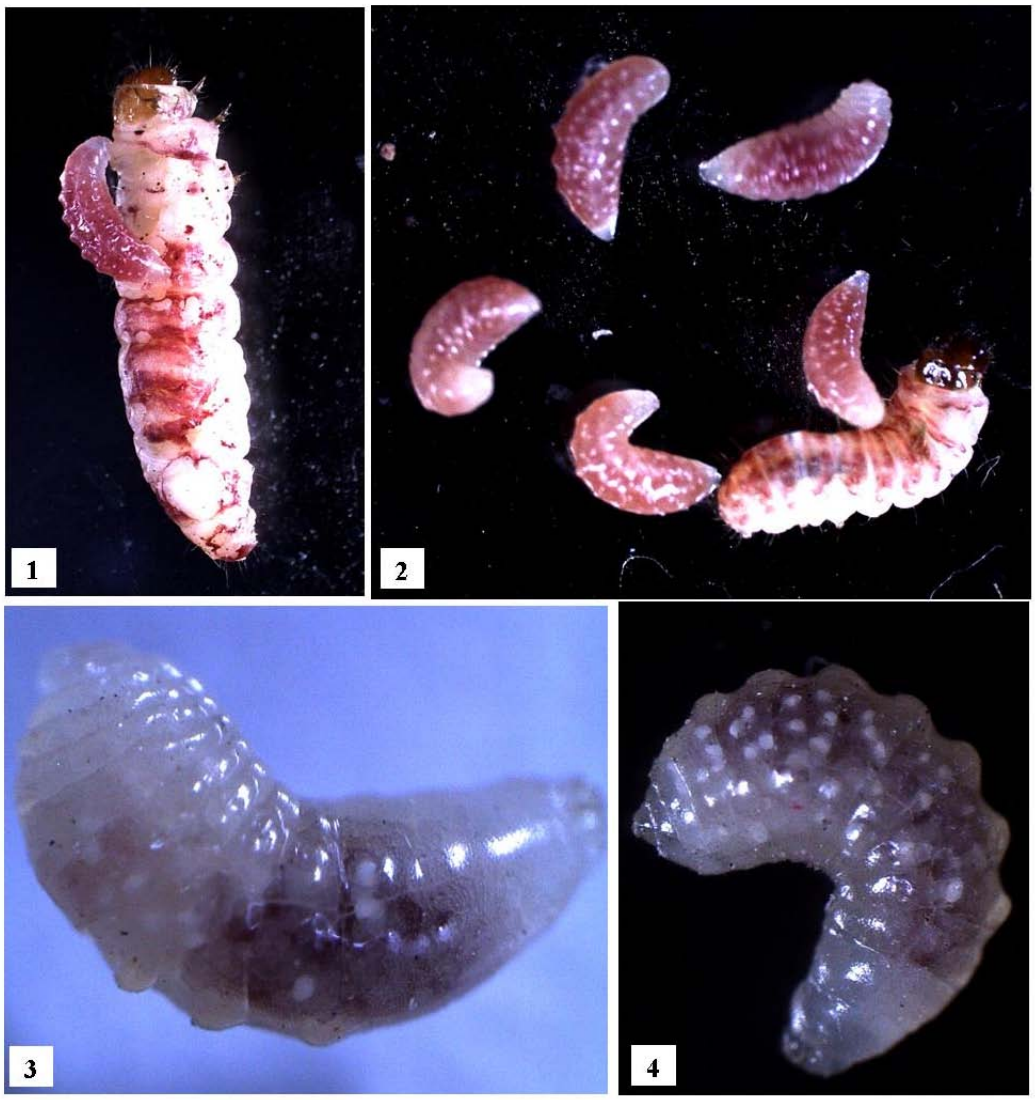
Cotton bolls infested with *P. gossypiella* larvae were collected from cotton fields of Bt (Cry1Ac), BG II (Cry1Ac +Cry2Ab) and NBt from different regions and brought to the Central Institute for Cotton Research (CICR), Nagpur during 2013-2014,2014-2015 and 2015-2016 from August to January every year. The green bolls were dissected for observing exit holes, mines on the epicarp, surviving larvae, dead larvae, total locules, and damaged locules. Single dead larva were kept in plastic tubes in the laboratory (24-26ÚC) to observe the emergence of parasitoid *Bracon lefroyi* (Dudgeon and Gough) (Hymenoptera: Braconidae) from the dead larvae. The number of larvae of *B. lefroyi* was recorded daily.

RESULTS AND DISCUSSION

Four braconid larval parasitoids of *P. gossypiella viz.*, braconids, *Apanteles angaleti* Muesebeck, *Bracon greeni* Ashmead, *Camptothlipsis* sp., and *Rogus* sp., were reported by Sekhon and Verma (1983) in North

India. *Bracon lefroyi* which is an ectoparasitoid of larvae of *Earias insulana* Boisduval (Hussain et al., 1976) and *Bracon hebetor* (Say) is a parasitoid of lepidopteran pests (Ashfaq et al., 2011). Bt cotton is not different in species to other cotton from which *B. lefroyi* had been reported. This is a new emerging parasitoid, and was observed after 40 years on pink bollworm of Bt cotton.

When dissected dead pink bollworm larvae were observed inside large number of green bolls. Dead larvae were placed individually in vials. Larvae of parasitoids were recorded in some vials along with the dead pink bollworm larvae (Figs.1-4). These larvae turned to pupa (Fig. 5) and adult (Fig. 6) emergence was recorded. Adults were identified as *Bracon lefroyi*. Emergence of the parasitoid was not recorded from all the larvae indicating that parasitoids might have emerged prior to collection of pink bollworm or that natural mortality might be due to some other factor. In 2013-2014 at CICR, Nagpur parasitizion was 47.0% in NBt cotton during first week of December. In 2016, emergence of *B. lefroyi* from pink bollworm population on BG-II in Surat was recorded. The pink bollworm larval recovery on BGII was 52%, and natural mortality of 11.81% was due to *B.lefroyi*. Likewise, at Sriganganagar, natural mortality due to *B.lefroyi* was up to 74.65 % compared to the other locations during 2015-2016 (Table 1; Fig. 7). The collection of green bolls was uniform across the North India, and during 2015-2016 the emergence of wasps was observed. The sudden appearance of wasps was because of increased incidence of pink bollworm.

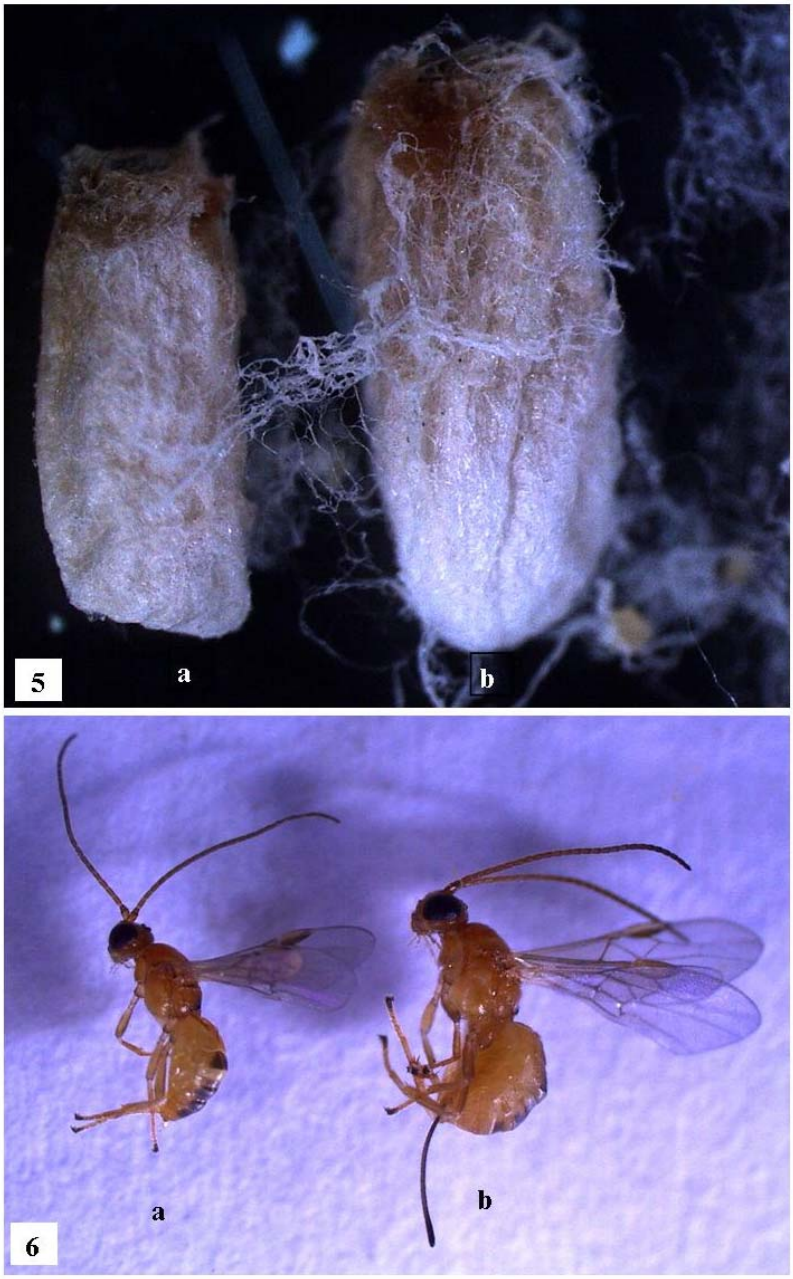


Figs. 1-4: Dead pink bollworm larva with *B. lefroyi* larva; 2: Dead pink bollworm larva with *B. lefroyi* larva: 3 and 4: Last instar larva of *B. lefroyi*.

Table 1. Incidence of parasitoids on the PBW from different locations (2013-14 to 2015-2016)

Location	Variety	2013-2014				2014-2015			2015-2016			
		No.of green bolls	No. of larvae recovered	No. of dead larvae	% parasi-tization	No. of green bolls	No. of larvae recovered	% parasitoids recovered	No. of green bolls	No. of larvae recovered	No. of dead larvae	% parasi-tization
Hisar	NBt Desi	60	7	Nil	Nil	-*		-	500	96	42	43.75
Bhatinda	NBt Desi	60	3	Nil	Nil	-		-	530	252	15	5.95
Faritkot	NBt Desi	260	30	Nil	Nil	900	170	Nil	1560	720	80	11.11
Abohar	NBt-Desi	60	7	Nil	Nil	925	101	Nil	1030	504	71	14.09
Sriganganagar	NBt	730	309	Nil	Nil	880	180	Nil	830	284	212	74.65
Surat	RCH2 BGII	190	36	Nil	Nil	200	6	Nil	275	144	17	11.81
Nagpur	NBt Suraj	3945	365	171	46.84	-		-	1000	684	7	1.02
Guntur	NBt	-	-	-	Nil	-		-	600	600	100	16.67
Guntur	ATM Bt	-	-	-	Nil	-		-	374	374	50	13.37

***-** no data taken



Figs. 5-6. *B. lefroyi* a- male cocoon, 5 b- female cocoon; 6: Adult; a- male, b- female.

Pink bollworm *P. gossypiella* is a major pest of cotton in India (Vennila et al., 2007; Arora et al., 2011; Chinna Babu Naik et al., 2014). Pink bollworm larvae feed in the bolls, on cotton fiber forming tissue as well as seeds. Among the various groups of biocontrol agents, hymenopteran parasitoids are well known for the management of different lepidopteran pests and are very effective in controlling bollworms (Hussain et al., 1976; Sekhon and Verma 1983; Bhatty et al., 2000; Malik 2001; Ashfaq et al., 2010) provided insecticides are not used indiscriminately. Among these, important species are *Apanteles* spp., *Bracon* spp., and *Trichogramma bactrae*. (Husain and Mathur, 1921; Stock, 1926; Hussain et al., 1976; Sekhon and Verma, 1983; Hutchison et al., 1990; Malik 2000, 2001; Thanavendan and Jeyarani, 2010). Among the various groups of biocontrol agents, braconids are well known for the management of different lepidopteran larvae, fruit borer *viz*., *Earias vitella (*F.), *Earias insulana (*F.) and *Helicoverpa armigera* (Hübner). *Bracon*

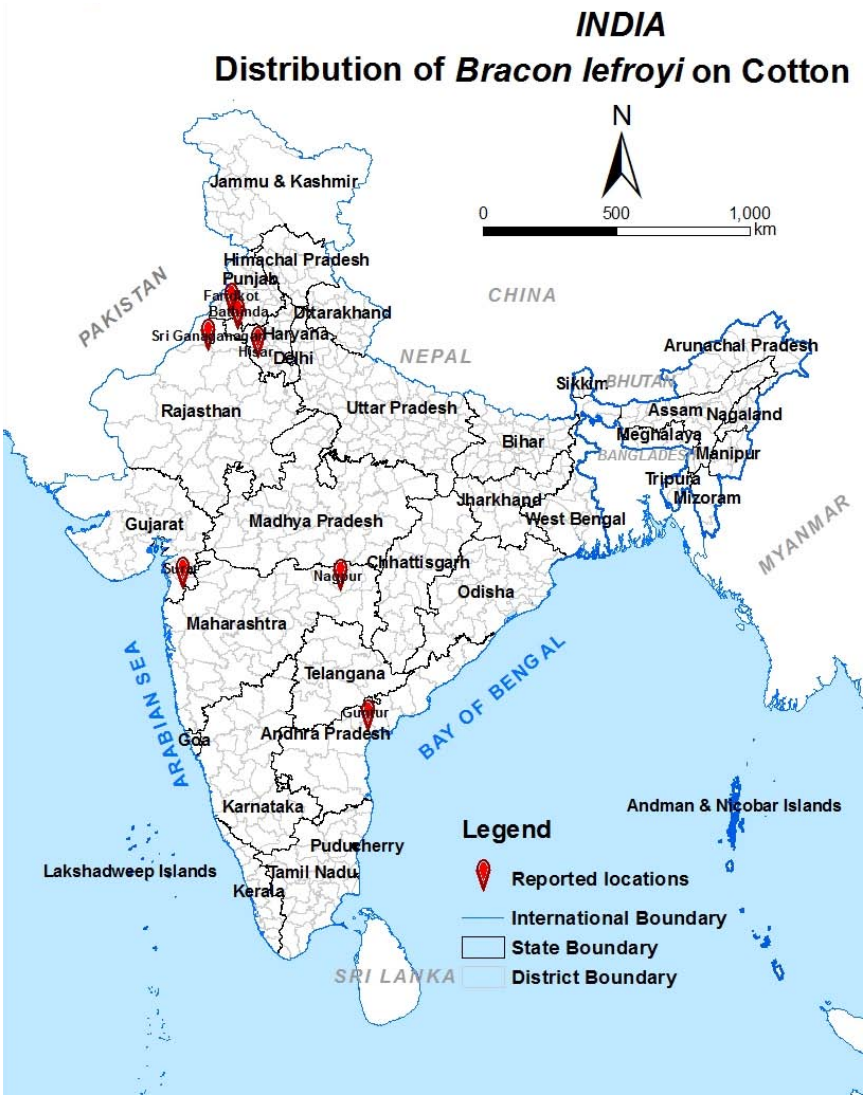


Fig. 7. Distribution of *B. lefroyi* on cotton pink bollworm

brevicornis Wesmael was found very effective against okra fruit borers, *H. armigera* (Thanavendan and Jeyarani, 2010). *Microplitis mediator* (Haliday) (Hymenoptera: Braconidae) is an endoparasitoid of cotton bollworm in China. It can provide up to 60- 70% control of bollworms (Li et al., 2004). *Microplitis mediator*, widely used as biological agents in Chinese cotton IPM systems (Luo et al., 2014). *Pseudapanteles dignus* (Hymenoptera: Braconidae) is a potential biological control agent against *Tuta absoluta* (Lepidoptera: Gelechiidae) in Argentina (Luna et al., 2015).

Cotton is one of the most important crops in India and major damage caused by pink bollworm results in decreased production and quality of lint. The attack of pink bollworm had adverse impact on cotton yield in Gujarat Maharashtra, Madhya Pradesh, Telangana, Andhra Pradesh and Karnataka; an estimated 25%-30% reduction in yield in Gujarat during 2015-16 is known. We recorded *B. lefroyi* as an important biocontrol agent for this pest. Biocontrol agents against insect pests have shown promise, and also provide efficacy besides safety to the environment. The larval stage of pink bollworm is usually buried within the cotton fruiting bodies making them unreachable to insecticidal sprays owing to which its management is a difficult task. There is urgent need to for development of biological control agents such as *B. lefroyi* which could be effective against pink bollworm on cotton in India.

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WEB-BASED SYSTEM FOR STUDY OF PEST DYNAMICS IN RELATION TO CLIMATE CHANGE

NIRANJAN SINGH, S. VENNILA AND D. B. AHUJA

ICAR- National Centre for Integrated Pest Management, LBS Building, IARI Campus, New Delhi 110012
**Email: Attri.ns@gmail.com (corresponding author)*

ABSTRACT

A web based system for study of Real Time Pest Dynamics (RTPD) was developed and implemented under National Initiative in Climate Resilient Agriculture to assess the field level impact of climate change on pest dynamics of four major crops viz., rice, pigeon pea, groundnut and tomato. Understanding pest dynamics *vis-a-vis* climate change is essential for prediction of pest severity. Predictions lead to pest forewarning that provides lead time for managing impending pest attacks, minimizes crop loss, and optimizes pest control leading to reduced cost of cultivation and better environmental safeguards. The current efforts mainly focus on pest data capture, reporting, analysis and its relation with weather data. The system consists of three major components *viz.* a database, an offline peat data capture application and online pest-weather reporting and analysis application. Pest and other relevant information obtained through regular monitoring of experimental and farmer's fields by Real Time Pest Surveillance (RTPS) locations established across the major agro ecological regions growing the target crops and daily weather data for these locations is captured on weekly basis by an offline application deployed at computers of RTPS locations which is transferred to central database. Subsequently, experts from research institutes view this information in various formats through online reporting and analysis application to compare pest scenarios, to study pest weather interactions as well as for generation of pest forewarning models.

Key words: Pest surveillance, real time, dynamics, climate change, weather, pest-weather interaction, data capture, mapping, reporting, analysis, forewarning

Climate change is the most important and complex global environmental issue to date. Effects of climatic change are already evident from the rising temperature, recurring droughts, and erratic rains and flooding. These changes may have serious impact on crop production and productivity. A recent study predicts that crop harvest will decline by more than 30% in Indian subcontinent by 2050 (Rao, 1999). Climate change will trigger major changes in geographical distribution and population dynamics of insect pests, insect- host plant interactions, abundance of natural enemies and efficacy of crop protection technologies.

Changes in geographical distribution and incidence will affect both crop production and food security (Sharma, 2016). Assessment of the changing pest scenarios, mapping of vulnerable regions of pest risks and to evolve curative and preventive pest management strategies towards climatic stress have been emphasized among many approaches to study the impact of climate change on pests. Climatic factors such as temperature, humidity and rainfall have very strong influence on the development, reproduction and survival of insect pests and diseases. These changes in climatic conditions could affect the population dynamics and the status of insect pests of the crops (Woiwod, 1997).

Hence, the very first step to study real time effect of climatic change on pest dynamics in the country is to capture the regular pest data from experimental as well as farmers fields spread across different agro ecological zones of the country. National Initiative in Climate Resilient Agriculture (NICRA) under its strategic component envisaged assessment of effects of climate change on pest dynamics on four target crops *viz.*, rice, pigeon pea, groundnut and tomato accounting the importance of role of these crops in food and livelihood security of the nation. In order to study the effect of weather variations on pest dynamics, the main requirement is to accrue quality pest, weather and other relevant information. Application of web based technologies can greatly facilitate the development of pest-weather database,

comparison of pest scenarios and pest-weather analysis.

In this regard, National Research Centre for Integrated Pest Management (NCIPM) conceptualized and developed a web based system consisting of offline data capture application, centralized database ad online pest reporting application by integrating the potential technical and administrative stakeholders of State and Central machinery involved in plant protection. Use of the system would help the researcher to have prompt and reliable pest incidence, comparative pest scenarios and pest-weather reports for use in understanding the changing patterns of pests and to advocate need based pest management options for their timely management.

1. Pest surveillance methodology

Studies relating to pest dynamics *vis-à-vis* climate change requires methods of surveillance streamlined through carefully designed data recording formats relating to crop pests, production and protection practices in addition to weather. Implementation of pest surveillance for selected crops across different agro ecological regions across the country offers *per se* heterogeneity of climate, and upon comparison helps to draw the underlying mechanism of the observed pest status. Analyses with weather would further aid in delineating climate effects on pests. Making pest surveillance operational through provision of pest scouts and data entry operators make it possible to capture quality data at field level guided by scientific staff. Hence, crop-wise appropriate plan and procedures for field selection, pest sampling and method of monitoring were devised to get accurate data.

Twenty five Real Time Pest Surveillance (RTPS) centers were established across four crops amongst selected agro ecological regions. Area of surveillance under each unit was clearly demarcated and required man power such as pest monitors, computer personnel and IT tools, I laptop, internet connection and GPS devices were provided to facilitate data collection, off line entry and on line upload to the server maintained at NCIPM, New Delhi.

Field selection: For rice and tomato, two main (one protected and another unprotected) fields at the experimental station and twenty amongst ten villages of the region were fixed for rice pest surveillance. Fixed fields, selected were continuously monitored till harvest on weekly basis for pests and diseases using the specified data sheet formats. For nursery surveillance, one nursery at the experimental station and one at each of the ten selected villages were selected for surveillance. General information on nursery and on nursery insect pests and diseases was also collected. Similarly for pigeon pea and groundnut crops as well, two fields each at the experimental station and in ten selected villages of the region were fixed for pest surveillance. There were no nursery fields as these are direct shown crop. One of the fields has to be unprotected without any plant protection measures and the other was protected using need based application of pesticides to keep the crop free from insects and diseases.

Pest observation: Separate performa were designed for each crop with technical inputs from pest management experts for recording observations form selected fields. Geographical, cropping system, Agronomic, pest and disease and weather details were the core components of data collection format. Each field was given a unique ID for surveillance and its geographical coordinate's viz. latitude and longitude were also recorded using GPS devices. All the relevant information, be it soil type, previous crop in the field, crop in adjacent field, inter cropping system, variety, sowing date, seed rate, seed treatment, crop stage, irrigation, pesticide sprayed and fertilizers, pest, trap catches, weather was recorded. The unit of observation was one acre. The sampling units for pest observations varied with crops, insects and diseases. As regard to the weather temperature (max, min), rainfall, relative humidity (morning & evening), sun shine and wind velocity of field location were observed.

Field scouting schedule: A weekly schedule was fixed for recording pest observations. Field scout had to take observations on four days in a week, viz., Monday, Tuesday, Wednesday and Thursday. On Friday and Saturday, the recorded data was fed into the data capture client application system and subsequently transferred to the centralized database. Pest experts form collaborating research institutions were given access to view the data in various report formats through online reporting and analysis application.

2. Design and development

Keeping in view the size of data and internet connectivity in remote areas of state, three tier architecture based system was designed consisting three major functional components viz. a database, offline data entry and transfer application and online

pest reporting and analysis application. Structure of the system is mentioned in Fig. 1.

The system was developed in ASP.net environment using C# & Java languages, Google@ API, SQL Server 2005 and XML technologies. The development of the system was very systematic and accomplished in different phases, having elaborate discussions with all the domain experts and insertion of their valuable suggestion.

Database: The database is the core component of the system. Once the scope of database finalized, the next step was to define the information needed by users. A blueprint of the database was developed in consultations with the domain experts, review of published research papers, pest management guides and pesticide databases. With blue print in hand, we moved to the physical design of the database by determination of specific storage, access methods and structures. Database was created using SQL Server 20005. A total of — tables consisting —- data fields were created for storage of information. Relationships were established among these tables to avoid data redundancy. Various stored procedures were written for data manipulation. Dummy data was entered into the database for testing purpose since it is easier to change the database during testing phase. A comprehensive coverage was established by creating a solid foundation for the system powering its functionality and integration capabilities, efficiently supporting application workflows and data manipulation. Due emphasis was given on database security and user access management.

Client application for data capture: Application was designed to capture, check and compile the pest and other information offline obtained from experimental and farmer's fields. For each RTPS center, a setup file was created so that each center can enter data obtained from its area of observation. This application started as standalone by introducing itself and asks the data entry operator for login. After successful login, data entry starts on the page of the application having links viz. location and field registration; pest and weather data entry; data uploading. Client application has the provision for data viewing and editing before transferring into the database. Once data fed into the application, it is compiled as xml files into a zip folder and finally transferred into data base as and when internet connectivity is available. XML is used for exchange of information between remote systems through internet.

Algorithm for field registration & data entry

Select {year, crop, season}

Select {State, District, Block, Village}

Enter {field geospatial coordinates}

Date of observation, submit.

Select crop

Pest-weather data form is generated. Feed & submit the data.

IF "data correct" = "yes" then compile data into a zip folder as XML files

Else "edit" data and then compile again into zip folder as XML files

Check internet connectivity if available, transfers the data into the database.

Pest reporting and analysis application: An online application was designed and developed for pest reporting, pest scenario comparisons and pest-weather reporting in various formats such as tabular, graphical as well as mapping. It has two modules: admin and pest reporting. Admin module facilitated database management; user creation; assignment of user access rights; creating setups for various monitoring units whereas pest reporting module generated various kinds

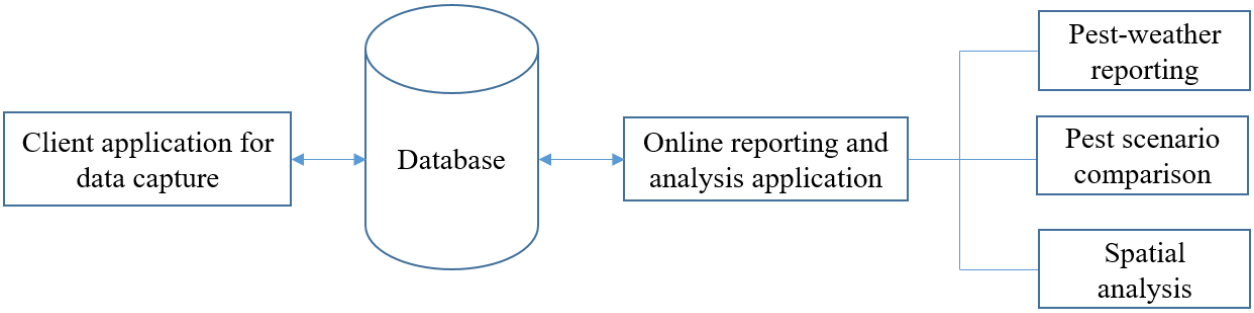


Fig. 1. Structure of the system

of reports i.e. nursery info, field details, crop nursery-pest, pest dynamics, crop pest scenario, pest trap catches, weather and weather comparison and spatial pest weather.

Pest reports provided location wise current and temporal (date wise, month wise and standard week wise) pest information of nursery as well as crop fields. User can also view SMW, date and month wise pest dynamics, pest scenarios, weather, crop age wise weather and other relevant information reports. These reports facilitate the experts in analyzing the effect of weather on pest and hence draw the inferences. These reports could be viewed field spot, village, block and district wise in tabular form as well as graphically (Fig. 2).

The pest scenario report generated based on the user selection criteria is as follows:

Select [Crop] = “Pigeopea” and

[Report type]=”Spot-wise**”** and [Year] =”2016"

[Pest type]=’Insects” and [Pest] =all”

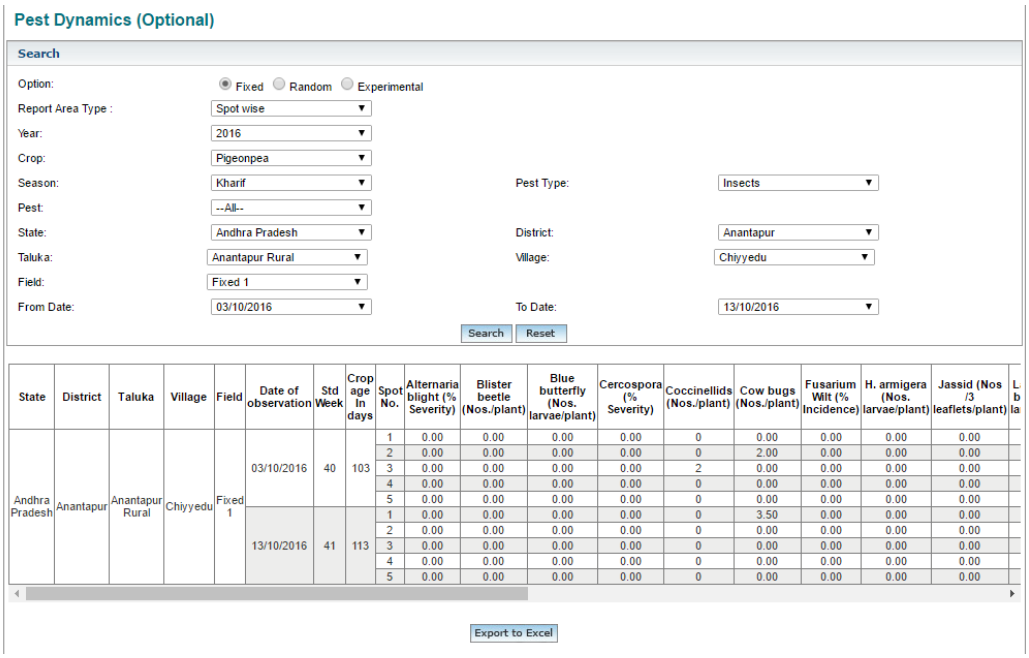
[State]=”Andhra Pradesh” and [District] =”Anantapur” and [Block] =” Anantapur rural” [Field] =” Fixed1"

[From date]=”03/102016" and [To date] =” 13/10/20160"

Then “Submit”

Reporting also has pest weather mapping which shows pest and weather information of selected location status on Google maps. The geographical coordinates of locations recorded using GPS devices in the surveillance provided the basis for thematic temporospatial pest weather maps. This application works on data managing layers. The first one is core layer of polygons vectors maps for country, state, districts and block. It is also capable to depict village polygons for the selected block under the desired district. The Google Map API was used to display the polygons as administrative boundaries on different scales. The Google® Maps API is relatively easy to program using many programming languages (Xia et al., 2009). The authentic vector polygons maps from Survey of India were used for state, district, block and village using GIS Arc info software. Module opens with multi selection options such as year, season, crop, pest, weather parameter, location and standard week. Based on user selection, module extracts the relevant information from database through SQL query and populated the results on Google map. Map of *H. armigera* incidence in pigeon pea and weather of Agri. Research Station (ARS), Gulbarga (Karnataka) for 44th-46th standard week is shown in Fig 3.

Development and implementation of RTPD system using web technology is an innovative initiative for easier and efficient collection and analysis the real-time pest and weather data from experimental and farmer fields so as to facilitate the researchers in studying pest dynamics *vis-a-vis* weather change. This



State	District	Taluka	Village	Field	Date of observation	Std Week	Crop age In days	Spot No.	Alternaria blight (% Severity)	Blister beetle (Nos./plant)	Blue butterfly (Nos. larvae/plant)	Cercospora (% Severity)	Coccinellids (Nos./plant)	Cow bugs (Nos./plant)	Fusarium Wilt (% Incidence)	H. armigera (Nos. larvae/plant)	Jassid (Nos /3 leaflets/plant)
Andhra Pradesh	Anantapur	Anantapur Rural	Chiyyedu	Fixed 1	03/10/2016	40	103	1	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
								2	0.00	0.00	0.00	0.00	0	2.00	0.00	0.00	0.00
								3	0.00	0.00	0.00	0.00	2	0.00	0.00	0.00	0.00
								4	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
								5	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
					13/10/2016	41	113	1	0.00	0.00	0.00	0.00	0	3.50	0.00	0.00	0.00
								2	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
								3	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
								4	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00
								5	0.00	0.00	0.00	0.00	0	0.00	0.00	0.00	0.00

Fig. 2. Pest scenario report

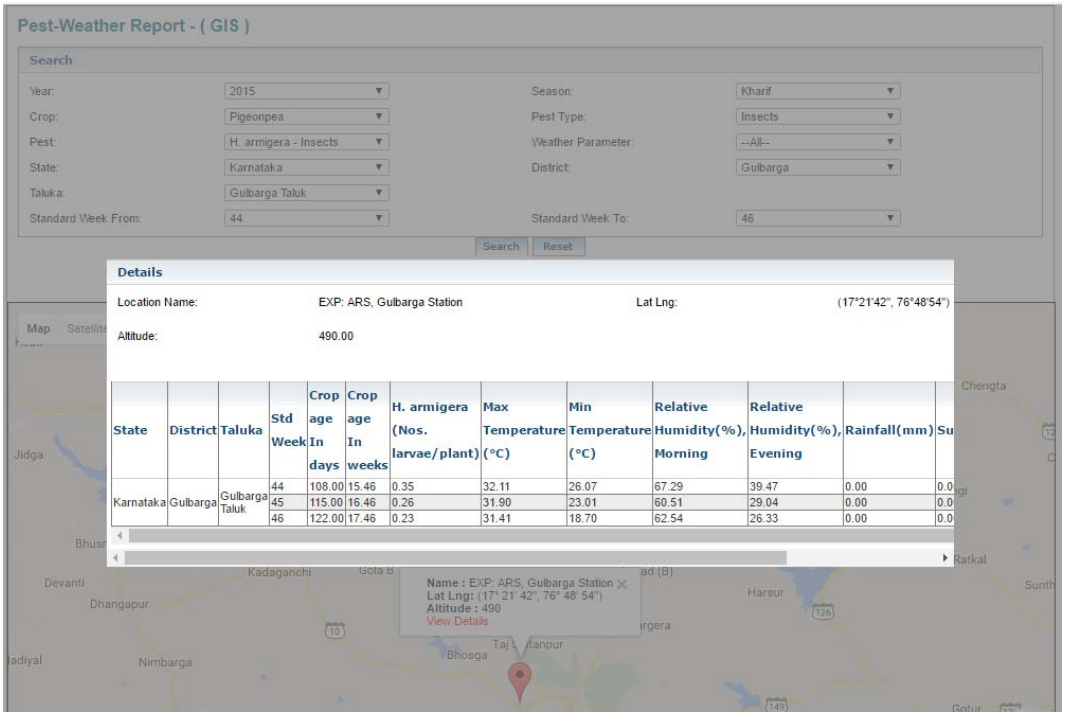


Fig. 3. Pest mapping view

system not only helped the collection and analysis of pest weather data but temporal quality database for developing pest forecasting models. The database thus developed can be used for various purposes such as identification of hot spots so as to gear up gear up the field staff to manage the impending crisis in the area of pest surveillance.

Use of RTPS system as a tool to study the pest dynamics vis-à-vis climate change helped the researchers in timely obtaining the pest and weather data form experimental stations and farmer fields and presenting the same in various formats for analysis. This technology seems to be applied 1st time for the purpose of studying the effect of weather on the pest dynamics.

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NYMPHALIDAE (LEPIDOPTERA) FROM TAMIL NADU

NISHA PRADEEPA, K.* AND RAMARAJU, K.

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

ABSTRACT

An updated checklist of the Nymphalidae (Lepidoptera) from Tamil Nadu is presented here. This list is based on the nymphalids collected from various districts of Tamil Nadu *viz.*, Coimbatore, Dharmapuri, Dindigul, Erode, Madurai, Perambalur, Salem, Theni, The Nilgiris, Tirunelveli, Tiruppur, Tiruchirappalli, and Tuticorin and on a detailed analysis of available published data. A total of 45 genera and 106 species are known, which fall under 11 subfamilies *viz.*, Apaturinae (2 spp.), Biblidinae (4), Charaxinae (6), Cyrestinae (2), Danainae (10), Heliconiinae (9), Libytheinae (4), Limenitidinae (20), Morphinae (3), Nymphalinae (13), Satyrinae (33). Nearly 56 species were collected from parts of Tamil Nadu, these catalogued alphabetically by genus and species under respective subfamily and presented.

Key words: Nymphalidae, Tamil Nadu, species diversity, 56 species, checklist, 106 species, subfamilies, distribution, catalogue

Of all the insects, butterflies and moths are the most admired, and these are good pollinators with some of their larval forms being agricultural pests. Approximately, 17,200 species of butterflies are known throughout the world (Kunte, 2000) of which 1,504 species are from the Indian subcontinent (Tiple, 2011). Of these 315 species had been reported from South India (Evans, 1932). Butterflies in the family Nymphalidae are among the most charismatic, occurring in many habitats, and their beauty and diversity inspire a lifelong passion for the natural world among scientists and enthusiasts alike (Wahlberg *et al*., 2009). Some of these are major pests of agricultural crops. The population status of butterflies in any area would help us to understand the status of ecosystem as they are good indicator species (Karemen 1992). Since they are good indicators of environment, capable of supplying information on changes in the ambient features of any ecosystem and also economically important, in the present study an attempt has been made to list the nymphalid fauna from Tamil Nadu.

Globally, nymphalids are represented by 6000 species placed in about 542 genera. In India there are 563 species of nymphalids known (Gasse, 2013). Variable estimates of nymphalids in South India are available: 83 **(**Gunathilagaraj *et al*., 2015), 41 (Singh, 2011), 85 species (Moore, 1890*)*, 65 species (Wynter-Blyth, 1957) and 70 (Antram, 1924). The present attempt provides an updated list of nymphalids from Tamil Nadu, based on field surveys and the literature review.

MATERIALS AND METHODS

The checklist given herein is based on the nymphalids collected from different districts of Tamil Nadu *viz.*, Coimbatore (Tamil Nadu Agricultural University, Mettupalayam, Kunjapannai); Dharmapuri (Hogenakkal); Dindigul (Kodaikanal, Kavunji, Mannavannur); Erode (Pollachi); Madurai (Othakadai); Perambalur; Salem (Yercaud); The Nilgiris (Udagamandalam); Theni (Periyakulam); Thoothukudi (Killikulam, Pudukottai); Tiruchirappalli; Tirunelveli (Courtallam, Sankarankovil); Tiruppur (Table 1). These collected specimens were identified with standard literature (Wynter-Blyth, 1957; Moore, 1890; Antram, 1924) and field guides (Gunathilagaraj *et al*., 2015; Singh, 2011). Also, inventory on butterflies including nymphalids from different parts of the state (till 2006) made subsequently were included: Alagar Hills (Sharmila and Thatheyus, 2013), Peraiyur taluk (Alagumurugan *et al*., 2011), Sirumalai hills Dindigul (Amala *et al.*, 2011), Srivilliputtur (Kumar *et al.*, 2014), Coimbatore (Gunathilagaraj *et al*., 1997), The Nilgiris (Larsen, 1987), Western Ghats (Padhye *et al*., 2006), Siruvani forest (Arun, 2002), Anaikatty hills (Eswaran and Pramod, 2005; Gunasekaran and Balasubramanian, 2010), Thengumarahada (Rufus and Sabarinathan, 2007), Tiruvallur district (Prabakaran *et al.*, 2014); Kalpakkam (Hussain *et al*., 2011), Aringnar Anna Zoo Park, Chennai (Rajagopal *et al.*, 2011) accounting to a total of 46 genera and 106 species in Tamil Nadu.

Table 1. Nymphalidae butterflies collected from Tamil Nadu

S.No	Place of collection	District	GPS Coordinates	Species collected
1.	Tamil Nadu Agricultural University	Coimbatore	11.0124° N, 76.55° E	1, 3-5, 7-9, 11- 28, 32, 34-36, 42,43,45- 54
2.	Mettupalayam		11.19°N 77.56°E	1, 3-5, 11, 12, 16- 27, 29, 30, 32, 36, 42, 45, 46, 52, 54
3.	Kunjapannai		-	31, 33, 38, 33, 44, 47, 49
4.	Hogenakkal	Dharmapuri	12.1158° N, 77.7781° E	11, 12, 16, 17, 22, 45, 46
5.	Kodaikanal	Dindigul	10.2381° N, 77.4892° E	2, 11, 24, 50
6.	Kavunji		10.2070° N, 77.3403° E	32, 39,
7.	Thadiyankudisai		11.4064° N, 76.6932° E	19, 40, 50, 53
8.	Mannavannur		10.2251° N, 77.3446° E	11, 16, 40, 26
9.	Pollachi	Erode	10.6573° N, 77.0107° E	1, 3-5, 7, 8, 11, 12, 17, 19- 28, 32, 34, 36, 37, 42, 45, 46, 54
10.	Othakadai	Madurai	9.9584° N, 78.1877° E	1, 3, 4, 11, 12, 15, 16, 18, 19, 20- 27, 29, 32, 42
11.	Perambalur	Perambalur	11.2410° N, 78.8666° E	1, 4, 11, 12, 16, 18, 19- 22, 24-27, 45, 46, 53
12.	Yercaud	Salem	11.7753° N, 78.2093° E	11, 12, 16, 18, 22, 24- 27, 45, 46,
13.	Udagamandalam	The The Nilgiris	11.4064° N, 76.6932° E	14, 38,41, 48, 49
14.	Periyakulam	Theni	10.1188° N, 77.5485° E	1, 3-5, 7, 16, 18, 19, 20- 27, 32, 33, 34, 42, 45, 46, 52
15.	Killikulam	Thoothukudi	8.7038° N, 77.8625° E	1, 3, 4, 7, 8, 11, 12, 16, 18, 19, 20- 22, 24- 27,32, 34, 45, 46
16.	Pudukottai		8.7369° N, 78.0509° E	8, 11, 12, 16
17.	Tiruchirappalli	Tiruchirappalli	10.7905° N, 78.7047° E	1, 4, 11, 12, 16, 20-22, 23-2732,45, 46
18.	Courtallam	Tirunelveli	8.9339° N, 77.2780° E	6, 9, 13, 14, 16, 18, 44, 49, 53
19.	Sankarankovil		9.1791° N, 77.5309° E	11, 12, 16, 18, 22, 24- 27, 45, 46
20.	Tiruppur	Tiruppur	11.1085° N, 77.3411° E	11, 12, 16, 37, 45, 46

Acraea terpsicore[1], *Argyreus hyperbius*[2], *Ariadne ariadne*[3], *Ariadne merione*[4], *Byblia ilithyia*[5], *Cethosia nietneri*[6], *Charaxes bernardus*[7], *Charaxes solon*[8], *Cupha erymanthis*[9], *Cyrestis thyodamus*[10], *Danaus chrysippus*[11], *Danaus genutia*[12], *Discophora lepida*[13], *Doleschallia bisaltide*[14], *Elymnias hypermnestra*[15], *Euploea core*[16], *Euploea klugii*[17], *Euploea sylvester*[18], *Euthalia aconthea*[19], *Hypolimnas bolina*[20], *Hypolimnas misippus*[21], *Junonia almana*[22], *Junonia atlites*[23], *Junonia hierta*[24], *Junonia iphita*[25], *Junonia lemonias*[26], *Junonia orithya*[27], *Lethe drypetis*[28], *Lethe europa*[29], *Lethe rohria*[30], *Libythea myrrha*[31], *Melanitis leda*[32], *Moduza procris*[33], *Mycalesis mineus*[34], *Mycalesis patnia*[35], *Neptis hylas*[36], *Neptis jumbah*[37], *Pantoporia hordonia*[38], *Parantica aglea*[39], *Parantica nilgiriensis*[40], *Parthenos sylvia*[41], *Phalanta phalantha*[42], *Charaxes agrarian*[43], *Tanaecia lepidea*[44], *Tirumala limniace*[45], *Tirumala septentrionis*[46], *Vanessa cardui*[47], *Vanessa indica*[48], *Vindula erota*[49], *Ypthima avanta*[50], *Ypthima asterope*[51], *Ypthima baldus*[52], *Ypthima ceylonica*[53], *Ypthima huebneri*[54].

The recent classification Nieukerken et al. (2011) is followed. The list was arranged alphabetically by genus and species. For all the species the most current grouping is followed by the author name and year. The catalogue provides scientific Latin names and common English names. The checklist is written based on the latest taxonomy and systematics of the family Nymphalidae.

RESULTS AND DISCUSSION

This nymphalids collected from various districts of Tamil Nadu *viz.*, Coimbatore, Dharmapuri, Dindigul, Erode, Madurai, Perambalur, Salem, Theni, The Nilgiris, Tirunelveli, Tiruppur, Tiruchirappalli, and Tuticorin from 20 localities is given in Table 1. This list provides the 54 species collected along with their distribution and GPS coordinates.

The inventory of the 54 species collected was supplemented and verified with the available information on the species known from Tamil Nadu. This updated inventory reveals that there are about 106 species of nymphalids known from Tamil Nadu. These fall under 45 genera and 11 subfamilies *viz.*, Apaturinae (2 spp.), Biblidinae (4), Charaxinae (6), Cyrestinae (2), Danainae (10), Heliconiinae (9), Libytheinae (4), Limenitidinae (20), Morphinae (3), Nymphalinae (13), Satyrinae (33). The detailed list

along with common names and distribution is given in Table 2 in the form of a checklist.

Thus the present manuscript provides the list of nymphalids from Tamil Nadu, which reveals that, of the 106 species, the subfamily Satyrinae has the most species diversity with 31% of all the species followed by Limentidinae (18.87%), Nymphalinae (12.26%),

Table 2. Checklist of nymphalids from Tamil Nadu (updated from literature review)

S.No	Genus	Species	Common Name	Distribution	Author
Subfamily Apaturinae					
1.	*Euripus* Doubleday, 1848	*Euripus consimilis* (Westwood, 1850)	Painted Courtesan	The Nilgiris	Antram, 1924 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Wynter-Blyth, 1957
2.	*Rohana* Moore, 1880	*Rohana parisatis* (Westwood, 1850)	Black Prince	Tiruvallur District Western Ghats	Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Prabakaran *et al.,* 2014 Wynter-Blyth, 1957
Subfamily Biblidinae					
3.	*Ariadne* Horsfield 1829	*Ariadne ariadne* (Linnaeus, 1763)	Angled castor	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve The Nilgiris Western Ghats	Alagumurugan *et al.*, 2011 Antram, 1924 Arun, 2002 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al*., 2015 Kumar *et al.*, 2014 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
4.		*Ariadne merione* (Cramer, 1777)	Common Castor	Kalakad Mundanthurai Tiger Reserve Kalpakkam Madurai The Nilgiris Tiruvallur District Western Ghats	Alagumurugan *et al.*, 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*,2014 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rajagopal *et al.*, 2011 Rufus and Sabarinathan, 2007 Wynter-Blyth, 1957
5.		*Ariadne merione taprobana* (Westwood, 1851)		The Nilgiris	Moore, 1890

6.	*Byblia* Hubner, 1819	*Byblia ilithyia* (Drury, 1773)	Joker	Western Ghats The Nilgiris	Antram, 1924 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Rufus and Sabarinathan, 2007 Wynter-Blyth, 1957
Subfamily Charaxinae					
7.	*Charaxes* Ochsenheimer, 1816	*Charaxes agrarian* (Swinhoe, 1887)	Anomalous Common Nawab	South India	Gunathilagaraj *et al*., 2015 Larsen, 1987 Wynter-Blyth, 1957
8.		*Charaxes bernardus* (Fabricius, 1793)	Tawny Rajah	Western Ghats	Gunathilagaraj *et al*., 2015 Larsen, 1987 Padhye *et al*., 2012
9.		*Charaxes bharata* Felder & Felder, 1867	Common Nawab	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve Madurai The Nilgiris Western Ghats	Alagumurugan *et al*., 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
10.		*Charaxes psaphon imna* Butler, 1870	Indian Tawny Rajah	Coonoor	Antram, 1924 Moore, 1890 Wynter-Blyth, 1957
11.		*Charaxes schreiberi* (Godart, 1824)	Blue Nawab	Western Ghats	Antram, 1924 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Wynter-Blyth, 1957
12.		*Charaxes solon* (Fabricius, 1793)	Black Rajah	Alagar hills, Madurai Throughout South India Western Ghats	Antram, 1924 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
Subfamily Cyrestinae					
13.	*Cyrestis* Boisduval, 1832	*Cyrestis thyodamus* Boisduval, 1846	Indian Map Butterfly	Kalakad Mundanthurai Tiger Reserve The Nilgiris Western Ghats	Antram, 1924 Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Rufus and Sabarinathan, 2007 Wynter-Blyth, 1957

14.	*Pseudergolis* Felder, 1867	*Pseudergolis wedah* (Kollar, 1848)	Tabby	Coimbatore	Murugesan *et al.*, 2011
Subfamily Danainae					
15.	*Danaus* Kluk, 1780	*Danaus chrysippus* (Linnaeus, 1758)	Plain Tiger	Alagar hills, Madurai Coimbatore Kalakad Mundanthurai Tiger Reserve Kalpakkam Madurai The Nilgiris Sirumalai Hills- Dindigul Tiruvallur District Western Ghats	Alagumurugan *et al.*, 2011 Amala *et al.*, 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al.*, 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al.*, 2012 Prabakaran *et al.*, 2014 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
16.		*Danaus genutia* (Cramer, 1779)	Common or Striped Tiger	Kalakad Mundanthurai Tiger Reserve Kalpakkam The Nilgiris Sirumalai Hills- Dindigul Tiruvallur District Western Ghats Alagar hills, Madurai	Amala *et al.*, 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al.*, 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al.*, 2012 Prabakaran *et al.*, 2014 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
17.	*Euploea* Fabricius, 1807	*Euploea core* (Cramer, 1780)	Common Indian Crow	Alagar hills, Madurai Kalpakkam Madras Madurai Sirumalai Hills- Dindigul Tiruvallur District Western Ghats	Alagumurugan *et al.*, 2011 Amala *et al.*, 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al.*, 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al.*, 2012 Prabakaran *et al.*, 2014 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
18.		*Euploea klugii* Moore, 1858	Blue King Crow	The Nilgiris Tiruvallur District Western Ghats	Gunathilagaraj *et al.*, 2015 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al.*, 2012 Prabakaran *et al.*, 2014 Wynter-Blyth, 1957

19.		*Euploea sylvester* (Fabricius, 1793)	Double-Branded Crow	The Nilgiris Western Ghats	Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Moore, 1890 Padhye *et al*., 2012 Rufus and Sabarinathan, 2007 Wynter-Blyth, 1957
20.	*Idea* Fabricius, 1807	*Idea malabarica* (Moore, 1877)	Malabar Tree Nymph	Kalakad Mundanthurai Tiger Reserve Madurai The Nilgiris	Antram, 1924 Alagumurugan *et al.*, 2011 Arun, 2002 Gunathilagaraj *et al*., 2015 Moore, 1890
21.	*Parantica* Moore, 1880	*Parantica aglea* (Stoll, 1782)	Glassy Tiger	Kalakad Mundanthurai Tiger Reserve Madurai The Nilgiris Tiruvallur District Western Ghats	Alagumurugan *et al.*, 2011 Antram, 1924 Arun, 2002 Gunathilagaraj *et al*., 2015 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rufus and Sabarinathan, 2007 Wynter-Blyth, 1957
22.		*Parantica nilgiriensis* (Moore, 1877)	Nilgiri Tiger	Sirumalai Hills- Dindigul Western Ghats Kalakad Mundanthurai Tiger Reserve	Amala *et al.*, 2011 Antram, 1924 Gunathilagaraj *et al*., 2015 Moore, 1890 Padhye *et al*., 2012 Rufus and Sabarinathan, 2007 Wynter-Blyth, 1957
23.	*Tirumala* Moore, 1880	*Tirumala limniace* (Cramer, 1775)	Blue Tiger	Kalakad Mundanthurai Tiger Reserve Kalpakkam Madurai The Nilgiris Sirumalai Hills- Dindigul Tiruvallur District Western Ghats	Alagumurugan *et al.*, 2011 Amala *et al.*, 2011 Antram, 1924 Arun, 2002 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rufus and Sabarinathan, 2007 Wynter-Blyth, 1957
24.		*Tirumala septentrionis* (Butler, 1874)	Dark Blue Tiger	Alagar hills, Madurai Coimbatore Kalakad Mundanthurai Tiger Reserve Kalpakkam Madurai Tiruvallur District Western Ghats	Alagumurugan *et al.*, 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957

Subfamily Heliconiinae					
25.	*Acraea* Fabricius, 1807	*Acraea terpsicore* (Fabricius, 1793)	Tawny Coster	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve Kalpakkam Madurai Sirumalai Hills- Dindigul Tiruvallur District Western Ghats	Alagumurugan *et al.*, 2011 Amala *et al.*, 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
26.	*Argyreus* Scopoli, 1777	*Argyreus hyperbius* (Linnaeus, 1763)	Indian Fritillary	Madurai The Nilgiris	Alagumurugan *et al.*, 2011 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Wynter-Blyth, 1957
27.	*Cirrochroa* Doubleday, 1847	*Cirrochroa thais* (Fabricius, 1787)	Tamil Yeoman	Kalakad Mundanthurai Tiger Reserve The Nilgiris Tiruvallur District	Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Prabakaran *et al.*, 2014 Wynter-Blyth, 1957
28.	*Cethosia* Fabricius, 1807	*Cethosia cyane* (Drury, 1773)	Leopard lacewing	Coimbatore	Antram, 1924 Murugesan *et al.*, 2011
29.		*Cethosia nietneri* Felder, 1867	Tamil Lacewing	Kalakad Mundanthurai Tiger Reserve Tiruvallur District Western Ghats	Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Wynter-Blyth, 1957
30.	*Cupha* Billberg, 1820	*Cupha erymanthis* (Drury, 1773)	Rustic	Kalakad Mundanthurai Tiger Reserve Ootacamund Tiruvallur District Western Ghats	Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Wynter-Blyth, 1957
31.	*Phalanta* Horsfield, 1829	*Phalanta alcippe* (Stoll, 1782)	Small Leopard	South India	Antram, 1924 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Wynter-Blyth, 1957

32.		*Phalanta phalantha* (Drury, 1773)	Leopard	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve Kalpakkam Sirumalai Hills- Dindigul Tiruvallur District Western Ghats	Amala *et al.*, 2011 Arun, 2002 Eswaran and Pramod, 2005 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al.*, 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Moore, 1890 Padhye *et al.*, 2012 Prabakaran *et al.*, 2014 Rajagopal *et al.*, 2011 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
33.	*Vindula* Hemming, 1934	*Vindula erota* (Fabricius,1793)	Cruiser	Kalakad Mundanthurai Tiger Reserve Madurai The Nilgiris	Alagumurugan *et al.*, 2011 Gunathilagaraj *et al.*, 2015 Larsen, 1987 Moore, 1890
Subfamily Libytheinae					
34.	*Libythea* Fabricius, 1807	*Libythea celtis* (Laicharting, 1782)	Nettle-tree Butterfly European Beak	The Nilgiris	Moore, 1890
35.		*Libythea lepita* (Moore, 1857)	Common Beak	Alagar hills, Madurai Western Ghats	Eswaran and Pramod, 2005 Gunathilagaraj *et al.*, 2015 Larsen, 1987 Padhye *et al.*, 2012 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
36.		*Libythea myrrha* Godart, 1819	Club Beak	Kalakad Mundanthurai Tiger Reserve Tiruvallur District Western Ghats	Antram, 1924 Gunathilagaraj *et al.*, 2015 Moore, 1890 Padhye *et al.*, 2012 Prabakaran *et al.*, 2014 Wynter-Blyth, 1957
37.		*Libythea rama* Moore, 1872		Anaimalai hills Ootacamund Palni Hills	Moore, 1890
Subfamily Limenitidinae					
38.	*Athyma* Westwood, 1850	*Athyma nefte* (Cramer, 1780)	Color sergeant	Western Ghats	Gunathilagaraj *et al.*, 2015 Larsen, 1987 Padhye *et al.*, 2012 Wynter-Blyth, 1957
39.		*Athyma perius* (Linnaeus, 1758)	Common sergeant	Western Ghats	Antram, 1924 Arun, 2002 Gunathilagaraj *et al.*, 2015 Larsen, 1987 Moore, 1890 Padhye *et al.*, 2012 Wynter-Blyth, 1957

40.		*Athyma ranga* Moore, 1858	Black Vein Sergeant	Kalakad Mundanthurai Tiger Reserve The Nilgiris	Antram, 1924 Arun, 2002 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890
41.		*Athyma selenophora* (Kollar, 1844)	Staff Sergeant	The Nilgiris	Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Wynter-Blyth, 1957
42.	*Dophla* Moore, 1880	*Dophla evelina* (Stoll, 1790)	Red-spot Duke	The Nilgiris	Moore, 1890
43.	*Euthalia* Hubner, 1819	*Euthalia aconthea* (Cramer, 1777)	Common baron	Alagar hills, Madurai Coimbatore Kalakad Mundanthurai Tiger Reserve Madras The Nilgiris Western Ghats	Alagumurugan *et al.*, 2011 Kumar *et al.*, 2014 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
44.		*Euthalia lubentina* (Cramer, 1777)	Gaudy Baron	Western Ghats	Gunathilagaraj *et al*., 2015 Larsen, 1987nai Moore, 1890 Padhye *et al*., 2012 Wynter-Blyth, 1957
45.		*Euthalia nais* (Forster, 1771)	Baronet	Alagar hills, Madurai Coimbatore Kalakad Mundanthurai Tiger Reserve	Antram, 1924 Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Kumar *et al.*, 2014 Larsen, 1987 Murugesan *et al.*, 2011 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
46.	*Lasippa* Moore, 1898	*Lasippa viraja* (Moore, 1872)	Yellowjack Sailer	South India	Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890
47.	*Moduza* Moore, 1881	*Moduza procris* (Cramer, 1777)	Commander	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve	Alagumurugan *et al.*, 2011 Antram, 1924 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
48.	*Neptis* Fabricius, 1807	*Neptis ananta* Moore, 1858	Yellow sailer	Alagar hills, Madurai	Sharmila and Thatheyus., 2013
49.		*Neptis clinia* Moore, 1872	Southern Sullid Sailer	Western Ghats	Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012

50.		*Neptis columella* (Cramer, 1780)	Shortbanded Sailer	The Nilgiris Western Ghats	Antram, 1924 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012
51.		*Neptis hylas* (Linnaeus, 1758)	Common Sailer	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve Kalpakkam The Nilgiris Tiruvallur District Western Ghats	Alagumurugan *et al.*, 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rajagopal *et al*., 2011 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013
52.		*Neptis jumbah* Moore, 1858	Chestnut-Streaked Sailer	Kalakad Mundanthurai Tiger Reserve Western Ghats	Antram, 1924 Arun, 2002 Gunathilagaraj *et al*., 2015 Larsen, 1987 Padhye *et al*., 2012 Rajagopal *et al*., 2011
53.		*Neptis nata* Moore, 1858	Dirty Sailer	Ootacamund	Larsen, 1987 Moore, 1890
54.		*Neptis soma* Moore, 1858	Sullied Sailer	Tiruvallur District Western Ghats	Antram, 1924 Gunathilagaraj *et al*., 2015 Larsen, 1987 Padhye *et al*., 2012 Prabakaran *et al.*, 2014
55.	*Pantoporia* Hubner, 1819	*Pantoporia hordonia* (Stoll, 1790)	Common Lascar	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve The Nilgiris Western Ghats	Alagumurugan *et al.*, 2011 Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Sharmila and Thatheyus., 2013
56.	*Parthenos* Hubner, 1819	*Parthenos sylvia* (Cramer, 1776)	Clipper	South India	Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Wynter-Blyth, 1957
57.	*Tanaecia* Butler, 1869	*Tanaecia lepidea* (Butler, 1868)	Grey Count	Kalakad Mundanthurai Tiger Reserve	Arun, 2002 Gunathilagaraj *et al*., 2015 Larsen, 1987 Wynter-Blyth, 1957
Subfamily Morphinae					
58.	*Discophora* Boisduval, 1836	*Discophora lepida* (Moore, 1857)	Southern Duffer	The Nilgiris	Antram, 1924 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Wynter-Blyth, 1957

59.		*Discophora sondaica* Boisduval, 1836	Common daffer	Coimbatore	Murugesan *et al.*, 2011
60.	*Thaumantis* Hubner, 1826	*Thaumantis diores* Doubleday, 1845	Jungle glory	Alagar hills, Madurai	Sharmila and Thatheyus., 2013
Subfamily Nymphalinae					
61.	*Doleschallia* Felder, 1860	*Doleschallia bisaltide* (Cramer, 1777)	Autumn Leaf	South India	Antram, 1924 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Wynter-Blyth, 1957
62.	*Hypolimnas* Hubner, 1819	*Hypolimnas bolina* (Linnaeus, 1758)	Great Eggfly	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve Kalpakkam Sirumalai Hills- Dindigul Tiruvallur District Western Ghats	Alagumurugan *et al.*, 2011 Amala *et al*., 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rajagopal *et al*., 2011 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
63.		*Hypolimnas misippus* (Linnaeus, 1764)	Danaid Eggfly	Kalpakkam Madurai Sirumalai Hills- Dindigul Tiruvallur District Western Ghats	Alagumurugan *et al.*, 2011 Amala *et al*., 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rajagopal *et al*., 2011 Rufus and Sabarinathan, 2007 Wynter-Blyth, 1957

63.		*Hypolimnas misippus* (Linnaeus, 1764)	Danaid Eggfly	Kalpakkam Madurai Sirumalai Hills- Dindigul Tiruvallur District Western ghats	Alagumurugan *et al.*, 2011 Amala *et al.*, 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rajagopal *et al.*, 2011 Rufus and Sabarinathan, 2007 Wynter-Blyth, 1957
64.	*Junonia* Hubner, [1819]	*Junonia almana* (Linnaeus, 1758)	Peacock Pansy	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve Kalpakkam The Nilgiris Tiruvallur District Western Ghats	Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rajagopal *et al.*, 2011 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
65.		*Junonia atlites* (Linnaeus, 1763)	Grey Pansy	Alagar hills, Madurai Kalpakkam Tiruvallur District	Alagumurugan *et al.*, 2011 Arun, 2002 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Prabakaran *et al.*, 2014 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
66.		*Junonia iphita* (Cramer, [1779])	Chocolate Pansy	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve Kalpakkam The Nilgiris Tiruvallur District	Alagumurugan *et al.*, 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014

			Western Ghats	Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rajagopal *et al*., 2011 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
67.	*Junonia hierta* (Fabricius, 1798)	Yellow Pansy	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve Kalpakkam The Nilgiris Sirumalai Hills- Dindigul Tiruvallur District Western Ghats	Amala *et al.*, 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rajagopal *et al*., 2011 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
68.	*Junonia lemonias* (Linnaeus, 1758)	Lemon Pansy	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve Kalpakkam The Nilgiris Sirumalai Hills- Dindigul Tiruvallur District Western Ghats	Alagumurugan *et al.*, 2011 Amala *et al.*, 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rajagopal *et al*., 2011 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
69.	*Junonia orithya* (Linnaeus, 1758)	Blue Pansy	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve Kalpakkam Sirumalai Hills- Dindigul Tiruvallur	Amala *et al.*, 2011 Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunasekaran and Balasubramanian, 2010 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014

				District Western Ghats	Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rajagopal *et al*., 2011 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
70.	*Kallima* Doubleday, 1849	*Kallima horsfieldii* Kollar, 1844	South Indian Blue Oakleaf	South India Western Ghats	Antram, 1924 Arun, 2002 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Wynter-Blyth, 1957
71.	*Nymphalis* Kluk, 1780	*Nymphalis canace* (Linnaeus, 1763)	Blue Admiral	Kalakad Mundanthurai Tiger Reserve	Antram, 1924 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Wynter-Blyth, 1957
72.	*Vanessa* Fabricius, 1807	*Vanessa cardui* (Linnaeus, 1758)	Painted lady	All over India	Antram, 1924 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Larsen, 1987 Moore, 1890 Wynter-Blyth, 1957
73.		*Vanessa indica* (Herbst, 1794)	Indian red admiral	The Nilgiris Sirumalai Hills- Dindigul	Amala *et al.*, 2011 Antram, 1924 Gunathilagaraj *et al*., 2015 Moore, 1890 Wynter-Blyth, 1957
Subfamily Satyrinae					
74.	*Elymnias* Hubner, 1818	*Elymnias caudata* Butler, 1871		The Nilgiris	Moore, 1890
75.		*Elymnias hypermnestra* (Linnaeus, 1763)	Common Palmfly	Kalakad Mundanthurai Tiger Reserve Western Ghats	Gunathilagaraj *et al*., 2015 Larsen, 1987 Padhye *et al*., 2012 Wynter-Blyth, 1957
76.	*Lethe* Hubner, 1819	*Lethe drypetis* (Hewitson, 1868)	Tamil Treebrown	The Nilgiris	Antram, 1924 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890
77.		*Lethe europa* (Fabricius, 1775)	Bamboo Treebrown	Western Ghats	Arun, 2002 Gunathilagaraj *et al*., 2015 Larsen, 1987 Padhye *et al*., 2012
78.		*Lethe rohria* (Fabricius, 1787)	Common Treebrown	The Nilgiris Western Ghats	Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Rufus and Sabarinathan, 2007 Padhye *et al*., 2012
79.	*Melanitis* Fabricius, 1807	*Melanitis leda* (Linnaeus, 1758)	Common Evening Brown	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve	Amala *et al.*, 2011 Arun, 2002 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014

				Kalpakkam The Nilgiris Sirumalai Hills- Dindigul Tiruvallur District Western Ghats	Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013 Wynter-Blyth, 1957
80.		*Melanitis phedima* (Cramer, 1780)	Dark Evening Brown	The Nilgiris Western Ghats	Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Wynter-Blyth, 1957
81.		*Melanitis zitenius* (Herbst, 1796)	Great Evening Brown	The Nilgiris	Antram, 1924 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Wynter-Blyth, 1957
82.		*Melanitis zitenius kalinga* Moore, 1894		The Nilgiris	Moore, 1890
83.	*Mycalesis* Hubner, 1818	*Mycalesis adolphei* (Guerin-Meneville, 1843)	Redeye Bushbrown	The Nilgiris	Antram, 1924 Larsen, 1987 Moore, 1890 Wynter-Blyth, 1957
84.		*Mycalesis anaxias* Hewitson, 1862	Whitebar Bushbrown	The Nilgiris	Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Rufus and Sabarinathan, 2007 Wynter-Blyth, 1957
85.		*Mycalesis igilia* Fruhstorfer, 1911	Small Longbrand Bushbrown	The Nilgiris	Chandrasekharan, 2017 Wynter-Blyth, 1957
86.		*Mycalesis intermedia* (Moore, 1892)	Palebrand Bushbrown	South India	Larsen, 1987 Wynter-Blyth, 1957
87.		*Mycalesis mamerta* (Stoll, 1780)	Blind-eye Bushbrown	Trichy	Larsen, 1987
88.		*Mycalesis mineus* (Linnaeus, 1758)	Dark Branded Bushbrown	The Nilgiris Tiruvallur District Western Ghats	Gunathilagaraj *et al*., 2015 Larsen, 1987 Kumar *et al.*, 2014 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014
89.		*Mycalesis nicotia* Westwood, 1850	Bright eye bush brown	Coimbatore	Murugesan *et al.*, 2011
90.		*Mycalesis oculus* Marshall, 1880	Red-Disc Bushbrown	Anaimalai hills	Antram, 1924 Gunathilagaraj *et al*., 2015 Moore, 1890 Wynter-Blyth, 1957
91.		*Mycalesis patnia* Moore, 1857	Gladeye Bushbrown	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve The Nilgiris	Arun, 2002 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Rufus and Sabarinathan, 2007

					Sharmila and Thatheyus., 2013
92.		*Mycalesis perseus* (Fabricius, 1775)	Common Bushbrown	Kalpakkam The Nilgiris	Wynter-Blyth, 1957 Antram, 1924 Arun, 2002 Gunathilagaraj *et al*., 2015 Hussain *et al.*, 2011 Kumar *et al.*, 2014 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Rufus and Sabarinathan, 2007
93.		*Mycalesis subdita* (Moore, 1890)	Tamil Bushbrown	Tiruvallur District	Wynter-Blyth, 1957 Larsen, 1987 Moore, 1890 Prabakaran *et al.*, 2014
94.		*Mycalesis visala* Moore, 1858	Long-Brand Bushbrown	Alagar hills, Madurai The Nilgiris Western Ghats	Wynter-Blyth, 1957 Antram, 1924 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Sharmila and Thatheyus., 2013
95.	*Orsotriaena* Wallengren, 1858	*Orsotriaena medus* (Fabricius, 1775)	Nigger	The Nilgiris Tiruvallur District	Wynter-Blyth, 1957 Arun, 2002 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Prabakaran *et al.*, 2014 Rufus and Sabarinathan, 2007
96.	*Parantirrhoea* Wood-Mason, 1881	*Parantirrhoea marshalli* Wood-Mason, 1881	Travancore Evening Brown	The Nilgiris	Wynter-Blyth, 1957 Moore, 1890
97.	*Ypthima* Hubner, 1818	*Ypthima asterope* (Klug, 1832)	Common Threering	Western Ghats	Gunathilagaraj *et al*., 2015 Larsen, 1987 Padhye *et al*., 2012 Rufus and Sabarinathan, 2007
98.		*Ypthima avanta* Moore, 1875	Jewel Fourring	Western Ghats	Gunathilagaraj *et al*., 2015 Larsen, 1987 Padhye *et al*., 2012
99.		*Ypthima baldus* (Fabricius, 1775)	Common Fivering	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve The Nilgiris Tiruvallur District	Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Prabakaran *et al.*, 2014 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013
100.		*Ypthima ceylonica* Hewitson, 1865	White Fourring	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve	Antram, 1924 Arun, 2002 Eswaran and Pramod, 2005 Gunathilagaraj *et al*., 2015 Kumar et al., 2014

				Madras The Nilgiris	Larsen, 1987 Moore, 1890 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013
101.		*Ypthima chenui* (Guérin-Méneville, 1843)	Nilgiri Fourring	Anamalai Hills, Coonoor, Ootacamund	Antram, 1924 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890
102.		*Ypthima huebneri* Kirby, 1871	Common Fourring	Alagar hills, Madurai Kalakad Mundanthurai Tiger Reserve The Nilgiris Tiruvallur District Western Ghats	Antram, 1924 Arun, 2002 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890 Murugesan *et al.*, 2011 Padhye *et al*., 2012 Prabakaran *et al.*, 2014 Rufus and Sabarinathan, 2007 Sharmila and Thatheyus., 2013
103.		*Ypthima philomela* (Linnaeus, 1763)	Baby Fourring	The Nilgiris Western Ghats	Antram, 1924 Larsen, 1987 Moore, 1890 Padhye *et al*., 2012 Rufus and Sabarinathan, 2007
104.		*Ypthima striata* Hampson, 1889	Striated Five-ring	The Nilgiris	Moore, 1890
105.		*Ypthima ypthimoides* (Moore, 1881)	Palani Fourring	Anamalai Hills Kalakad Mundanthurai Tiger Reserve	Antram, 1924 Gunathilagaraj *et al*., 2015 Moore, 1890
106.	*Zipaetis* Hewitson, 1863	*Zipaetis saitis* Hewitson, 1863	Tamil Catseye	The Nilgiris	Antram, 1924 Gunathilagaraj *et al*., 2015 Larsen, 1987 Moore, 1890

Danainae (9.43%), Heliconiinae (8.49%), Charaxinae (5.66%), Biblidinae and Libytheinae (3.77%), Morphinae (2.83%) and Apaturinae and Cyrestinae (1.88%). The genus that has the highest number of species were *Mycalesis* (12 spp.), *Ypthima* (9 spp.), *Neptis* (7 spp.), and *Junonia* (6 spp.).

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FORAGING ECOLOGY OF INSECT POLLINATORS ON APPLE BLOSSOMS IN KASHMIR HIMALAYA

M.A.PARAY*, RIZWANA KHURSHEED, MUNAZAH YAQOOB SHIFA AND DEELAK AMIN

Research and Training Centre for Pollinators, Pollinizers and Pollination Management
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir
Shalimar, Srinagar 190025
**Email: sajadzoo@gmail.com (corresponding author)*

ABSTRACT

A study was undertaken in five districts of Kashmir during 2012-15 at 15% bloom to study the foraging time, foraging rate, foraging speed and loose pollen grain load by insect pollinators visiting apple blossoms. This revealed that among the insect pollinators/ visitors, the earliest mean initiation foraging activity of 0723 ± 0012 h was reported with *Apis cerana* followed by *Xylocopa* spp. (0742 ± 0019 h), *Andrena* spp. (0747± 0015 h), *Lassioglossum* spp. (0756± 0016 h) and *Apis mellifera* (0859± 0016 h), respectively. Late cessation was recorded in *A. cerana* (1800± 0019 h) followed by *A. mellifera* (1735± 0014 h), *Xylocopa* spp. (1659± 0021 h), *Andrena* spp. (1658± 0013 h) and *Lassioglossum* spp. (1656± 0015 h). The observations on the number of flowers visited/ min and time spent/ flower revealed that *Xylocopa* spp. visited maximum number of flowers (14.6± 1.14) in 6.2 ± 2.60 sec. Maximum pollen grains (11121± 635 and 10937± 492) under caged conditions was observed with *A. mellifera* and under natural conditions, and maximum pollen grains (15636± 1026 and 14034± 1136) was carried by *Xylocopa* spp.

Key words: Apple blossoms, insect pollinators, bees, *Apis mellifera, A. cerana, Andrena, Lassioglossum, Xylocopa*, foraging activity- time, rate, speed, pollen load

Kashmir valley is the apple bowl of India both in terms of area under plantation and production. During the past decade, farmers have been recording falling yield (up to 30- 40%) due to inadequate crop pollination. Apples are typically self incompatible and require pollen transfer from another "pollinizers" cultivar to set fruit in marketable quantities. Wind and self pollination are insignificant in apple and therefore insects such as bees and hover flies are the predominant pollination vectors and their activity in orchards is essential (Delaplane and Mayer, 2000; Klein et al., 2007). The availability of suitable pollinators during flowering time is crucial for achieving optimum pollination. Insect pollinators help in sustaining the hybrid vigour, create variation and maintain the gene flow in the ecosystem (Subhaker and Sreedevi, 2015). Pratap and Pratap (2002) concluded that bees play very important role in the pollination of apple in Himalaya.

Foraging behavior is one of the important characteristic of bees and it is critical for pollination. Pollination of apples is more complicated in comparison to other fruits as five stigmas have to be pollinated separately (as the transmitting tissue of each style is separate; Pratt, 1988) otherwise misshaped fruits result (Free, 1993). Foraging rate is one of the important factors to compare pollination efficiency of these bees. More the foraging frequency more is the pollination efficiency (Singh et al., 2006). Pollination by insect pollinators is many times taken for granted and little attention is paid to the foraging ecology, especially with those visiting apple blossoms. Therefore, the present study which evaluates foraging activity of some major insect pollinators in apple.

MATERIALS AND METHODS

Study was carried out in five districts of Kashmir Himalaya *viz;* Baramulla, Bandipora, Budgam, Pulwama and Shopian during April, 2014. Five orchards were selected in each district to study the foraging time, foraging rate, foraging speed and loose pollen grain load at 15% apple bloom. The observations were recorded on sunny days. Colonies of *Apis mellifera* and *A. cerana* were placed in the selected orchards with equal number of frames in brood chamber with similar strength and almost equal amount of brood. The initiation and cessation activity of the pollinators/ visitors visiting flowers were recorded. Foraging speed

was recorded in terms of time in sec spent by them on each flower and the number of flowers visited/ min. (foraging rate) as per Free (1993). The mean foraging speed was expressed as sec./flower. The time spent/ flower was recorded with a stop watch (accuracy of 0.01 sec.).

The number of flowers visited/min. was recorded from the time a pollinator alighted on flower untill it left the field including flying time from one flower to another. For recording the number of pollen grains collected, the pollen gatherer were captured on flower gently with the help of forceps and killed immediately in 70% ethanol in glass vial after amputating the hind pair of legs. The vials were shaken thoroughly to remove the loose pollen grains from the body. The bees were further rinsed to remove the adhering pollen grains. Total volumes of reinstate were made to 3 ml before pollen count. An aliquot, 0.01 ml (with 5 replications) was observed the number of pollen grains counted with a haemocytometer and stereozoom microscope (10x). Number of pollen grains in the whole reinstate was calculated (n=10). Foraging group was observed for counting the pollen grains. For this study, bees were captured between 1130 and 1400 hr.

RESULTS AND DISSCUSSION

Insect pollinators

The field observations during 2012-15 revealed 43 species belonging to 11 families and 25 genera under Hymenoptera, Diptera and Lepidoptera (Table 1). Currently farmers manage only 11 of the 20000 to 30000 bee species worldwide (Parker et al. 1987). European honey bee (*A. mellifera*) and indigenous honey bee (*A. cerana*) are the most important used for pollination and for honey production in India and Jammu and Kashmir. The pollinators that can used for pollination purpose include *Bombus simillmus* Smith and *B. tunicatus* Smith. *Lassioglossum himalayense* Bingham, *L. nursei* Blüthgen, *L. rugolatum* Smith, *L. polyctor* Bingham, *L. marginatum* Brullé, *L. sublaterale* Blüthgen, *L. leucozonium* Schrank, *Halictus constrictus* Smith, *H.* (*Seladonia*) *propinquus* Smith and *Megachile conjuncta* Smith are the other wild bees that can be used.

Well known pollinators that had been used to replace honey bees include alfalfa leaf cutter bee (*Megachile rotundata*) and alkali bee (*Nomia melanderi*) (Cane, 2002), meson bee (*Osmia* spp.) for pollination of orchards (Bosch and Kemp, 2002; Maccagnani et al., 2003) and bumble bee (*Bombus* spp.) for pollination of crops requiring buzz pollination (Velthuis and van Doorn, 2006). Paray et al. (2014) studied the distributional diversity of insect pollinators in apple orchards of Kashmir valley.

Foraging activity

In apple orchards of Kashmir *A. cerana*, *A. mellifera*, *Lassioglossum* spp. and *Andrena* spp. were the most frequent visitors. The initiation and cessation activity of such insect pollinators/visitors in apple blossoms revealed that essential mean initiation foraging of *A. cerana* was 0723± 0019 h, followed by *Xylocopa* spp. (0742± 0019 h), *Andrena* spp. (0747± 0015 h), *Lassioglossum* spp. (0756± 0016 h) and *A. mellifera* (0859± 0016 h), respectively. Similarly late cessation was also recorded in *A.cerana* (1800± 0019 h) followed by *A. mellifera* (1735± 0014 h), *Xylocopa* spp. (1659± 0021 h), *Andrena* spp. (1658± 0013 h) and *Lassioglossum* spp. (1656± 0015 h) (Table 2).

As regards number of flowers visited/min snd time spent/ flower given in Table 3 reveal that *Xylocopa* spp. visited maximum number of flowers (14.6 ± 1.14) in 6.2± 2.60 sec followed by Apis 2.60 sec. followed by *A. cerana* (8.2± 1.64), *A. mellifera* (6.8 ± 0.85), *Lassioglossum* spp. (5.0± 1.67), *Andrena* spp. (3.5± 0.55) and *syrphids* (2.8± 1.30) in 4.9± 1.20; 5.7± 1.90; 8.4± 1.70; 3.6± 1.20 and 9.6± 1.8 sec., respectively. The highest number of pollen grains (11121 ± 635 and 10937 ± 492) under caged conditions was found in *A. mellifera* followed by *A. cerana* in Budgam and Srinagar, respectively (Table 4, 5).

The data on the gathering of pollen grains revealed that the maximum number (15636± 1026 and 14034± 1136) was observed with *Xylocopa* spp. followed by *A. mellifera* (8390± 571 and 8249± 582), and others (Table 6,7). Results showed that *A. cerana* started its activity earlier (0723± 0012 h) and attained its peak between 1200-1300 hr. *Apis mellifera* started later (0859± 0016 h) and got its peak at 1100-1200 h.

These observations corroborate with those of Rymahesvskii (1956), Verma and Dutta (1986), Dhaliwal and Bhalla (1980), Raj and Rana (1994), Singh et al. (2006), Joshi and Joshi (2010), Pratap and Pratap (2001) and Paray et al. (2014).

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Table 1. Insect pollinators/visitors in apple-Kashmir

S.No.	Species	Family	Order
1.	*Xylocopa valga* Gerstaecker	Apidae	Hymenoptera
2.	*Xylocopa violacea* Linn	Apidae	Hymenoptera
3.	*Bombus simillmus* Smith	Apidae	Hymenoptera
4.	*Bombus tunicatus* Smith	Apidae	Hymenoptera
5.	*Bombus trifasciatus* Smith	Apidae	Hymenoptera
6.	*Amegilla fallax* (Smith)	Apidae	Hymenoptera
7.	*Apis cerana* Fabricius	Apidae	Hymenoptera
8.	*Apis mellifera* Linn.	Apidae	Hymenoptera
9.	*Mellitina harrietae* Bingham	Apidae	Hymenoptera
10.	*Lassioglossum himalayense* Bingham	Halictidae	Hymenoptera
11.	*Lassioglossum nursei* Blüthgen	Halictidae	Hymenoptera
12.	*Lassioglossum rugolatum* Smith	Halictidae	Hymenoptera
13.	*Lassioglossum polyctor* Bingham	Halictidae	Hymenoptera
14.	*Lasioglossum marginatum* Brullé	Halictidae	Hymenoptera
15.	*Lasioglossum sublaterale* Blüthgen	Halictidae	Hymenoptera
16.	*Lasioglossum leucozonium* Schrank	Halictidae	Hymenoptera
17.	*Halictus constrictus* Smith	Halictidae	Hymenoptera
18.	*Halictus* (*Seladonia*) *propinquus* Smith	Halictidae	Hymenoptera
19.	*Sphecodes tantalus* Nurse	Halictidae	Hymenoptera
20.	*Sphecodes lasimensis* Blüthgen	Halictidae	Hymenoptera
21.	*Andrena patella* Nurse	Andrenidae	Hymenoptera
22.	*Andrena cineraria* Linn.	Andrenidae	Hymenoptera
23.	*Andrena floridula* Smith	Andrenidae	Hymenoptera
24.	*Andrena flavipes* Panzer	Andrenidae	Hymenoptera
25.	*Ceratina hieroglyphica* Smith	Ceratidae	Hymenoptera
26.	*Ceratina propinqua* Cameron	Ceratidae	Hymenoptera
27.	*Ceratina lepida* Smith	Ceratidae	Hymenoptera
28.	*Anthidium conciliatum* Nurse	Megachalidae	Hymenoptera
29.	*Megachile conjuncta* Smith	Megachalidae	Hymenoptera
30.	*Megachile sp.*	Megachalidae	Hymenoptera
31.	*Heriades spp.*	Megachalidae	Hymenoptera
32.	*Athalia proxima* Klug	Tenthredinidae	Hymenoptera
33.	*Metasyrphus bucculatus* Rondani	Syrphidae	Diptera
34.	*Sphaerophoria bengalensis* Macqaurt	Syrphidae	Diptera
35.	*Episyrphus balteatus* (Degeer)	Syrphidae	Diptera
36.	*Eristalodes paria* (Bigot)	Syrphidae	Diptera
37.	*Eristalis tenax* Linn	Syrphidae	Diptera
38.	*Eoseristalis cerealis* Fabricius	Syrphidae	Diptera
39.	*Bibio sp.*	Bibionidae	Diptera
40	*Plecia sp.*	Bibionidae	Diptera
41.	*Scathophaga sp.*	Scathophagidae	Diptera
42.	*Pieris brassicae* Linn	Pieridae	Lepidoptera
43.	*Vanessa cashmirensis* Kollar	Nymphalidae	Lepidoptera

Table 2. Foraging period of insect pollinators

Insect pollinators/visitors	Mean pollination/foraging activity time (hour)		
	Initiation	Peak	Cessation
Apis cerana	0723±0012	1200-1300	1800 ±0019
A.mellifera	0859±0016	1400-1500	1735 ±0014
Xylocopa	0742±0019	1100-1200	1659 ±0021
Lassioglossum	0756±0016	1130-1230	1656 ±0015
Andrena	0747±0015	1100-1200	1658 ±0013

Table 3. Foraging activity of insect pollinators

Insect Pollinators	Mean no. of flowers visited / 15 min.	Mean timespent / flower (sec.)
Apis cerana	8.2±1.64	4.9±1.20
A.mellifera	6.8±0.85	5.7±1.90
Xylocopa sp	14.6±1.14	6.2±2.60
Lassioglossum sp.	5.0±1.67	8.4±1.70
Andrena	3.5±0.55	3.6±1.20
Syrphid	2.8±1.30	9.6±1.8

Table 4. Loose pollen grains carried by insect pollinators (caged conditions)

Pollinator	Budgam			Mean
	Khag	Beerwah	Khansahib	
Apis mellifera	11373 ± 473	10902 ± 636	11089 ± 796	11121 ± 635
Apis cerana	7756 ± 597	8599 ± 548	7765 ± 682	8040 ± 609

Table 5. Loose pollen grains carried by insect pollinators (caged conditions)

Pollinator	Srinagar			*Mean
	Harwan	Gulab Bagh	Tailbal	
Apis mellifera	11484 ± 398	10978 ± 453	10350 ± 627	10937 ± 492
Apis cerana	7953 ± 496	7208 ± 512	8021 ± 423	7727 ± 477

*Mean of 10 replications

Table 6. Loose pollen grains carried by insect pollinators (natural conditions)

Pollinator	Budgam			*Mean
	Khag	Beerwah	Khansahib	
Apis mellifera	8965 ± 521	8074 ± 549	8132 ± 645	8390 ± 571
Apis cerana	7171 ± 501	7531 ± 523	7241 ± 611	7314 ± 545
Halictidae	5469 ± 422	5393 ± 511	5031 ± 474	5297 ± 469
Syrphidae	3123 ±312	3342 ± 361	3213 ± 311	3226 ± 328
Xylocopa sp.	14257±1021	15721±934	16930±1124	15636±1026

*Mean of 10 replications

Table 7. Loose pollen grains carried by insect pollinators (natural conditions, Dist. Srinagar)

Pollinator	Srinagar			Mean
	Harwan	Gulab Bagh	Tailbal	
Apis mellifera	8231 ± 610	7987 ± 545	8531 ± 591	8249 ±582
Apis cerana	6937 ± 522	7201 ± 553	6975 ± 484	7037 ± 519
Lassioglossum sp	6213 ± 392	5931 ± 456	5527 ± 502	5890 ± 450
Syrphids	2975 ± 296	3472 ± 341	3493 ± 378	3313 ± 298
Xylocopa sp	14241±1221	14112±1037	13749±1152	14034±1136

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FIELD EFFICACY OF ENTOMOFUNGAL PATHOGENS AGAINST SORGHUM STEM BORER *CHILO PARTELLUS* (SWINHOE)

B. RAMANUJAM*, KRISHNA JAPUR AND B. POORNESHA

ICAR-National Bureau of Agricultural Insect Resources
H.A. Farm post, Bellary Road, Bengaluru 560024
**Email: bonamramanujam58@gmail.com (corresponding author)*

ABSTRACT

The field experiment was carried out to assess the efficacy of four isolates of entomofungal pathogens of *Beauveria bassiana* (Bb-5a, Bb-23 and Bb-45) and *Metarhizium anisopliae* (Ma-35) against sorghum stem borer, *Chilo partellus* (Swinhoe) during *kharif* 2015 and 2016 at the ICAR-National Bureau of Agricultural Insect Resources (NBAIR), Attur Farm, Yelhanka, Bengaluru. All the tested fungal isolates showed suppression of damage and the pooled data revealed lesser deadhearts (6.4-11.8%), stem tunnelling (3.51-7.4 cm/plant), galleries (0.3-1.3 no./plant) and exit holes (0.43-1.62 no./plant) compared to untreated control, which showed 18.4% deadhearts, 9.61 cm stem tunnelling/plant, 1.9 galleries/ plant and 2.02 exit holes/plant. Amongst the four isolates tested, Bb-23 and Bb-5a revealed significantly superior effect in lowering the incidence of deadhearts, stem tunnelling, galleries and exit holes, with higher yield of 11.61 and 11.52 q/ha respectively.

Key words: Stem borer, *Chilo partellus*, entomofungal pathogens, *Beauveria bassiana*, *Metarhizium anisopliae*, deadhearts, stem tunnelling, galleries, exit holes, grain yield

Sorghum bicolor (L.) Moench is the fifth most important cereal and insect pests are the major constraints for its production and productivity. The stem borers mainly *Chilo partellus* (Swinhoe) (Crambidae: Lepidoptera) are the most severe, causing 18–53% yield losses (Gethi *et al*., 2001). Being internal feeders, these are difficult to manage with only insecticidal sprays. Despite intensive evaluation of insecticidal management under Indian conditions, the work on biological control, particularly using microbial pathogens is lacking. The shift from conventional synthetic insecticides to biological control is necessitated due to environmental concerns and insecticides resistance. The entomopathogenic fungi are safe and ecofriendly (Miranpuri and Kachatourian, 1993). In our earlier studies, promising strains of *B. bassiana* (NBAII-Bb-5a, 23 and 45) and *Metarhizium anisopliae* (NBAII-Ma-35) were identified against *C. partellus* in the laboratory bioassay (Renuka *et al.*, 2015; Ramanujam *et al.*, 2015). The present study evaluates the effect of the four isolates of these entomofungal pathogens on the damage by *C. partellus* during *kharif*.

MATERIALS AND METHODS

The field experiment was carried out at the ICAR-NBAIR Attur Farm, Bengaluru during *kharif* 2015 and 2016. Four promising isolates of *Beauveria bassiana* Bb-5a, Bb-23, Bb-45 and *Metarhizium anisopliae* Ma-35) were evaluated on the popular commercial variety of sorghum, Maldandi (M-35-1). The experiment was laid out in Randomized Block Design with four replications and with a plot size of 58 m^2 and spacing of 45 x 30 cm. All the agronomic practices recommended by University of Agricultural Sciences, Bengaluru (Agricultural and horticultural crops-cultivation practices, 2014) were followed. Oil formulations isolates were prepared using liquid paraffin oil (98%), Tween-80 (0.01%) and conidia (2%) having a spore concentration of $1x10^{10}$/ml. The spray fluid was prepared by diluting the oil formulation @ 10ml/l of water which contained the spores at the concentration of $1x10^{8}$/ml. Two rounds of foliar sprays were given on 15th and 30th day after germination. A week after second spray laboratory reared *C. partellus* larvae of 2nd instar @ ten /plant were released carefully into the inner leaf whorl with a camel hair brush.

Observations on the number of deadhearts (DH), extent of stem tunneling (cm/plant) (ST), number of galleries and exit holes/plant (EH), surviving number of larvae/plant, and grain yield data were recorded at harvest by splitting the plant longitudinally from top to the base. The data were statistically analyzed with SPSS v16 software and later subjected to Duncan's Multiple

Range Test (DMRT). The data was transformed using square root transformation. The treatment-wise grain yield/plant was recorded and converted to q/ha.

RESULTS AND DISCUSSION

Data obtained on % deadhearts, stem tunnelling/ plant (cm), number of exit holes/ plant, survival larvae and pupae/plant and grain yield during *kharif* 2015 are given Table 1 and of 2016 in Table 2. The pooled data analysis is given in Table 3.

Deadhearts: The results revealed that during 2015, % deadhearts ranged from 6.78-13.22% in the treated plots compared to 19.78% in the untreated control. Among the tested isolates, Bb-23 of *B. bassiana* showed significantly lower values of 6.78%, followed by Bb-5a (9.33%) of *B. bassiana* and Ma-35 (10.0%) of *M. anisopliae* which were on par with each other (Table 1). Similarly, during 2016, the % deadhearts ranged from 6.0-10.33% in the treated plots compared to untreated control which recorded 17.11%. Bb-5a, Bb-23 and Ma-35 showed lower deadhearts of 6.0, 6.11 and 6.78%, respectively and were on par with each other (Table 2). The pooled data revealed that the lowest % deadheart with Bb-23 (6.4%) and Bb-5a (7.7%) which were statistically on par (Table 3).

Maize plants treated with liquid or granular formulations of *B. bassiana* conidia at the whorl stage of development became internally colonized by the fungus (Lewis *et al*., 1996). Tefera and Pringle during 2007 in Ethiopia noticed *B. bassiana* and *M. anisopliae* in maize with considerable reduction of deadhearts due to *C. partellus*, when these isolates were applied as foliar sprays under greenhouse condition. Cherry *et al.* (2004) observed that seed dressing of maize with

Table 1. Effect of isolates of entomofungal pathogens on *C. partellus* - *kharif* 2015

Treatment	Isolate	Average No. of dead-hearts	Dead-heart (%)	No. of galleries plant	No. of Exit holes/ plant	Stem tunneling/ plant (cm)	Survival larvae/ plant	Grain yield/ 10 plants (gm)	Grain yield (q/ha)
T1	Bb-5a	2.80^{ab} (1.82)	9.33 9.33	0.48^{a} (0.99)	0.73^{a} (1.11)	4.32^{bc} (2.19)	0.08^{a} (0.76)	160^{a} (12.67)	11.84 11.84
T2	Bb-23	2.03^{a} (1.59)	6.78	0.47^{a} (0.98)	0.38^{a} (0.94)	3.75^{a} (2.06)	0.04^{a} (0.74)	167^{a} (12.93)	12.33
T3	Bb-45	3.97^{b} (2.11)	13.22	1.43^{b} (1.39)	1.77^{b} (1.51)	7.76^{bc} (2.87)	0.30^{a} (0.89)	147^{a} (12.13)	10.85
T4	Ma-35	3.00^{ab} (1.87)	10.00	0.48^{a} (0.99)	0.80^{a} (1.14)	5.30^{bc} (2.41)	0.08^{a} (0.76)	153^{a} (12.40)	11.35
T5	Control	5.93^{c} (2.54)	19.78	2.00^{b} (1.58)	2.10^{b} (1.61)	10.18^{c} (3.27)	0.50^{b} (1.28)	140^{a} (11.85)	10.36
CD @ 0.05	1.58	-	0.74	0.65	3.77	0.7	NS	-	

Means followed by similar letters in columns not significantly different at 5% by DMRT.

Table 2. Effect of isolates of entomofungal pathogens on *C. partellus*- *kharif* 2016

Treatment	Isolate	Mean No. of dead-hearts	Dead-heart (%)	No. of galleries plant	No. of Exit holes/ plant	Stem tunneling/ plant (cm)	Survival larvae/ plant	Grain yield/ 10 plants (gm)	Grain yield (q/ha)
T1	Bb-5a	1.80^{a} (1.52)	6.00	0.22^{a} (0.85)	0.35^{a} (0.92)	2.85^{a} (1.83)	0.00^{a} (0.71)	151^{a} (12.32)	11.20
T2	Bb-23	1.83^{ab} (1.53)	6.11	0.20^{a} (0.84)	0.47^{a} (0.98)	3.27^{a} (1.94)	0.04^{a} (0.74)	147^{ab} (12.14)	10.88
T3	Bb-45	3.10^{b} (1.90)	10.33	1.17^{b} (1.29)	1.47^{b} (1.40)	7.03^{bc} (2.74)	0.50^{ab} (1.00)	125^{bc} (11.22)	9.27
T4	Ma-35	2.03^{ab} (1.59)	6.78	0.22^{a} (0.85)	0.50^{a} (1.00)	4.30^{bc} (2.19)	0.03^{a} (0.73)	132^{ab} (11.51)	9.77
T5	Control	5.13^{c} (2.37)	17.11	1.80^{b} (1.52)	1.93^{b} (1.56)	9.03^{c} (3.09)	1.07^{b} (1.25)	105^{c} (10.27)	7.77
CD @ 0.05	1.28	-	0.81	0.79	3.52	0.58	23.40	-	

Means followed by similar letters in columns not significantly different at 5% by DMRT.

Table 3. Pooled effect of isolates of entomofungal pathogens on *C. partellus*

Treatment	Isolate	Mean No. of dead-hearts	Dead-heart (%)	No. of galleries plant	No. of Exit holes/ plant	Stem tunneling/ plant (cm)	Survival larvae/ plant	Grain yield/ 10 plants (gm)	Grain yield (q/ha)
T1	Bb-5a	2.30^{ab} (1.67)	7.7	0.4^{b} (0.92)	0.54^{a} (1.02)	3.58^{a} (2.02)	0.04^{a} (0.74)	156^{a} (12.50)	11.52
T2	Bb-23	1.93^{a} (1.56)	6.4	0.3^{a} (0.91)	0.43^{a} (0.96)	3.51^{a} (2.00)	0.04^{a} (0.74)	157^{a} (12.54)	11.61
T3	Bb-45	3.53^{bc} (2.01)	11.8	1.3^{c} (1.34)	1.62^{b} (1.45)	7.40^{bc} (2.81)	0.40^{ab} (0.95)	136^{bc} (11.68)	10.06
T4	Ma-35	2.52^{bc} (1.74)	8.4	0.4^{b} (0.92)	0.65^{a} (1.07)	4.80^{ab} (2.30)	0.06^{a} (0.74)	143^{ab} (11.97)	10.56
T5	Control	5.53^{c} (2.46)	18.4	1.9^{c} (1.55)	2.02^{b} (1.59)	9.61^{c} (3.18)	0.78^{b} (1.13)	123^{c} (11.09)	9.07
CD @ 0.05	1.43	-	0.8	0.72	3.65	0.64	24.8	-	

Means followed by similar letters in columns not significantly different at 5% by DMRT.

B. bassiana strain against *Sesamia calamistis* (Hampson) showed significant reduction of deadhearts, in Republic of Benin. Kavitha and Manjunatha (2015) observed that foliar application of *B. bassiana* and *M. anisopliae* in Shivamogga in Karnataka against *C. partellus* in maize showed statistically lowest deadhearts.

Stem tunnelling: It ranged from 3.75-7.76cm/ plant during 2015 in the treated plots compared to untreated control (10.18 cm/plant), with the minimum being with Bb-23 (3.75 cm/plant) (Table 1). Similar results were obtained during 2016 (2.85-7.03 cm/ plant vs. 9.03 cm/plant in control), the values being 2.85 and 3.27 cm/plant with Bb-5a and Bb-23, respectively (Table 2). The pooled data revealed that it ranged from 3.51-7.40 cm/plant against 9.61 cm/ plant in control, with the least damage being in Bb-23 and Bb-5a (Table 3).

The reduced stem borer activity in sorghum was due to the *B. bassiana* isolates and the present observations corroborate those of earlier workers. Reddy *et al*. (2009) observed such lesser stem tunnelling due to *C. partellus* in sorghum treated with *B. bassiana*. Cherry *et al*. (2004) observed the efficacy of stem injection of *B. bassiana* conidia ($1x10^8$) into maize stem which led to reduction of stem tunnel length (7.25 cm) caused by maize stem borer, *S. calamistis* under green house and field conditions. Similar effects were also noticed when maize plants were injected with *B. bassiana* under field condition resulting in reduction of tunnelling caused by European corn borer, *Ostrinia nubilalis* (Hubner) as observed by Bing and Lewis (1991). The whorl application of granular formulations of *B. bassiana* in corn against *O. nubalis* in Iowa (USA) was found to be most effective in reducing the larval tunnelling by 20-53% (Lewis *et al.*, 2002).

No. of galleries: During 2015 it ranged from 0.47-1.43/plant in the treated plots compared to 2.0/plant in control. The lesser galleries were noticed in Bb-23 (0.47/plant) and Bb-5a, Ma-35 treated plots (0.48/plant) (Table 1). Similar results were obtained during 2016 too (0.20-1.17/plant as against 1.80/plant in control, with the least values being in Bb-23 (0.20/plant) followed by Bb-5a and Ma-35 (0.22/plant) which were on par (Table 2). The pooled data revealed that it ranged from 0.3-1.3/plant against 1.9/plant in control, with the least values being in Bb-23 (Table 3).

Survival of larvae/plant: The results revealed that the surviving larvae inside the stem at harvesting stage were reduced due to entomofungal pathogenic isolates. With the pooled data it ranged 0.04-0.4/plant against 0.78/plant in control. Reddy *et al*. (2009) revealed reduction in number of larvae of *C. partellus* in sorghum treated with *B. bassiana*. Tefera and Pringle (2007) observed such reductions in the number of larvae in maize when *B. bassiana* and *M. anisopliae* isolates were applied as foliar sprays under greenhouse condition.

Number of exit holes: It varied from 0.38 to 1.77/ plant in the treated plots during 2015 as against 2.10/ plant in control, with the least being in Bb-23 (0.38/ plant) followed by Bb-5a (0.73/plant) and Ma-35 (0.8/ plant) which were on par (Table 1). Similarly, during 2016, it ranged from 0.35 to 1.47/plant, with the least

incidence being in Bb-5a, Bb-23 and Ma-35 treated plots, respectively (Table 2), and the pooled data too revealed similar trend (Table 3). The decrease in exit holes could be because of lesser survival of larva due to activity of *B. bassiana* and *M. anisopliae* isolates. Conidial suspension of *B. bassiana* and *M. anisopliae* sprayed on maize plants under greenhouse condition showed reduction in exit holes (0.2-3.3/plant) (Tefera and Pringle, 2007).

Grain yield: The pooled data revealed that all the four isolates resulted in superior grain yield ranging from 10.06 to 11.52 q/ha as against 9.07 q/ha in control (Table 3). The maximum yields were noticed in Bb-23 (11.61 q/ha) and Ba-5a (11.52 q/ha) isolates of *B. bassiana* treated plots. These higher yields might be due to the effective suppression of stem borer by these isolates. Reddy *et al*. (2009) obtained significantly higher yield in sorghum treated with *B. bassiana.*

Amongst all the four entomofungal pathogenic isolates evaluated, Bb-23 and Bb-5a isolates of *B. bassiana* were observed to be superior and effective, which resulted in increased yield, exhibiting that this ecofriendly strategy could be recommended for management of sorghum stem borer.

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INFESTATION AND POPULATION DYNAMICS OF STRIPED FLEA BEETLE *PHYLLOTRETA STRIOLATA* FABRICIUS IN CRUCIFEROUS VEGETABLES IN KASHMIR

BASHIR A. RATHER* AND BARKAT HUSSAIN**

Krishi Vigyan Kendra/Extension Training Centre, Pulwama, SKUAST-K, Srinagar, J & K
***Division of Entomology, SKUAST-K, Shalimar, Srinagar 191121, J & K*
**Email: entobashir@gmail.com (corresponding author)*

ABSTRACT

Field surveys to study the infestation and population dynamics of the most abundant striped flea beetle, *Phyllotreta striolata* Fabricius, on two abundantly grown cruciferous crops viz., kale (*Brassica oleraceae L.* var.*acephala*) and turnip (*Brassica rapa* L.) revealed that these suffered with moderate and severe infestation, respectively. The maximum infestation was at cotyledonary stage as compared to true leaf stage. The pooled data of two year study revealed the maximum mean % infestation, severity, and number of flea beetle catches/sweep on turnip as compared with kale. Southern zone revealed the highest mean % infestation, severity and number of beetle catches/sweep followed by the Central and Northern zones. The extent of damage, severity and population build-up was more during 2012 compared to 2013. Emergence of the overwintering generation started from the second fortnight of March up to the end of May in kale while the subsequent generations started emerging at the beginning of June and the maximum trap catches were obtained during the second fortnight of July i.e. from 27th to 29th standard weeks and the minimum catches by the end of October. In turnip, the pest started its activity in the first week of August i.e. from 32nd standard week, immediately after sowing and remained active until end of October. Maximum catches of flea beetles were observed in the second fortnight of September i.e. in the 38th standard week and thereafter it decreased to its lowest during the end of October. The study further revealed that the temperature influenced the activity of the flea beetles significantly.

Key words: *Phyllotreta striolata*, *Brassica oleraceae L.* var.*acephala*, *Brassica rapa*, severity, cotyledonary stage, true leaf stage, Kashmir, zones, temperature, trap catches, overwintering, population dynamics

Cruciferous vegetables are abundantly grown throughout the year in Kashmir valley, and these are attacked by a number of insect pests which include cabbage butterfly (*Pieris brassicae* L.), cabbage aphid (*Brevicoryne brassicae* L.) and mustard aphid (*Lipaphis erysimi* Kalt.) and diamond back moth (*Plutella xyllostella* L.), as major pests; and cabbage semilooper (*Thysanaplucia orichalcia*), flea beetles (*Phyllotreta* sp.), mustard sawfly (*Athalia colibri* (F.), cut worm (*Agrotis ipsilon* Hufnagel) and leaf miner (*Chromotomyia horticola* Goureau) as minor pests. These insects have a close association with the phenology of the crop from the seedling stage to the true leaf stage, and cause yield and economic losses in *Brassica* crops (Bhat et al., 2011). Although flea beetles colonize crops every year, their population densities vary widely (Heiisar et al., 2009).

Recently, the farmers of Kashmir valley suffered due to the damage caused by the flea beetles, earlier considered as minor pest. A total of four flea beetle species had been reported in cruciferous vegetables viz., *Psylliodes tenebrosus* Jacoby, *Phyllotreta striolata* Fabricius, *Altica himensis* Shukla and *Psylliodes* sp. indet. Amongst these *P. striolata* has been observed to be the most abundant and serious pest throughout the growing season (Rather, 2015). There have been few studies on the extent and severity of damage caused by these flea beetles and their population dynamics. Hence, the present study on the population dynamics and extent of damage by the pest in the various agroecological zones of Kashmir.

MATERIALS AND METHODS

The infestation by the *P. striolata* in cruciferous vegetable ecosystem was carried out in various agroecological zones of Kashmir valley, comprising Central (Srinagar, Ganderbal, and Budgam), Northern (Baramulla, Bandipora and Kupwara) and Southern (Anantnag, Kulgam and Pulwama) regions, during 2012 and 2013. Twenty seven sites (nine from each zone with three from each district) with kale (*Brassica oleraceae var. acephala*), being abundantly grown throughout the year, and turnip (*Brassica rapa* L.) grown as a rabi crop from August onwards were selected (Table 1).

Table 1. Study regions and areas in Kashmir

S. No.	Agroecological Zone	Districts	Locations
1.	Northern zone	Baramulla	Stadium Colony, Armpora, Braught
		Bandipora	Sadunara, Hakabara, Malroo
		Kupwara	Langate, Mandigam, Kachur,
2.	Central Zone	Srinagar	Darbagh, Noorbagh, Shalimar
		Ganderbal	Wakura, Batwina, Zazuna
		Budgam	Narkara, Chadoora, Budgam
3.	Southern Zone	Anantnag	Bangidar, Dabrun, Doru
		Kulgam	Khandaypora, Awneera, Tamil,
		Pulwama	Banagund, Muran, Drabgam

The infestation % was evaluated at two phenological stages viz., cotyledonary and true leaf stage, with 20 plants at cotyledonary stage (3 observations) and 10 plants at true leaf stages (7 observations) randomly selected, in a quadrant of 1 M^2 each. The % foliage damage index was scored as follows: flea beetles bite feeding holes on the leaves in a characteristic manner; severity of infestation was assessed on a visual rating method based on the amount of leaf area removed from the samples of randomly selected leaves in a scale (Soroka, 2011)- Score 1: no damage; 2: 1-20; 3: 21-40; 4: 41-60; 5: > 60 or completely damaged, all expressed in %, using the formula-

$$\% \text{ Foliage damage Index} = \frac{\sum (\text{Infestation rating} \times \text{No. of leaves present in the scale})}{(\text{Total number of leaves examined} \times \text{Maximum rating scale})} \times 100$$

The observations on the population dynamics were taken at fortnightly intervals in Srinagar district only, from March when the adult beetles became active till their overwintering/ Data on maximum and minimum temperature was obtained from the Division of Agronomy. In turnip, population buildup was determined fortnightly observations from August onwards in all the three zones without taking into consideration the weather parameters as it is considered as the most susceptible host (Heiisar et al., 2006). The sampling was done with a sweep net made of muslin cloth (30 cm dia at the mouth x 60 cm bag length) @10 sweeps at 180°, and consistency ensured through randomly selected ten quadrats from each. A total of 14 samplings/ year were carried out on kale and seven samplings on turnip.

RESULTS AND DISCUSSION

Observations revealed that *P. striolata* is the most abundant and serious (Fig. 1A) followed by *Psylliodes tenebrosus, Altica himensis* and *Psylliodes* sp. indet. (Rather, 2015). This is also in conformity with the findings of Furth (1980) who reported *Phyllotreta* to be the most dominant genus in different surveyed sites, because of its wider range of habitat and host plant preference than most of the Alticinae genera. Bhat et al. (2011) also reported *Phyllotreta* spp. as a new pest on cruciferous crops causing economic damage in seven districts of Kashmir *viz.* Anantnag, Badgam, Bandipora, Baramulla, Ganderbal, Pulwama and Srinagar, from March 2004 to October 2008.

The present study during 2012 and 2013 revealed that the pest appeared in all the regions during the second fortnight of March on kale and remained active

Fig. 1. A. Striped flea beetle, *P. striolata*

B. Damage in cotyledonary stage

C. Damage in true leaf stage-on *B. oleraceae var. acephala*

throughout, however, the infestation was higher during 2012. Similar observations had been reported earlier by Hiiessar et al. (2009). The infestation was more during cotyledonary stage compared to true leaf stage (Fig. 1B,C); South zone recorded maximum infestation (29.65%) followed by 25.76 and 24.32% in Central and North zones, respectively. Infestation of only 15.73, 13.36 and 10.95% at true leaf stage in South, Central and North zones, respectively (Table 2, 3). Highest infestations of 34% (at cotyledonary stage) and 18.39% (at true leaf stage) was observed in district Anantnag; and the lowest (18.71 and 8.49%, respectively) was observed in district Kupwara.

Tahvanainen and Root (1972) observed the *P. cruciferae* Goeze activity on *Brassica oleracea* and revealed that adults were more abundant on collards (*B. oleracea* var. *acephala*) grown in monocultures than on those grown adjacent to natural vegetation. The emergence of individuals forming the new annual generation was also greater in the pure stands. Vaughn and Hoy (1993) also observed similar results of host plant preference during cotyledonary and true leaf stages in collard and kale leaves; further it was found that the host preference was associated with chemical and morphological differences and could help to explain the spatial patterns in population density. The present observations are also in conformity with those of Mayoori and Mikunthan (2009) revealing that amongst insect pests of Brassicaceae crops, *P. cruciferae* emerged as a serious pest in Jaffna district of Sri Lanka and inflicted severe damage in the seedling stage of cabbage.

Infestation by *P. striolata* on turnip determined on standard week basis revealed that it was confirming that it is de a susceptible crop (Hiiesaar et al., 2006). Variation in susceptibility of cruciferous plants to flea beetles had been observed by many researchers (Bodnaryk et al., 1994; Palaniswamy et al., 1997). The results given in Table 4 reveal that the highest infestation of 70.11% was in the district Anantnag, with overall infestation being higher in South zone (66.70 %). Maximum infestation of 69.94% was in the 40th standard week, found to be at par with that recorded in 34th (68.56 %) and 38th (68.61 %) standard weeks in South zone; in Central and North zones the highest infestation of 72.39 and 75.55% was in the 38th standard week, respectively.

Bohinc and Trdan (2012) too observed the highest damage index on turnip throughout most of the growth period, whereas oilseed rape and white mustard were preferred only during a certain growth period. Burgess (1977) reported that flea beetle emergence, movement and feeding are greatest during periods of warm, sunny, dry and calm weather. Cold wet conditions reduce movement, feeding and intensity of attack. Carcamo et al. (2008) also observed differences in flea beetle infestation in North, Central and South zones. Soroka (2012) observed variations in infestation, population development and number of species in different locations in Canadian praries and North Dakota during a survey period of five years from 2007 to 2011.

The seasonal activity was observed to be similar

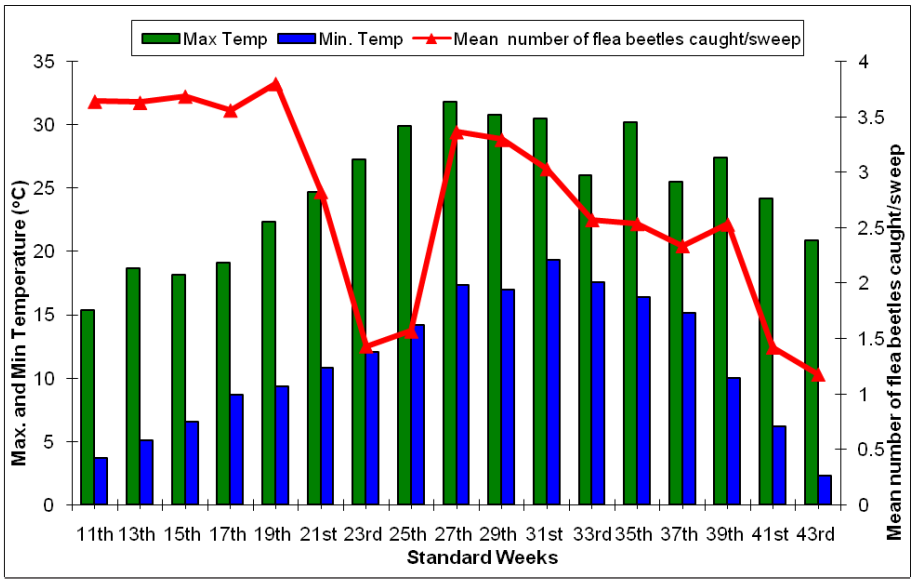

Fig. 2. Population dynamics of *P. striolata* on *B. oleraceae var. acephala* vs. maximum and minimum temperature (District Srinagar, pooled data 2012 & 2013)

Table 2. Infestation of flea beetle on *Brassica oleraceae var. acephala* in Kashmir (pooled data, 2012 & 2013)

Districts	Locations	% infestation observed at fortnightly interval											
		----Cotyledonary stage----				----------True leaf stage----------							
Sampling period (standard weeks)		13th	15th	17th	Mean	19th	21th	23rd	25th	27th	29th	31th	Mean
South	Anantnag	29.88 (32.85)	35.69 (36.64)	36.42 (37.06)	34.00 (35.52)[a]	29.70 (32.90)	21.79 (29.48)	19.66 (26.19)	22.96 (28.47)	18.58 (26.00)	10.43 (18.75)	5.55 (13.42)	18.39 (25.03)[d]
	Kulgam	32.53 (34.71)	33.41 (35.26)	30.56 (33.52)	32.17 (34.49)[a]	19.13 (25.84)	16.60 (23.16)	14.48 (21.70)	23.94 (29.06)	10.03 (19.06)	9.10 (17.39)	6.15 (14.16)	14.20 (21.48)[e]
	Pulwama	25.31 (29.96)	19.23 (25.91)	23.76 (29.14)	22.77 (28.34)[c]	18.32 (25.19)	15.22 (22.82)	15.07 (22.27)	13.44 (21.38)	12.34 (20.62)	11.00 (19.31)	6.28 (14.44)	13.09 (20.86)[e]
Central	Budgam	26.86 (31.08)	29.08 (32.43)	26.36 (30.55)	27.43 (26.35)[c]	22.66 (28.28)	15.16 (22.83)	16.81 (23.67)	11.14 (19.26)	17.33 (21.31)	7.56 (15.79)	5.81 (13.80)	13.79 (19.99)[e]
	Ganderbal	23.72 (29.11)	23.52 (28.98)	33.79 (35.11)	27.01 (31.06)[b]	10.25 (14.88)	17.98 (22.00)	17.27 (24.57)	12.96 (18.58)	18.34 (20.88)	8.22 (14.46)	8.72 (10.02)	13.39 (17.91)[f]
	Srinagar	21.63 (28.23)	23.69 (26.40)	23.24 (29.27)	22.85 (27.96)[c]	12.60 (16.79)	14.98 (20.61)	17.29 (23.73)	10.73 (15.39)	17.55 (19.34)	7.39 (14.01)	9.85 (12.20)	12.92 (17.44)[f]
North	Baramulla	23.72 (28.78)	32.76 (34.69)	25.23 (29.57)	27.24 (31.01)[b]	19.80 (26.02)	22.13 (24.11)	17.29 (24.62)	16.60 (25.79)	11.89 (20.11)	10.67 (18.83)	3.31 (13.77)	14.49 (21.89)[e]
	Bandipora	25.78 (30.26)	26.23 (30.79)	28.97 (32.50)	27.01 (31.18)[b]	9.54 (17.79)	18.05 (24.88)	11.31 (14.61)	9.32 (17.56)	11.20 (19.47)	6.47 (14.58)	3.28 (10.26)	9.88 (17.02)[f]
	Kupwara	17.17 (24.43)	17.08 (24.13)	21.89 (27.70)	18.71 (25.42)[c]	12.23 (20.19)	10.91 (18.73)	8.76 (17.19)	7.28 (15.46)	9.36 (17.58)	6.02 (14.05)	4.84 (7.47)	8.49 (15.81)[g]
	CD (≤0.05)	1.51	2.51	1.66	1.85	1.50	1.69	1.56	1.91	1.35	1.54	1.11	1.51

Figures within parentheses arc sine transformed values; figures superscripted by same letter not significantly different; figure represent mean % infested plants (from 20 and 10 plants during cotyledonary and true leaf stages, respectively)

Table 3. Infestation of flea beetle on *Brassica oleraceae var. acephala* in Kashmir (pooled data, 2012 & 2013)

S. No	Zones	% infestation observed at fortnightly interval					
		----Cotyledonary stage----			----------True leaf stage----------		
		2012	2013	Mean	2012	2013	Mean
1.	South	33.67 (35.32)^{a}	25.63 (30.23)^{d}	29.65 (32.78)^{g}	18.67 (24.42)^{j}	12.80 (20.47)^{m}	15.73 (22.45)^{p}
2.	Central	29.86 (29.60)^{b}	21.66 (27.31)^{e}	25.76 (28.46)^{hi}	14.64 (21.93)^{k}	12.08 (14.94)^{n}	13.36 (18.44)^{q}
3.	North	29.89 (32.95)^{bc}	18.73 (25.44)^{f}	24.32 (29.20)^{h}	13.13 (19.67)^{l}	8.67 (16.79)^{o}	10.95 (18.24)^{qr}
CD (p≤0.05)		2.19	2.12	1.85	1.73	1.69	1.51

Figures within parentheses arc sine transformed values; figure represent mean % infested plants from 20 and 10 plants during cotyledonary and true leaf stages, respectively); figures superscripted by same letter not significantly different

during both the years (Fig. 3); it started its activity during the second fortnight of March when the beetles of overwintering generation emerged and remained active up to the end of October; and observed to be multivoltine. These results are in conformity with those of Kinoshita (1976) who observed about seven to eight generations in India. Population density revealed continuous fluctuation from second fortnight of March to last week of October, increased from 11th standard week to 19th standard week and then decreased up to 23rd standard week and again increased from 25th to 29th standard weeks and then declined, with number of beetles/ sweep more during 2012.

The turnip crop was observed to be more susceptible, as observed by Chittenden and Marsh (1920), in turnip, mustards (*Brassica.* spp.), and radish (*Raphanus spp*.) as the most preferred hosts of *Phyllotreta* spp. in North America. In turnip, it started its activity in the first week of August i.e. from 32nd standard week, immediately after sowing and remained active up to end of October, with infestation and population buildup being similar during both the years. Maximum catches were obtained in the second fortnight of September i.e. in the 38th standard week and thereafter decreased, with minimum being by the end of October. The perusal of data reveal the maximum of 5.32, 5.10 and 5.07 beetles/sweep in Central, South and North zones, respectively with insignificant differences; and maximum of 5.69 beetles/ sweep in the district Ganderbal was followed by Bandipora and Pulwama (5.43 and 5.32 beetles/sweep, respectively).

These results are in conformity with those of MaoXin et al. (2000) on *P. striolata* on crucifer vegetables, who observed that there are seven generations annually, with infestation peaks from early April to late May, and in mid-September, with numbers

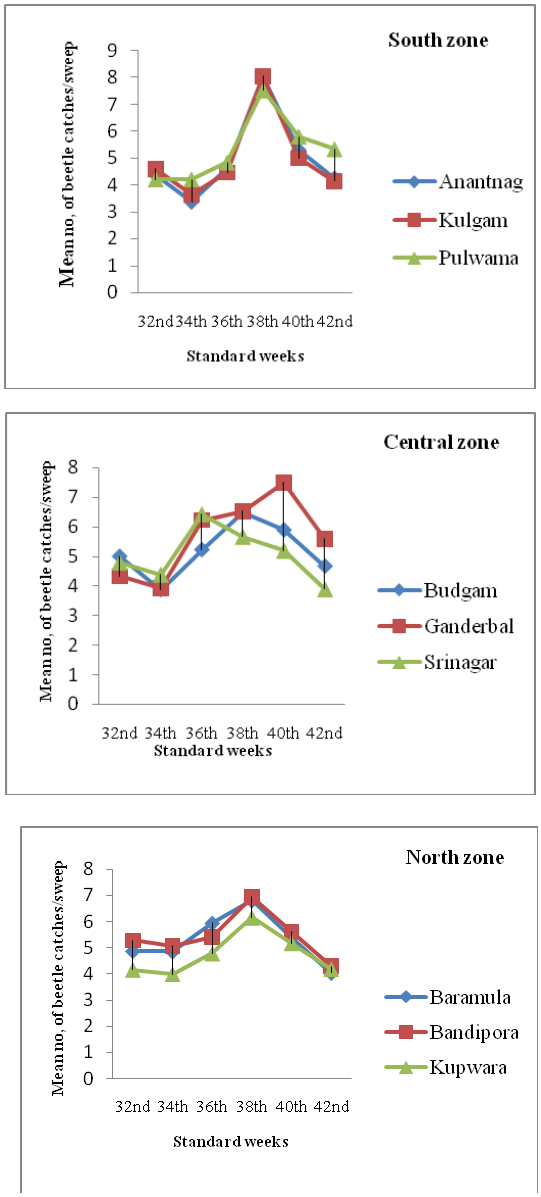

Fig. 3. Population dynamics of *P. striolata* on *B. rapa* in Kashmir (pooled data, 2012 & 2013)

Table 4. Infestation of flea beetle on *B. rapa* in Kashmir (pooled data, 2012 & 2013)

S.No	Zones		% infestation on standard week basis							
		Districts	Locations	32nd	34th	36th	38th	40th	42nd	Mean
1.	South	Anantnag	Bangidar	67.00 (56.37)	71.34 (57.89)	75.17 (59.29)	74.50 (58.92)	72.17 (58.06)	60.50 (54.24)	70.11 (57.46)[a]
		Kulgam	Khandypora	62.50 (52.32)	73.50 (59.23)	51.83 (46.05)	66.83 (63.51)	69.17 (56.44)	71.50 (57.86)	65.89 (55.90)[b]
		Pulwama	Muran	66.83 (54.98)	60.83 (51.32)	62.50 (52.33)	64.50 (53.56)	68.50 (56.08)	61.50 (51.72)	64.11 (53.33)[b]
			Mean	65.44 (54.56)[e]	68.56 (56.15)[d]	63.17 (52.55)[f]	68.61(58.66)[c]	69.94 (56.86)[d]	64.50 (54.60)[e]	66.70 (55.56)
			CD(0.05)	Locations=1.72:	Std. weeks=1.44:	Locations x weeks=4.22				
2.	Central	Budgam	Narkara	58.67 (50.01)	60.17 (50.94)	68.34 (55.94)	70.17 (57.03)	67.67 (63.03)	68.33 (55.87)	65.55 (55.47)[g]
		Ganderbal	Wakura	55.17 (47.97)	60.84 (51.31)	64.67 (53.63)	78.00 (62.24)	67.83 (55.56)	64.67 (53.61)	65.19 (54.05)[g]
		Srinagar	Noorbagh	60.00 (50.80)	53.00 (46.73)	62.67 (52.53)	69.00 (56.26)	62.00 (52.00)	50.83 (45.46)	59.58 (50.63)[h]
			Mean	57.94 (49.59)[j]	58.00 (49.66)[j]	65.22 (54.03)[j]	72.39 (58.51)[i]	65.83 (56.86)[i]	61.28 (51.64)[j]	63.44 (53.38)
		CD (0.05)		Locations=1.88:	Std.weeks=2.66:	Locations x weeks=4.62				
3.	North	Baramula	Armpora	60.67 (50.52)	58.00 (49.43)	81.00 (60.47)	75.35 (84.22)	60.33 (52.85)	70.67 (56.36)	67.66 (54.67)
		Bandipor	Malroo	57.00 (48.18)	54.33 (49.02)	68.33 (4.49)	81.33 (63.42)	61.33 (53.25)	62.33 (52.46)	64.11 (53.47)
		Kupwara	Langate	62.00 (51.14)	60.67 (48.20)	67.33 (52.16)	70.00 (56.32)	54.33 (49.31)	48.67 (44.40)	60.50 (50.25)
			Mean	59.89 (49.94)[l]	57.67 (48.88)[l]	72.22 (55.70)[k]	75.55 (59.38)[k]	58.66 (51.80)[l]	60.55 (51.07)[l]	64.09 (52.80)
		CD (0.05)		Locations=1.54:	Std.weeks=5.02:	Locations x weeks= 8.69				

being closely correlated to precipitation and mean of 10-day temperature. Shitong et al. (2006) also observed that *P. striolata* adults were active from April to November and had two peaks of incidence (spring and summer, autumn), with spring and summer peaks being higher, and at mean temperature above 10°C adults became more active. But when daily average temperature exceeded 26°C, the activity of *P. striolata* adults decreased, with peaks at 17.5 and 24.4°C in general.

Brown et al. (2004) reported variations in *P. cruciferae* injury both among species and among genotypes, and revealed infestation and feeding injury differences, regardless of the ontogenetic stage of seedlings. They further observed that synchrony between the phenology of the insect herbivores and that of the host plant and the weather conditions had a major impact on the population densities (Eber, 2004; Van Asch and Visser, 2007). Temperature and wind orientation had a significant positive correlation with dispersion of *P. cruciferae* while humidity weakly influenced their activity (Gao et al., 2005).

The seasonal activity on kale when evaluated in relation to weather parameters, particularly maximum and minimum temperatures, it was observed that the pest appeared in the second fortnight of March (about 15°C), with maximum catches of the overwintering adults obtained from second fortnight of March until the mid of May i.e. from 11th standard week to 19th standard week (Fig. 2). The emergence of the new generation started at the beginning of June and the numerous catches were observed up to the second week of July i.e. from 27th to 29th standard weeks. The catches/ sweep were observed to decrease afterwards and minimum catches obtained by the end of October. In turnip too, maximum and minimum temperature was observed to have direct impact on the population build up. Similar results were observed by MaoXin et al. (2000), Shi-tong et al. (2006) and Toshova and Csonka (2007).

The severity determined monthly from March to October differed significantly among all the districts (Table 5), with highest severity being at cotyledonary stage compared to true leaf stage. Pooled data revealed the highest severity of 30.04% (Scale-3) in district Anantnag and the lowest of 18.56% (Scale-2) in district Kupwara.The severity determined fortnightly on standard week basis from August to October differed significantly among all the districts (Table 6). Pooled

Table 5. Severity of flea beetle damage on *Brassica oleraceae var. acephala* in Kashmir (pooled data, 2012 & 2013)

No.	Zones	Districts	Mean % severity								Overall Mean
			March	April	May	June	July	August	September	October	
	South	Anantnag	36.67 (37.20)	38.67 (38.38)	37.67 (37.80)	30.50 (33.33)	29.50 (36.44)	26.50 (30.73)	20.17 (26.42)	20.67 (26.84)	30.04 (33.39)[a]
		Kulgam	30.34 (32.88)	32.33 (33.58)	32.00 (28.47)	32.50 (31.15)	26.17 (28.84)	29.50 (27.48)	20.33 (23.01)	22.00 (24.65)	28.15 (28.75)[b]
		Pulwama	31.00 (33.73)	30.67 (33.54)	20.67 (26.86)	24.83 (29.61)	26.50 (30.82)	19.50 (25.60)	18.00 (24.86)	20.00 (26.36)	23.89 (28.91)[c]
		Mean	32.67 (34.74)	33.89 (35.50)	30.11 (33.00)	29.28 (32.51)	27.39 (32.53)	25.17 (29.67)	19.50 (25.96)	20.89 (26.99)	27.36 (30.35)
	Central	Budgam	31.17 (33.94)	31.34 (33.37)	33.00 (34.96)	29.13 (2.487)	21.83 (31.17)	22.17 (27.74)	18.50 (25.13)	20.33 (26.57)	25.93 (30.66)[d]
		Ganderbal	24.33 (29.42)	28.33 (30.80)	28.67 (32.23)	26.83 (30.94)	19.00 (25.63)	23.83 (28.92)	19.00 (25.63)	18.67 (25.37)	23.58 (28.61)[c]
		Srinagar	28.34 (31.90)	24.67 (31.27)	22.00 (27.78)	24.50 (29.37)	23.33 (28.72)	17.17 (23.87)	17.50 (24.44)	19.67 (26.10)	22.14 (27.92)[e]
		Mean	27.94 (28.52)	28.11 (27.42)	27.89 (25.98)	26.83 (28.40)	21.39 (23.37)	21.06 (25.22)	18.33 (22.44)	19.56 (23.46)	23.88 (29.07)
	North	Baramulla	23.67 (28.96)	20.67 (27.82)	19.83 (26.09)	24.83 (29.61)	22.67 (28.22)	21.50 (27.26)	20.00 (26.36)	18.67 (25.20)	21.47 (27.43)[e]
		Bandipora	23.50 (28.79)	21.67 (28.41)	21.67 (27.57)	22.84 (28.00)	15.00 (22.48)	20.50 (26.49)	19.33 (25.87)	19.00 (25.60)	20.43 (26.64)[f]
		Kupwara	23.67 (28.91)	22.33 (28.44)	13.00 (20.74)	20.50 (26.50)	10.00 (17.87)	22.67 (28.15)	17.33 (24.35)	19.00 (25.60)	18.56 (25.06)[g]
		Mean	25.89 (28.89)	24.80 (28.22)	21.65 (24.80)	24.31 (28.03)	18.98 (22.85)	22.11 (27.30)	19.00 (25.52)	19.11 (25.47)	20.15 (26.38)
		CD (p≤0.05)	1.54	1.36	1.76	0.65	1.87	1.35	NS	NS	1.59

Figures within parentheses arc sine transformed values; figures superscripted by same letter not significantly different; figure represents mean % severity of foliage damage (5 replication of 10 leaves each)

data for two years revealed highest severity of 58.84% in district Kulgam followed by district Pulwama (57.33%), Bandipora (56.39%), Anantnag (54.00%), Ganderbal (52.67%), Budgam (52.19%), Baramulla (52.08%), Kupwara (50.14%) and Srinagar (47.22%) all falling in Scale-4, respectively. Again the pooled data also revealed highest severity during the 36th and 38th standard weeks in all the three zones.

Species of Brassicaceae and their cultivars might differ in their susceptibility and attack by flea beetles. Mayoori and Mikunthan (2009) reported such differences in *P. cruciferae* (Goeze), a serious pest in Jaffna district of Sri Lanka in cabbage. It was observed that the extent of damage on other brassicaceous crops i.e in cauliflower, radish, mustard and leafy cabbage was 52.6, 62.5, 60.7, and 35.6 %, respectively, and with severe feeding pressure the seedlings ultimately died and reported dramatic yield losses. Lamb (1988) also observed reduced crop stand, plant growth and eventually yield losses due to flea beetle damage.

Flea beetles are an important pest of cruciferous vegetables and cause a significant damage at both the phenological stages of the crops i.e. cotyledonary and true leaf stage, resulting in seedling mortality, reduced

Table 6. Severity of flea beetle on *Brassica rapa* in Kashmir (pooled data, 2012 & 2013)

S. No.	Zones	Districts	Mean % severity						
			32nd	34th	36th	38th	40th	42nd	Mean
1.	South	Anantnag	51.00 (45.55)	45.00 (42.08)	67.33 (55.27)	69.67 (56.63)	48.33 (44.01)	42.67 (40.71)	54.00 (47.38)[a]
		Kulgam	58.67 (50.00)	58.33 (49.80)	68.67 (56.04)	68.67 (56.00)	40.00 (39.17)	58.67 (50.08)	58.84 (50.19)[a]
		Pulwama	58.33 (49.80)	66.00 (54.38)	69.67 (56.65)	67.67 (55.39)	40.33 (55.39)	42.00 (40.35)	57.33 (49.32)[a]
		Mean	56.00 (48.45)[g]	56.44 (48.76)[g]	68.56 (55.99)[f]	68.67 (56.01)[f]	42.89 (40.85)[h]	47.78 (43.72)[i]	56.72 (48.96)
		CD (0.05)	Locations=1.97 :		Std. weeks= 2.38:		Locations x weeks= 4.12		
2.	Central	Budgam	50.50 (45.27)	55.17 (47.99)	68.17 (55.76)	62.84 (52.53)	35.83 (36.61)	40.67 (39.55)	52.19 (46.29)[b]
		Ganderbal	59.00 (50.22)	45.00 (42.09)	67.67 (55.43)	67.33 (55.24)	37.00 (37.38)	40.003 (39.14)	52.67 (46.58)[b]
		Srinagar	45.67 (42.47)	40.00 (39.13)	56.67 (48.87)	56.67 (48.85)	48.17 (43.92)	36.17 (36.86)	47.22 (43.35)[c]
		Mean	51.72 (45.99)[l]	46.72 (43.07)[m]	64.17 (53.35)[j]	62.28 (52.21)[k]	40.33 (39.30)[n]	38.95 (38.52)[n]	50.69 (45.41)
3.	North	CD (0.05)	Locations=1.76:		Std. weeks=2.48:		Locations x weeks= 4.31		
		Baramulla	49.67 (44.78)	54.50 (47.60)	62.83 (52.53)	62.83 (52.51)	46.17 (42.75)	36.50 (37.05)	52.08 (46.20)[e]
		Bandipora	50.50 (45.27)	51.50 (45.85)	62.83 (52.54)	62.83 (52.61)	51.83 (46.04)	58.83 (50.15)	56.39 (48.74)[d]
		Kupwara	47.17 (43.34)	49.50 (44.69)	64.17 (53.32)	58.83 (50.13)	44.83 (41.96)	36.34 (36.96)	50.14 (45.06)[e]
		Mean	49.11 (44.46)[q]	51.83 (46.05)[p]	63.28 (52.80)[o]	61.50 (51.75)[o]	47.61 (43.58)[q]	43.89 (41.39)[q]	52.87 (46.67)
		CD (0.05)	Locations=1.89 :		Std. weeks=2.67:		Locations x weeks=4.63		

Figures within parentheses arc sine transformed values; figure represent mean % severity of foliage damage (based on 5 replication of 10 leaves each)

plant growth, delayed and uneven maturity and finally the marketability. Regular monitoring of the pest activity is an important aspect of IPM and the evaluation of pest populations and providing information about the optimal time for control measure applications is required (Toshova et al., 2009). Thus our results could be used in IPM approach for flea beetle control.

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SEX PHEROMONE BLENDS FOR RICE CASEWORM *PARAPONYX STAGNALIS* ZELLER

K. KARTHIKEYAN, A.R. PRASAD*, K.N. JYOTHI*, L. PRASUNA* AND M.C. NARAYANAKUTTY

Regional Agricultural Research Station
Kerala Agricultural University, Pattambi 679306, Kerala
**Indian Institute of Chemical Technology, Hyderabad 500007, Telangana*
**Email:profkarthi@yahoo.co.in (corresponding author)*

ABSTRACT

Studies on sex pheromone of rice caseworm, *Paraponyx stagnalis* (Zeller) using EAG and GC-MS indicated the presence of four pheromone compounds *viz.*, Z-13-octadecenyl acetate, Z-9-hexadecenal, Z-11-hexadecenal and Z-11-hexadecenyl acetate in the ovipositor extract. Five different blends prepared from the tentatively identified compounds were evaluated for their field efficacy in rice fields at Pattambi, Kerala. Pheromone blends with Z-13-Octadecenyl acetate alone and with Z-11- Hexadecenal as a two component blend in the ratio of 1:1 were found promising in attracting more number male moths of rice caseworm in the field study.

Key words: *Paraponyx stagnalis*, sex pheromones, Z-13-octadecenyl acetate, Z-11- hexadecenal, Z-11-hexadecenyl acetate, Z-9-hexadecenal,moth catches

Rice caseworm (*Paraponyx stagnalis*) is assuming major pest status and posing major threat in all rice growing tracts of India viz., Assam (Gogai and Bora, 2013), Madhya Pradesh (Patel and Khatri, 2001), north western Uttar Pradesh (Singh and Singh, 2014), and Bihar, Odisha and West Bengal (http://www.rkmp.co.in// research themes/changing pest scenario). Management of this pest is difficult with chemical insecticides due to survival of insects in stagnant water. Using semiochemical/pheromone based methodologies is one of the promising alternative for an effective, potential and ecologically safe pest management for such pests inhabiting cryptic living habitat.

However, lack of an effective pheromone lure for caseworm is hampering its control. In collaboration with Indian Institute of Chemical Technology (CSIR-IICT), Hyderabad, the existence of female based pheromone system with electrophysiological behavioural bioassays has been brought out now. Isolation and identification of the four probable pheromone compounds from females under this collaborative programme (unpublished) has been achieved. Herein, the evaluation of the field efficacy and confirmation of the sex pheromone blends in the rice fields of Regional Research Station of Kerala Agricultural University (KAU) at Pattambi, Kerala is presented.

MATERIALS AND METHODS

The experiments were conducted at the Regional Agricultural Research Station, Kerala Agricultural University, Pattambi in collaboration with Indian Institute of Chemical Technology, Hyderabad during 2014-15 and 2015-16. Studies on characterization of pheromonally active chemical components from ovipositor extracts (from females collected at Pattambi) using Electroantennography (EAG), Gas chromatography linked EAG (GC-EAD), High Pressure Liquid Chromatography (HPLC) and Gas Chromatography-Mass Spectrometry (GC-MS) etc. were conducted at CSIR-IICT. All field evaluations were conducted in the experimental rice fields of Kerala Agricultural University, Pattambi, with the pheromone blend components provided by CSIR-IICT.

Field collected larvae were maintained individually in 10 ml test tubes until females emerged in the insectary at 28 ± 2p C and 70% RH. Ovipositor clipping of two days old virgin females was done during early hours of scotophase period as most females exhibited calling posture during this period, for collection of pheromonally active constituents. Excision was done with micro scissors by gently pressing the abdominal tips. The excised ovipositors were then soaked in HPLC grade hexane for 10 min and the supernatant transferred to a glass vial after subjecting it to microfiltration and stored at -30°C until used.

Electroantennogram Recording Technique (EAG): For electrophysiological recordings, Syntech EAG (Syntech, Hilversum, The Netherlands) was employed

as described earlier (Jyothi *et al*., 2014). Antennae were excised along with the head and were mounted on to a metal electrode holder (stainless steel) with two to three droplets of electrically conductive gel. The antenna was continuously flushed with charcoal filtered and moistened air stream through a stainless tube (8mm id) ending 2 cm before preparation. The EAG signals were amplified and recorded with a data acquisition controller and software (Syntech, The Netherlands).

Stimulus preparation was done as follows: Fifty µl of the test solution of ovipositor extract/HPLC fraction / synthetic standards to be tested were transferred to a Whatman No. 1 filter paper (7 x 16 mm). After complete evaporation of the solvent, the filter paper strip was inserted into glass Pasteur pipette. Stimuli were provided by connecting the pipette for 1 sec into the air stream flushing over the antenna. An equal volume of solvent alone (hexane) spread on the filter paper served as the control. EAG responses were evaluated by measuring the maximum amplitude of depolarization triggered by stimuli. At least 30 sec was allowed between two continuous stimuli for recovery of the antenna. EAG responses were recorded from five male insects individually to each tested compound.

High Pressure Liquid Chromatography (HPLC) of the filtered ovipositor extract was done after concentration to 1 ml at the IICT Semiochemicals laboratory with the following conditions viz., Solvent mobile phase : 1% Ethyl acetate in hexane (isocratic system); Flow rate: 1ml/min; Wave length: 254 nm; Duration: 40 min; Column type : Si 100 5um (MERCK) with dimensions: 25cm x 0.4 cm; and Inject vol.: 10 µl - 20 µl. For every 2 min, the fractions were collected. However, as when and then there is appearance of peak, the fractions were collected till the termination of the respective peaks. In the process eleven such peaks were obtained. Accordingly, EAG responses were recorded using antennae (of males that emerged from the pupae brought from Pattambi and maintained at IICT insectary). These fractions were further combined as Fraction I (Combined fractions 3, 4 & 5), fraction II (combined fractions 6 &7) and final fraction III (combined fractions 8, 9, 10 & 11). These fractions I, II & III were checked for EAG activity and accordingly subjected to GC-MS analysis (Table 1).

Gas Chromatography linked Mass spectrometry (GC-MS) was done based on the antennal activity from EAG, with the active fractions being evaluated for identification of probable compounds. The GC-MS unit used was of make Varian GC- 240 MS with capillary column with dimension of 5m, 25 mm and 25µm. Temperature programming for each fraction was: initial 60°C with 2min hold, with raise of 10°C/ up to 110 °C with 1 min hold and raise of 5°C/ min up to 150°C with hold of 1 min and finally 10°C/ min up to 240°C with 10 min hold.

Table 1. HPLC fractions from ovipositor extracts vs male antennal response by EAG

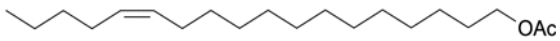
HPLC Fraction No	Time (min.)	EAG response (-mV)
1.	0-3	0
2.	3-3.5	0.5-0.75
3.	3.5-4.5	1
4.	4.5-5.0	0.75
5.	5.0-6.0	0.75
6.	6.0-6.25	0.75
7.	6.25-6.5	1
8.	6.5-7.0	1.2
9.	7.0-13.0	1.5; 1.75
10.	13.0-13.5	0.75
11.	13.5-18.0	1.0
Fraction I	3.5-6.0	3.5
Fraction II	6.0-6.5	1.5
Fraction III	6.5-18	3.25

Preparation of lures in different blend ratios for mini field evaluations in rice was done with all the four tentatively identified pheromone compounds provided by IICT. As suggested by IICT, six blends were formulated and their field efficacy evaluated (Table 3). Black coloured rubber septa (1.5cm height and 0.5cm width) supplied by Sun Lures Co., Chennai were used as dispensers. Lures were prepared by impregnating 3 mg of the blend components in HPLC grade hexane along with equal quantity of Butylated Hydroxy Toluene (BHT) as an antioxidant. Yellow coloured delta sticky traps of 24 (L) x 11.5 (W) x 10.5 (H) size were used for trapping. The dispenser was tied with thread and hung above the sticky surface of the delta trap (Plate 1). The trap was installed in the field after 25 days after transplanting at the Regional Agricultural Research Station, Pattambi in kharif 2016. The traps were tied to bamboo pole at a height of 50cm from the ground level facing north-east direction. Moth catches were recorded every alternate day and mean and cumulative catch data computed (Table 4).

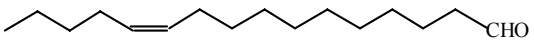
RESULTS AND DISCUSSION

EAG activity recorded with male case worm antennae against ovipositor extract of virgin female moths (Five female equivalents) ranged up to 8 -mV as shown in Fig.1, and the EAG values in -mV for the various HPLC fractions given in Table 1. These reveal that the EAG activity is more significant with Fraction No. 3 and highest in fraction no. 9; the pooled fractions I, II and III elicited antennal responses of -3.5 mV, -1.5 mV and -3.25 mV, respectively; with the GC-MS spectra indicating the presence of Z-13-octadecenyl acetate, Z-9-hexadecenal, Z-11-hexadecenal and Z-11-hexadecenyl acetate (IICT unpublished data) as given below. Table 2 provides the EAG values of male obtained with the identified compounds.

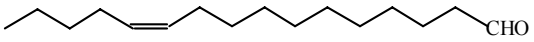
1. Z-13-octadecenyl acetate



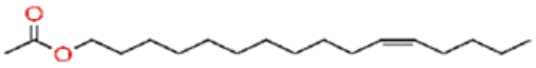
2. Z-9-hexadecenal



3. Z-11-hexadecenal



4. Z-11-hexadecenyl acetate



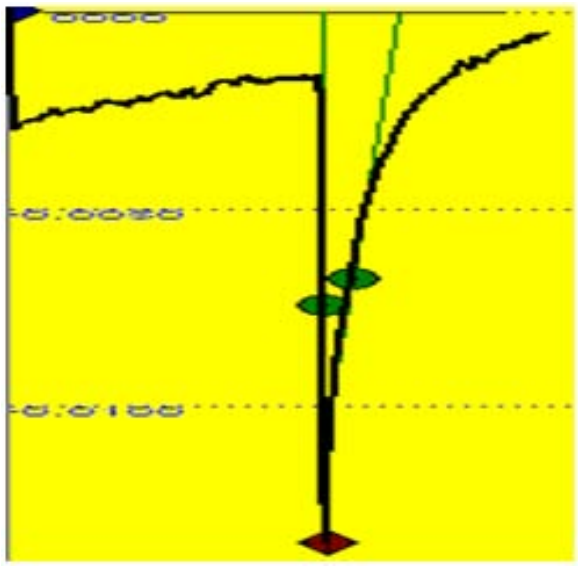


Fig 1. EAG response of male caseworm (5 female equivalents of ovipositor extract)

Table 2. EAG response of male towards tentatively identified compounds from ovipositor extract (-mV)

Pheromonal compounds	Antennal activity (-mV)
(Z)-11-hexadecenyl acetate	2.5-3.5
(Z)-13-octadecenyl acetate	2.3-2.5
(Z)-11- Hexadecenal	1.5-1.7
(Z)-9- Hexadecenal	1.0-1.25
n-Hexane	0.25-0.6

The preliminary field evaluations carried out at Pattambi using the four identified pheromone compounds formulated in the five blend combinations are given in Table 3. These reveal that amongst the blends, blend II (50% Z-13-octadecenyl acetate and 50% Z-11-hexadecenal) resulted in maximum catches of males (33.2 moths/trap; and cumulative catches of 28.72 moths/trap across five locations (Fig. 2). This is followed by blend I (10% Z-13-octadecenyl acetate) and blend III; blend IV (100% Z-13-octadecenyl acetate and 10% Z-11-hexadecenyl acetate) resulted 9.5 moths/trap and cumulative catches of 8.24 moths/trap; and blend V (50% Z-13-octadecenyl acetate and 50% Z-9-hexadecenal) giving the least in terms of catch data (Table 4).

These observations are contrary to earlier study of Sampathkumar *et al.,* (2015) who reported that the blend of Z-13-octadecenyl acetate and Z-11-hexadecenyl acetate in the ratio of 100:1 attracted most male moths (8.75 moths/trap/day with a cumulative catch of 17.50 moths/trap).

Thus preliminary field trials conducted reveal that maximum male moth catches were obtained with blend II comprising of Z-13-octadecenyl acetate & Z-11-Hexadecenal in 1: 1 ratio. Blend I comprising of Z-13-

Table 3. Pheromone blend formulations evaluated for field efficacy

Blend No	Combinations
I	100% Z-13-octadecenyl acetate
II	50% Z-13-octadecenyl acetate and 50% Z-11-hexadecenal
III	75 % Z-13-octadecenyl acetate and 25 % Z-11-hexadecenal
IV	50% Z-13-octadecenyl acetate and 50% Z-9-hexadecenal
V	100% Z-13-octadecenyl acetate and 10% Z-11-hexadecenyl acetate

Table 4. Male catch/trap with blends pheromones (Cumulative catches for three weeks)

Blends	Location-1	Location-2	Location-3	Location-4	Location-5	Average Catches
I	12.2	20.2	23.4	10.5	25.8	18.42
II	32..2	28.2	33.2	25.2	24.8	28.72
III	10.5	8.5	25.2	9.5	23.2	15.38
IV	8.5	7.2	9.5	6.8	9.2	8.24
V	3.5	4.2	2.5	8.2	5.2	**4.72**

Fig. 2. Delta trap at crop canopy level

octadecenyl acetate only gave 28.42/trap, while addition of 10 % Z-11- hexadecenyl acetate resulted in decline of catches to 4.72 moths/ trap. Similarly, addition of Z-9-hexdecenal to Z-13- octadecenyl acetate resulted in decline of catches to 8.24 moth/trap. Results demonstrate that blends I-III comprising of (Z)-13 octadecenyl acetate and (Z)-11-hexadecenal are promising in attracting male moths of caseworm and the other two components i.e., Z-11-hexadecenyl acetate and Z-9-hexadecenal have lesser role.

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PERSISTENCE AND RESIDUAL TOXICITY OF INSECTICIDES AGAINST *BEMISIA TABACI* (GENNADIUS) IN COTTON

G. K. GREWAL AND VIJAY KUMAR*

Department of Entomology, Punjab Agricultural University, Ludhiana 141004
**Email: vijay_ento@pau.edu*

ABSTRACT

Among the insecticides evaluated against *Bemisia tabaci* on cotton, triazophos @ 1500 ml/ha persisted for 9.14 days while buprofezin @ 625 ml/ha persisted for shortest period of 2.19 days during 2015-16. However, during 2016-17, the LT_{50} values were found higher in case of buprofezin @ 1250 ml/ha (8.00 days) while buprofezin @ 625 ml/ha persisted for shortest period of 1.35 days.

Key words: *Bemisia tabaci*, Cotton, residual toxicity, persistence, triazophos, buprofezin, ethion, diafenthiuron, spiromesifen, pyriproxyfen, acetamiprid

Before introduction of Bt cotton, bollworms and sucking insect pests were causing losses to crops, but with Bt cotton, efforts are to be made for protection against sucking pests. Among these whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) is widely distributed polyphagous pest in tropical and subtropical regions causing considerable economic losses. To manage this pest, a number of insecticides belonging to different groups had been recommended, and many of these traditional ones had become ineffective, even at very high doses. Newer insecticides with high toxicity at lower doses do not persist in environment as compared to conventional insecticides (Singh and Singh, 2000). The residual toxicity resulting from foliar application of insecticides could be of great significance in indicating an effective period over which an insecticide could persist in biologically active stage and the periodic evaluation for their effectiveness is also essential under the field conditions. Therefore, present investigation was conducted to know the persistence and residual toxicity of some insecticides against *B. tabaci*.

MATERIALS AND METHODS

The study was carried out in the IPM Laboratory, Department of Entomology, Punjab Agricultural University, Ludhiana during *kharif* 2015-16 and 2016-17. Cotton hybrid, RCH 650 BGII was sown during 2015-16 and 2016-17. There were eight treatments including control with three replications. The insecticides evaluated include: ethion (2000, 1000 ml/ha), triazophos (1500, 750 ml/ha), diafenthiuron (500, 250 g/ha), spiromesifen (500, 250 ml/ha), pyriproxyfen (1250, 625 ml/ha), buprofezin (1250, 625 ml/ha) and acetamiprid (50, 25 g/ha). These were also then sprayed separately on potted cotton plants with small hand operated knapsack sprayer to provide uniform coverage of the leaves with spray liquid. The cotton leaves with stalk were collected at random from the treated pots after 1, 3, 5, 7, 9, 11 and 15 days of spraying and brought to laboratory. The adults of *B. tabaci* were collected from the unsprayed Bt cotton fields with an aspirator and released on the stalked leaves in the petri plates having agar-agar and kept at room temperature. Mortality counts were taken 24, 48 and 72 hr after the release, and % mortality was calculated. The values of LT_{50} (time for 50% mortality) were calculated with software of probit analysis (Finney, 1971). The product of average residual toxicity (PT) and the period (P) for which the toxicity persisted was used as an index of persistent toxicity (Pradhan, 1967; Sarup *et al*., 1970).

RESULTS AND DISCUSSION

The observations given Table 1 and 2 revealed that ethion @ 2000 ml/ha resulted in 100 % mortality 48 hr after treatment on 1st , 3rd and 5th day which declined to 91.66, 86.66t and 36.66 % after 7th, 9th and 11th day. Similarly, ethion @ 1000 ml/ha provided 100 % mortality after 72 hr on 1st and 3rd day after treatment which declined to 90.00, 75.00, 60.00 and 0.00% after 5th, 7th, 9th and 11th day, respectively. Triazophos @ 1500 ml/ha resulted in 100% mortality after 1st, 3rd, 5th and 7th day which declined to 95 and 45% on 9th and 11th day, respectively. Similarly, triazophos @ 750 ml/ha gave 100% mortality after 72

Table 1. Persistent toxicity of insecticides against *B. tabaci* on Bt cotton (2015-16)

Treatment	Days after treatment														
	1st	3rd	5th		7th		9th		11th		15th				
	48hr	48hr	48hr	72hr	48hr	72hr	48hr	72hr	48hr	72hr	48hr	72hr	PT	R.E.	O.R.E.
Ethion 50EC @	100.00	100.00	81.66	100.00	85.00	91.66	0.00	86.66	21.66	36.66	0.00	0.00	944.13	1.13	3
2000 ml/ha	(89.96)	(89.96)	(64.66)	(89.96)	(67.18)	(76.22)	(0.00)	(68.63)	(27.07)	(37.07)					
Triazophos	100.00	100.00	90.00	100.00	70.00	100.00	76.66	95.00	25.00	45.00	0.00	0.00	990	1.18	1
40EC @	(89.96)	(89.96)	(74.96)	(89.96)	(56.97)	(89.96)	(61.73)	(79.51)	(29.91)	(42.07)					
1500ml/ha															
Diafenthiuron	100.00	95.00	91.00	100.00	60.00	100.00	71.66	90.00	5.00	12.66	0.00	0.00	912.37	1.09	4
50WP @ 500	(89.96)	(79.51)	(76.22)	(89.96)	(50.74)	(89.96)	(57.83)	(71.92)	(10.44)	(17.03)					
g/ha															
Spiromesifen	100.00	100.00	91.66	100.00	70.00	100.00	51.66	75.00	31.66	53.00	0.00	0.00	968	1.16	2
22.9SC @	(89.96)	(89.96)	(76.22)	(89.96)	(56.97)	(89.96)	(45.96)	(60.05)	(34.13)	(46.74)					
500ml/ha															
Pyriproxyfen	98.33	100.00	85.00	85.00	41.00	81.66	66.66	82.50	41.66	81.66	0.00	0.00	970.10	1.16	2
10EC @	(85.65)	(89.96)	(67.37)	(67.37)	(40.18)	(64.66)	(54.81)	(65.28)	(40.18)	(64.66)					
1250ml/ha															
Buprofezin	100.00	100.00	80.00	100.00	80.00	90.00	60.00	75.00	60.00	75.00	0.00	0.00	990	1.18	1
25EC @ 1250	(89.96)	(89.96)	(63.52)	(89..96)	(68.04)	(74.96)	(50.74)	(60.75)	(50.83)	(64.97)					
ml/ha															
Acetamiprid 20	100.00	100.00	50.00	70.00	41.66	61.66	31.66	61.66	5.00	61.66	0.00	0.00	834.13	1.00	5
SP@ 50 g/ha	(89.96)	(89.96)	(44.98)	(61.98)	(40.15)	(51.73)	(34.21)	(51.73)	(10.44)	(51.78)					
Control	0.000	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)					
LSD (P=0.05)	4.56	5.78	17.84	15.96	13.72	11.26	7.82	9.59	11.09	18.52					

PT = Persistent toxicity index; R.E. = Relative efficacy based on PT; O.R.E. = Observational rating of efficacy

Table 2. Persistent toxicity of insecticides against *B. tabaci* on Bt cotton (2015-16)

Treatment	Days after treatment																
	1st		3rd		5th		7th		9th		11th		15th				
	48hr	72hr	48hr	72hr	48hr	72hr	48hr	72hr	48hr	72hr	48hr	72hr	48hr	72hr	PT	R.E.	O.R.E
Ethion 50EC @ 2000ml/ha	100.00 (89.96)	100.00 (89.96)	95.00 (79.51)	100.00 (89.96)	71.66 (58.23)	90.00 (71.53)	30.00 (32.20)	75.00 (59.97)	35.00 (36.22)	60.00 (50.76)	0.00 (0.00)	0.00 (0.00)	0.00	0.00	637.47	1.01	6
Triazophos 40EC @ 1500ml/ha	100.00 (89.96)	100.00 (89.96)	90.00 (74.96)	100.00 (89.96)	90.00 (74.96)	100.00 (89.96)	71.66 (59.59)	100.00 (89.96)	56.66 (49.01)	71.66 (57.83)	56.66 (48.84)	71.66 (57.83)	0.00	0.00	996.08	1.58	1
Diafenthiuron 50WP @ 500g/ha	100.00 (89.96)	100.00 (89.96)	100.00 (89.96)	100.00 (89.96)	50.00 (44.98)	65.00 (53.70)	55.00 (47.85)	66.66 (54.98)	56.66 (48.84)	61.66 (51.90)	31.66 (28.96)	40.00 (38.56)	0.00	0.00	794.42	1.26	5
Spiromesifen 22.9SC @ 500ml/ha	91.66 (76.22)	91.66 (76.22)	75.00 (64.97)	100.00 (89.96)	60.00 (50.74)	100.00 (89.96)	66.66 (54.72)	75.00 (60.28)	41.66 (39.58)	50.00 (44.98)	26.66 (25.94)	41.66 (35.46)	0.00	0.00	840.25	1.33	3
Pyriproxyfen 10EC @ 1250ml/ha	85.00 (71.30)	100.00 (89.96)	50.00 (44.98)	91.66 (76.22)	70.00 (56.81)	86.66 (72.37)	36.66 (36.88)	55.00 (47.94)	60.00 (55.75)	60.00 (55.75)	20.00 (26.05)	55.00 (47.94)	0.00	0.00	821.92	1.30	4
Buprofezin 25EC @ 1250ml/ha	70.00 (61.98)	80.00 (68.04)	61.66 (51.90)	71.66 (59.59)	30.33 (31.80)	56.66 (49.79)	40.00 (39.21)	55.00 (47.85)	20.00 (26.43)	45.00 (41.62)	16.66 (24.03)	35.00 (36.22)	0.00	0.00	629.42	1.00	7
Acetamiprid 20 SP @ 50 g/ha	61.66 (51.78)	100.00 (89.96)	61.66 (51.78)	100.00 (89.96)	70.00 (56.97)	91.66 (76.22)	50.00 (44.98)	70.00 (56.81)	40.00 (44.98)	60.00 (56.81)	26.66 (30.93)	55.00 (47.86)	0.00	0.00	873.87	1.38	2
Control	0.00 (0.00)	0.000 (0.00)	0.00 (0.00)	0.00 (0.00)	0.000 (0.000)	0.000 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.000 (0.000)	0.000 (0.000)	0.000 (0.00)	0.00	0.00			
LSD (P=0.05)	20.46	14.30	18.45	12.37	14.42	17.57	14.43	8.52	23.40	24.30	23.07	22.89					

PT = Persistent toxicity index; R.E. = Relative efficacy based on PT; O.R.E. = Observational rating of efficacy

hr on 1st, 3rd, 5th and 7th day which declined to 71.66% on 9th and 11th day.

Diafenthiuron @ 500 g/ha provided 100% mortality after 1st, 5th and 7th day which declined to 90.00 and 12.66% on 9th and 11th day. Similarly, diafenthiuron @ 250g /ha provided 100.00% mortality after 72 hr on 1st and 3rd day which declined to 65.00, 66.66, 61.66 and 40.00% on 5th, 7th, 9th and 11th day. According to Afzal *et al*. (2014) imidacloprid, diafenthiuron, acetamiprid and thiamethoxam were most effective insecticides against whitefly up to seven days after application while imidacloprid and diafenthiuron provided maximum mortality after 72 hr of application. Spiromesifen 22.9SC @ 500 ml/ha resulted in 100 % after 1st, 3rd, 5th, 7th day which declined to 75 and 53 % on 9th and 11th days; and @ 250 ml/ha provided 91.66, 100, 100 % mortality on 1st 3rd and 5th day, respectively, which declined to 75, 50, 41.66 % on 7th, 9th and 11th day, respectively. Pyriproxyfen 10EC @ 1250 ml/ha resulted in 98.33 and 100 % mortality after 1st and 3rd day which declined to 85, 81.66, 82.50 and 81.66 % on 5th, 7th and 9th and 11th day, respectively; and @ 625 ml/ha gave 100 % mortality after 1st day which declined to 91.66, 86.66, 55, 60, 55% after 3rd, 5th, 7th, 9th and 11th day, respectively. Such results obtained with buprofezin @1250 and 625 ml/ha, acetamiprid @ 50 g and 25 g/ha are given in Table 1 and 2.

These revealed the decreasing order of persistent toxicity (PT) as: triazophos @1500 ml, buprofezin @1250 ml, pyriproxyfen @ 1250ml, spiromesifen @ 500 ml, ethion @ 2000 ml followed by diafenthiuron @ 500 ml and acetamiprid @ 50 g/ha; similarly, it was triazophos @ 750ml, acetamiprid @ 50 g > spiromesifen @ 250 ml > pyriproxyfen @ 625 ml > diafenthiuron @ 250 g> ethion @ 1000 ml > buprofezin @ 625 ml/ha during 2015-16, respectively. Patil (2015) observed that the PT (product of toxicity) values of evaluated insecticides against *Aphis craccivora* (Koch) were in the order of imidacloprid (1381.40), acetamiprid (910.00), dimethoate (858.03), thiamethoxam (604.32), diafenthiuron (308.06), spiromesifen (499.20) and chlorfenapyr (279.40) at 48 hr.

During 2016-17 ethion @ 2000 ml/ha gave 98.33 % mortality after 1st and 3rd day, and 100 % mortality after 72 hr on 5th day, which declined to 85 and 86.66 % after 7th and 9th day, respectively; this further declined to 36.66 % after 72 hr on 11th day (Table 5, 6); and ethion @ 1000 ml/ha gave 98.33 % mortality after 72 hr, which declined to 95.00, 81.66, 55.00, 55.00 and 0% 5th, 7th, 9th and 11th day, respectively. Triazophos @ 1500 ml/ha resulted in 100 % mortality after 1st and 3rd, 5th and 7th day which declined to 91.66 and 43.33% after 9th and 11th day, respectively; also, at 750ml/ha gave 100% mortality after 72 hr on first and 3rd day, which declined to 95, 98.33 and 73.33% , after 5th, 7th and 9th day, respectively. According to Lal and Jat (2015) after one day spray, 90% of blister beetle was observed with decamethrin 2.8EC followed by thiodicarb 75WP and triazophos 40EC (80%) and quinalphos 25EC (65%); up to three days of spray, decamethrin gave 90% mortality; and at 4th and 5th days after spray, it maintained its persistence and caused 80% mortality.

Diafenthiuron @ 500 g/ha provided 100, 93.33 and 100 % mortality after 1st, 3rd, 5th and 7th day, respectively and it declined to 85 and 11.66% after 9th and 11th day, respectively. Similarly, @ 250 ml/ha also it gave 100 % mortality after 72 hr on first day which declined to 96.66, 60, 55 and 31.66% after 3rd, 5th, 7th, 9th and 11th day, respectively. According to Khattak *et al*. (2004), imidacloprid and diafenthiuron showed significant reduction in the whitefly population at 72 hr and even at 120 hr after spray. Spiromesifen @ 500 ml/ha and @ 250 ml/ha gave different values of mortality as given in Table, but according to Cruz *et al*. (2015) it showed persistence by even 24 and 41 days after application.

During 2016-17, the decreasing order of persistent toxicity (PT) was found to be: pyriproxyfen @ 1250 ml (PT 989.98)>triazophos @ 1500 ml (PT980.81)> spiromesifen @ 1250 ml (PT977.14)> buprofezin @ 1250 ml (PT976.23)> ethion @ 2000 ml (PT925.79)> diafenthiuron @ 500 ml (PT898.31)> acetamiprid @ 50 g (PT824.98).

However, more appropriate results could be derived by comparing LT_{50} values (Table 3, 4); these were higher (9.14 days) with triazophos while with buprofezin @ 625 ml/ha it was shortest (2.188 days), during 2015-16, respectively. The insecticides in the decreasing order of LT_{50} values was: triazophos @ 1500 ml/ha (9.142 days)> ethion @ 2000 ml/ha (8.669 days)> triazophos @ 750 ml/ha (8.607 days)>buprofezin @ 1250 ml/ha (8.603days)> diafenthiuron @ 500 g/ha (7.969 days)> pyriproxyfen @ 1250 ml/ha (7.459 days)> spiromesifen @ 500 ml/ha (7.201 days)> diafenthiuron @ 250 g/ha (7.071 days)> acetamiprid @ 50 g/ha (6.387 days)> ethion @ 1000 ml/ha (6.385 days)> pyriproxyfen @ 625 ml/ha (5.516 days)> spiromesifen @ 250 ml/ha (4.872

Table 3. Residual toxicity of insecticides against adults of *B. tabaci* on Bt cotton (2015-16)

Treatment	Lethal Time (LT_{50}) (Days)	Fiducial limits	Chisquare ($\chi 2$)	Degree of freedom	Heterogeneity	Slope±S.E.	Regression Equation	R.E.	O.R.E.
Ethion 50EC @ 2000ml/ha	8.669	6.601-11.187	13.285	5	2.6571	0.714±0.120	y=24.545-1.7162x	3.96	2
Ethion 50EC@ 1000 ml/ha	6.385	5.356-7.394	2.303	5	0.461	0.454±0.073	y=19.963-1.5149x	2.91	8
Triazophos 40EC@ 1500 ml/ha	9.142	8.013-10.449	5.0306	5	1.0061	0.620±0.103	y=24.348-1.6087x	4.17	1
Triazophos 40EC@ 750ml/ha	8.607	6.549-11.348	7.0507	5	1.4101	0.320±0.057	y=20.622-1.2471x	3.93	3
Diafenthiuron 50WP @ 500g/ha	7.969	6.674 - 9.376	6.1602	5	1.2320	0.602±0.097	y=23.373-1.6922x	3.64	4
Diafenthiuron 50WP @250 g/ha	7.071	4.765-9.462	8.2621	5	1.6524	0.351±0.060	y=19.611-1.3455x	3.23	7
Spiromesifen 22.9SC @ 500ml/ha	7.201	4.885-9.650	7.8154	5	1.5631	0.331±0.058	y=19.419-1.2986x	3.29	6
Spiromesifen 22.9SC @ 250ml/ha	4.872	-0.109-7.510	6.4076	5	1.2815	0.216±0.049	y=14.522-0.913x	2.22	10
Pyriproxyfen 10EC @ 1250ml/ha	7.459	2.481-7.722	5.6876	5	1.1375	0.318±0.056	y=19.492-1.2689x	3.40	5
Pyriproxyfen 10EC @ 625 ml/ha	5.516	5.146-10.022	7.647	5	1.5295	0.252±0.052	y=15.89-1.0446x	2.52	9
Buprofezin 25EC @ 1250ml/ha	8.603	5.816-12.687	13.237	5	2.6474	0.381±0.064	y=21.689-1.3764x	3.93	3
Buprofezin 25EC @ 625ml/ha	2.188	-1.535-4.030	2.179	5	0.436	0.234±0.056	y=11.268-0.7975x	1.00	12
Acetamiprid 20SP @ 50g/ha	6.387	3.475-9.152	13.732	5	2.7464	0.465±0.075	y=20.078-1.5309x	2.91	8
Acetamiprid 20SP @ 25g/ha	3.787	0.645-5.596	3.866	5	0.773	0.208±0.050	y=13.158-0.8421x	1.73	11

R.E. = Relative efficacy based on PT; O.R.E. = Observational rating of efficacy

Table 4. Residual toxicity of insecticides against adults of *B. tabaci* on Bt cotton (2016-17)

Treatment	Lethal Time (LT_{50}) (Days)	Fiducial limits	Chisquare ($\chi 2$)	Degree of freedom	Heterogeneity	Slope±S.E.	Regression Equation	R.E.	O.R.E.
Ethion 50EC@ 2000 ml/ha	7.884	5.883-10.167	11.011	5	2.2022	0.546±0.087	y=22.879-1.643x	5.84	2
Ethion 50EC @ 1000ml/ha	5.811	4.693-6.857	1.932	5	0.386	0.421±0.070	y=23.607-3.0357x	4.30	7
Triazophos 40EC @ 1500ml/ha	7.696	5.978-9.594	7.9499	5	1.5900	0.485±0.077	y=22.119-1.5767x	5.70	4
Triazophos 40EC @ 750ml/ha	5.394	4.090-6.541	4.376	5	0.875	0.363±0.063	y=17.268-1.2975x	3.99	9
Diafenthiuron 50WP @ 500g/ha	6.497	4.538-8.410	8.4895	5	1.6979	0.462±0.074	y=20.229-1.532x	4.81	6
Diafenthiuron 50WP @250g/ha	4.873	3.640-5.933	2.267	5	0.453	0.408±0.070	y=16.741-1.3238x	3.60	11
Spiromesifen 22.9SC @ 500 ml/ha	5.600	4.508-6.613	1.967	5	0.393	0.441±0.073	y=18.449-1.4428x	4.14	8
Spiromesifen 22.9SC @250ml/ha	3.855	1.175-5.510	3.027	5	0.605	0.231±0.052	y=13.465-0.905x	2.85	12
Pyriproxyfen 10EC @ 1250 ml/ha	6.827	4. 427-9.191	7.2477	5	1.4495	0.312±0.056	y=18.622-1.2471x	5.05	5
Pyriproxyfen 10EC @ 625 ml/ha	5.077	1.726-7.273	5.8168	5	1.1634	0.252±0.052	y=15.323-1.0252x	3.76	10
Buprofezin 25EC @ 1250ml/ha	8.004	6.151-10.167	7.1102	5	1.4220	0.382±0.064	y=21.162-1.4027x	5.92	1
Buprofezin 25EC@ 625ml/ha	1.350	3.637-3.469	1.968	5	0.394	0.217±0.056	y=10.243-0.714x	1.00	14
Acetamiprid 20SP @ 50g/ha	7.842	7.049-8.669	3.256	5	0.651	0.680±0.111	y=2.107-1.2857x	5.80	3
Acetamiprid 20SP @ 25g/ha	2.915	1.549-5.005	4.384	5	0.877	0.185±0.049	y=15.817-1.0744x	2.15	13

PT = Persistent toxicity index; R.E. = Relative efficacy based on PT; O.R.E. = Observational rating of efficacy

Table 5. Persistent toxicity of insecticides against *B. tabaci* on Bt cotton (2016-17)

Treatment	Mean % mortality after different day intervals														
	1st	3rd	5th		7th		9th		11th		15th				
	48hr	48hr	48hr	72hr	48hr	72hr	48hr	72hr	48hr	72hr	48hr	72hr	PT	R.E.	O.R.E
Ethion 50EC @ 2000ml/ha	98.33 (85.65)	98.33 (85.65)	78.33 (62.26)	100.00 (89.96)	0.00 (0.00)	85.00 (67.37)	80.00 (63.52)	86.66 (68.82)	11.66 (16.13)	36.66 (37.18)	0.00	0.00	925.79	1.12	3
Triazophos 40EC @ 1500ml/ha	100.00 (89.96)	100.00 (89.96)	91.66 (76.22)	100.00 (89.96)	60.00 (50.83)	100.00 (89.96)	73.33 (59.30)	91.66 (73.76)	21.66 (27.20)	43.33 (41.11)	0.00	0.00	980.81	1.18	2
Diafenthiuron 50WP @ 500g/ha	100.00 (89.96)	93.33 (75.21)	61.66 (51.73)	100.00 (89.96)	88.33 (73.82)	100.00 (89.96)	66.66 (54.76)	85.00 (67.37)	6.66 (11.89)	11.66 (16.44)	0.00	0.00	898.31	1.08	4
Spiromesifen 22.9SC @ 500ml/ha	100.00 (89.96)	100.00 (89.96)	70.00 (57.26)	100.00 (89.96)	85.00 (71.73)	100.00 (89.96)	45.00 (41.79)	71.66 (57.88)	30.00 (33.14)	61.33 (51.74)	0.00	0.00	977.14	1.18	2
Pyriproxyfen 10EC @ 1250ml/ha	100.00 (89.96)	100.00 (89.96)	100.00 (89.96)	100.00 (89.96)	83.33 (65.92)	83.33 (65.92)	63.33 (52.72)	80.00 (63.40)	38.33 (35.22)	76.66 (61.12)	0.00	0.00	989.98	1.20	1
Buprofezin 25EC @ 1250ml/ha	100.00 (89.96)	100.00 (89.96)	75.00 (60.05)	100.00 (89.96)	76.66 (61.89)	88.33 (73.82)	63.33 (52.85)	72.50 (63.47)	53.33 (46.90)	71.66 (58.33)	0.00	0.00	976.23	1.18	2
Acetamiprid 20SP @ 50g/ha	100.00 (89.96)	100.00 (89.96)	48.33 (43.83)	71.66 (63.05)	38.33 (38.17)	60.00 (50.76)	30.00 (33.14)	60.00 (50.76)	3.66 (9.02)	58.33 (49.97)	0.00	0.00	824.98	1.00	5
Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00	0.00			
LSD (P=0.05)	4.56	4.95	14.18	15.60	16.49	9.83	11.24	16.00	13.85	14.24					

PT = Persistent toxicity index; R.E. = Relative efficacy based on PT; O.R.E. = Observational rating of efficacy

Table 6. Persistent toxicity of insecticides against *B. tabaci* on Bt cotton (2016-17)

Treatment	Mean % mortality after different day intervals																
	1st		3rd		5th		7th		9th		11th		15th				
	48hr	72hr	48hr	72hr	48hr	72hr	48hr	72hr	48hr	72hr	48hr	72hr	48hr	72hr	PT	R.E.	O.R.E
Ethion 50EC @ 1000ml/ha	91.66 (76.22)	98.33 (85.65)	88.33 (70.08)	95.00 (79.51)	65.00 (53.84)	81.66 (65.16)	26.66 (30.28)	55.00 (47.94)	33.33 (35.09)	55.00 (47.86)	0.00 (0.00)	0.00 (0.00)	0.00	0.00	577.48	1.00	5
Triazophos 40EC @ 750 ml/ha	86.66 (73.57)	100.00 (89.96)	60.00 (51.31)	100.00 (89.96)	86.66 (72.37)	95.00 (82.37)	91.66 (76.22)	98.33 (85.65)	50.00 (44.98)	73.33 (59.03)	48.33 (44.02)	56.66 (48.84)	0.00	0.00	959.42	1.66	1
Diafenthiuron 50 WP @ 250 g/ha	98.33 (85.65)	100.00 (89.96)	96.66 (83.82)	96.66 (83.82)	53.33 (46.90)	60.00 (50.96)	50.00 (44.98)	60.00 (50.93)	45.00 (42.10)	55.00 (47.86)	25.00 (24.98)	31.66 (28.96)	0.00	0.00	739.42	1.28	3
Spiromesifen 22.9SC @ 250 ml/ha	53.33 (46.90)	98.33 (85.65)	71.66 (58.83)	95.00 (79.51)	83.33 (69.97)	91.66 (76.80)	65.00 (53.84)	71.66 (58.23)	36.66 (36.13)	55.00 (47.95)	21.66 (22.88)	38.33 (33.06)	0.00	0.00	824.96	1.42	2
Pyriproxyfen 10EC @ 625ml/ha	78.33 (66.81)	100.00 (89.96)	45.00 (42.07)	88.33 (73.51)	63.33 (52.77)	81.66 (64.78)	18.33 (24.98)	76.66 (61.30)	55.00 (52.08)	61.66 (56.74)	28.33 (31.24)	41.66 (40.09)	0.00	0.00	824.94	1.42	2
Buprofezin 25EC @ 625ml/ha	63.33 (53.83)	85.00 (71.11)	56.66 (49.30)	83.33 (66.23)	23.33 (28.22)	43.33 (40.79)	25.00 (24.98)	45.00 (41.71)	25.00 (29.21)	41.66 (39.98)	6.66 (12.28)	16.66 (19.67)	0.00	0.00	577.46	1.00	5
Acetamiprid 20SP 25g/ha	65.00 (53.84)	88.33 (70.66)	50.00 (44.98)	88.33 (73.51)	51.66 (45.83)	56.66 (49.02)	38.33 (38.14)	61.66 (51.81)	36.66 (37.10)	50.00 (44.95)	18.33 (24.98)	35.00 (35.66)	0.00	0.00	696.63	1.20	4
Control	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00	0.00			
LSD (P=0.05)	22.14	12.64	19.78	16.62	18.35	17.46	18.37	13.75	26.46	21.81	22.46	28.56					

PT = Persistent toxicity index; R.E. = Relative efficacy based on PT; O.R.E. = Observational rating of efficacy

days)> acetamiprid @ 25 g/ha (3.757 days)> buprofezin @ 625 ml/ha (2.188 days). The LT_{50} values ranged between 3.098 to 15.560 days (48 hr after treatment).

During 2016-17, the LT_{50} values were higher with buprofezin (8.004 days) while @ 625 ml/ha it required shortest time of 1.350 days; the decreasing order of LT_{50} values was observed to be: buprofezin @ 1250 ml/ha (8.004 days)> ethion @ 2000 ml/ha (7.884 days)> acetamiprid @ 50 g/ha (7.842 days)> triazophos @ 1500ml/ha (7.696 days)> pyriproxyfen @ 1250 ml/ha (6.827 days)> diafenthiuron @ 500 g/ha (6.497 days) > ethion @ 1000 ml/ha (5.811 days)> spiromesifen @ 500 ml/ha (5.600 days)> triazophos @ 750 ml/ha (5.394days) > pyriproxyfen @ 625ml/ha (5.077 days) diafenthiuron @ 250 g/ha (4.873 days)> spiromesifen @ 250 ml/ha (3.855 days)> acetamiprid @ 25 g/ha (2.915 days)> buprofezin @ 625 ml/ha (1.350 days). Thus the present study reveals that among the insecticides evaluated against *B. tabaci* on cotton, triazophos @ 1500 ml/ha, buprofezin @ 1250 ml/ha and pyriproxyfen @ 1250ml/ha (i.e. at higher dosages) persisted for longer period and their toxicity was also significantly higher as compared to their lower dosages.

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CHEMICAL ECOLOGY OF *ACEROPHAGUS PAPAYAE* NOYES AND SCHAUFF *VIS-À-VIS* GAS CHROMATOGRAPHY

R. NISHA* AND J.S. KENNEDY

**Department of Crop Protection, Imayam Institute of Agriculture and Technology, Thuraiyur, Trichy 621206*
Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore 641 003
**Email: nisharengadoss@gmail.com*

ABSTRACT

The chemical ecology of the parasitoid *Acerophagus papayae* Noyes and Schauff was studied with Gas Chromatography- Mass Spectrometry (GC-MS) volatiles analysis. The biochemical constituents and secondary metabolites in the host plant leaves revealed variation in influencing the growth and development of papaya mealybug *Paracoccus marginatus* Williams and Granara de Willink, which indirectly influenced the parasitoid efficiency too. Healthy and infested leaves of papaya and tapioca were analysed for the released volatile compounds (VOCs), and identified with GC-MS. It was observed that the VOCs like octanol, isocaryophyllene, hexadecane, pentadecane, heptadecane, morphinan and octasiloxane might probably attract the mealybug for sustained feeding in papaya. In tapioca, heptane, pyran, á-ocimene, octadien-3-ol, decane, butylated hydroxytoluene and dibutyl phthalate (DBP) were observed as probable reasons for repelling or prohibiting the mealybug from feeding.

Key words: *Acerophagus papayae*, *Paracoccus marginatus*, papaya, tapioca, leaves, volatiles analysis, attractants, repellents, parasitoid efficiency

Acerophagus papayae Noyes and Schauff is an effective parasitoid of papaya mealybug, *Paracoccus marginatus* (Williams & Granara de Willink) (PMB), which is a serious polyphagous pest. A widespread parasitoid like that of *A. papayae*, will encounter its various hosts in its range differently, as parasitoids vary in their interaction with their sympatric host species. Insect parasitoids are attracted to their hosts by semiochemicals called "kairomones", through signals enabled with communication systems (Law and Regnier, 1971). The induced volatiles emitted by plants vary considerably between their species and also genotypes (Dicke, 2009; Dicke, 1999). Moreover, the induced odours, in the same species, differ over time, showing some compounds immediately after damage and others needing more time to be synthesised by the attacked plants. These differences often were found to be reflected in the attractiveness of the plant for parasitoids, both in quantity and quality (Fritzsche- Hoballah *et al*., 2002; Oluwafemi *et al*., 2012). Such information on the chemical ecology of *A. papayae* under Indian conditions is lacking. Hence, the present study evaluated the influence of host plant volatiles on the parasitoid efficiency with two host plants namely papaya and tapioca.

MATERIALS AND METHODS

The experiment was carried out at the Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore in 2014. To study the chemical ecology of *A. papayae*, the volatiles from *P. marginatus* (preferred host) were extracted, and its two host plants *viz*., papaya (highly attracted to) and tapioca (poorly attracted to) were evaluated with four types of olfactometers *viz*., eight, six, two armed and 'Y'- tube (Nisha and Kennedy, 2015). The plants were obtained from pot culture with uniform stage of leaves selected for study. A preliminary study was carried out to extract the leaf volatiles from healthy and infested plants to check the presence of volatile compounds attracting/repelling the parasitoid.

The experimental set up included a glass container with a tight lid having two holes for inlet and outlet tubes, with approximately 20 g of healthy and infested leaves enclosed in them. An air filter with charcoal was inserted into the inlet hole of the lid, and an aquarium pump used to release pressure on one end of the filter. Thus air purified by the charcoal in the filter gets released into the enclosed container. The outgoing green leaf volatiles were collected in a glass tube fitted in the outlet hole. The experiment was run overnight and the tube with collected volatiles washed with 2 ml of HPLC grade hexane four times and collected in airtight glass tubes. The entire setup was washed thoroughly with hexane and the unit oven dried

between experiments (John Byers, 2006*;* Xu *et al*., 2002)

The green leaf volatiles in the hexane samples were analyzed by Gas Chromatography- Mass Spectrometry (GC-MS) equipment, with a DSQ II operator having the mass range between 50 and 650 m/z. A column (TR5MS, 0.25mmID, 0.25uf, 30m) was used with helium as carrier gas. GC oven temperature was kept at 50ºC for 2 min and programmed to 120 ºC @ 4ºC / min, and to 180 ºC @ 8ºC /min and then programmed to 195ºC @ 8ºC /min and finally kept constant to 350ºC for 10 min. The injector was at 200ºC in splitless and constant flow method (Kendra *et al*., 2011). Individual components were identified by comparison of their mass spectra using GC-MS library. Relative % amounts of the separated compounds were calculated automatically from peak areas of the total ion chromatograms (TIC). *n*-Alkanes were used as reference points in the calculation of relative retention indices.

RESULTS AND DISCUSSION

It was observed that both healthy and infested leaves of papaya and tapioca released volatile compounds (VOCs) (Table 1), and these were analysed and identified using GC-MS (Figs. 1-4). Papaya healthy leaves had ten alcohols, one ketone, ten alkanes, two

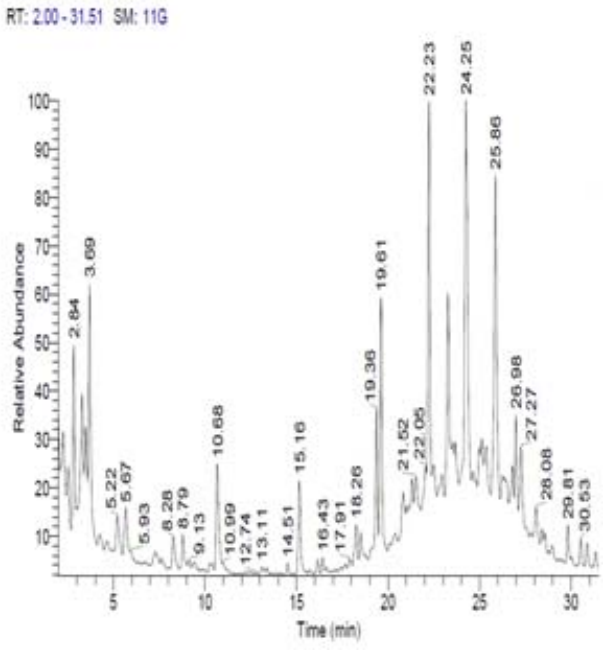

Fig. 1. Chromatogram of volatile compounds- healthy papaya leaves

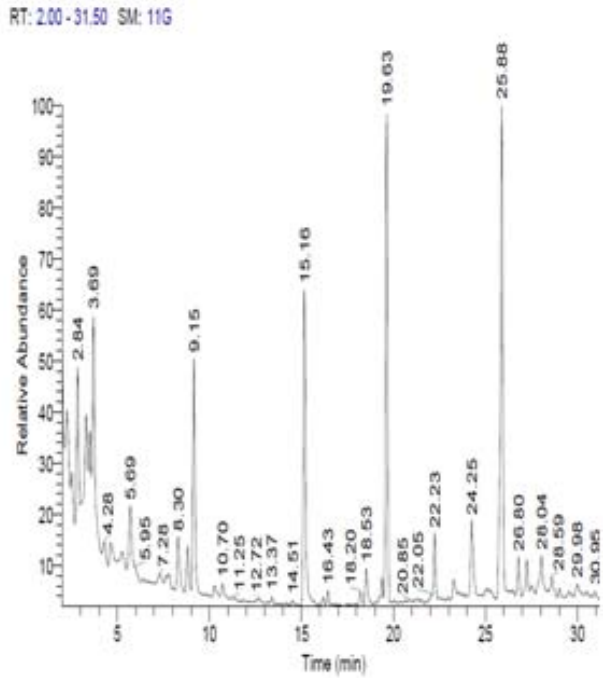

Fig. 2. Chromatogram of volatile compounds- mealybug infested papaya leaves

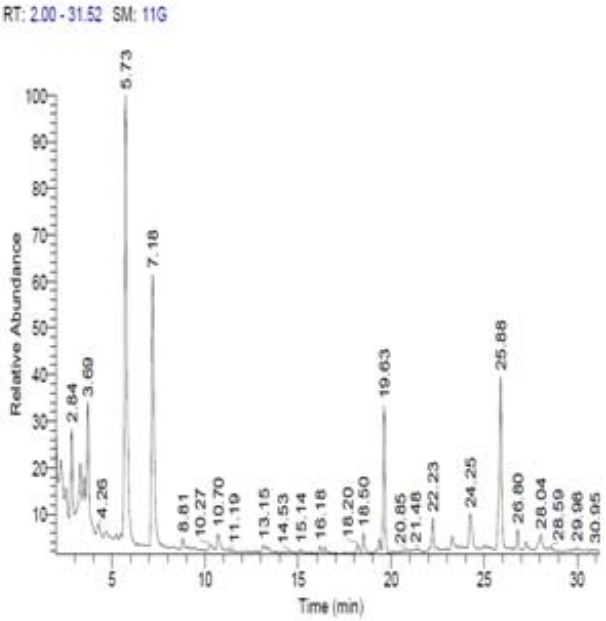

Fig. 3. Chromatogram of volatile compounds- healthy tapioca leaves

alkenes and oxides each, six acids, an ether, one aromatic compound, sesquiterpene, two benzenes, six cyclic compounds, and one thiol group compounds. It can be concluded that octanol, isocaryophillene, hexadecane, pentadecane, heptadecane, morphinan, octasiloxane might be the ones attracting mealybug.

Table 1. Volatile compounds in papaya and tapioca (healthy and mealybug infested leaves)

S. No	Volatile Compound		Papaya		Tapioca	
		Category	Healthy	Infested	Healthy	Infested
1.	2-Octanol, 3-methyl	Alcohol	1.47	-	-	0.83
2.	Diallylmethylsilane	Alkane	1.00	-	-	-
3.	2-Hexanone, 3,4-dimethyl-	Ketone	3.45	-	-	-
4.	Hydroperoxide, 1-ethylbutyl	Oxide	5.62	-	-	-
5.	1-Pentene, 3-ethyl-3-methyl-	Alkene	5.52	-	-	-
6.	1-Pentanol, 2-ethyl-4-methyl-	Alcohol	0.32	0.67	0.82	-
7.	Hydroperoxide, hexyl	Oxide	0.22	3.66	3.11	2.71
8.	Cyclobutylsilane	Cyclic	1.53	3.16	-	-
9.	Decane, 2,5,6-trimethyl-	Alkane	0.50	0.45	0.09	-
10.	Cyclohexane, 1-(1,1-dimethyl ethyl)-4-methyl-	Cyclic	0.10	-	-	0.33
11.	Benzenepropanoic acid, à-(hydroxyimino)-	Acid	0.86	-	-	-
12.	Bornyl chloride	Alkane	0.79	1.48	0.57	0.62
13.	Benzothiazole	Cyclic	3.07	0.42	1.02	3.43
14.	Cyclohexasiloxane, dodecamethyl-	Cyclic	0.20	-	-	0.11
15.	Benzene, (isothiocyanatomethyl)-	Benzene	2.39	11.11	-	-
16.	Isocaryophyllene	Terpene	0.24	-	-	-
17.	Oxalic acid, isobutyl nonyl ester	Acid	0.24	-	0.21	-
18.	Heptadecane, 2,6,10,14-tetramethyl-	Alkane	1.00	0.79	0.80	0.76
19.	4-t-Butyl-2-(1-methyl-2-nitroethyl) cyclohexanone	Cyclic	0.58	-	-	-
20.	Butylated Hydroxytoluene	Benzene	9.75	15.21	8.49	23.18
21.	2-Piperidinone, N-[4-bromo-n-butyl]-	Cyclic	0.25	-	-	-
22.	tert-Hexadecanethiol	Thiol	1.76	-	-	-
23.	Methoxyacetic acid, 3-tridecyl ester	Acid	2.59	0.19	-	-
24.	Hexadecane	Alkane	11.00	-	1.72	5.94
25.	Hexadecane, 1,1-bis(dodecyloxy)-	Alkane	0.66	-	-	-
26.	Pentadecane, 2,6,10-trimethyl-	Alkane	7.54	-	-	8.53
27.	Heptadecane, 2,6-dimethyl-	Alkane	12.91	-	-	-
28.	9-Hexadecenoic acid	Acid	0.13	-	-	-
29.	1-Hexadecanol, 2-methyl-	Alcohol	1.95	-	-	-
30.	Estra-1,3,5(10)-trien-17á-ol	Alcohol	1.30	-	-	-
31.	Silane, trichlorodocosyl-	Alkane	9.47	0.35	-	-
32.	1-Hexadecanol, 2-methyl-	Alcohol	1.28	-	0.15	-
33.	1-Hexadecanol	Alcohol	3.10	-	-	-
34.	1-Hexadecanol, 2-methyl-	Alcohol	2.11	-	-	2.12
35.	Estra-1,3,5(10)-trien-17á-ol	Alcohol	0.92	-	-	-
36.	Morphinan-4,5-epoxy-3,6-di-ol, 6-[7-nitrobenzofurazan-4-yl]amino-	Aromatic	0.23	-	-	-
37.	Octasiloxane, 1,1,3,3,5,5,7,7,9,9,11,11,13,13,15, 15-hexadecamethyl-	Alkane	0.55	-	-	-

38.	2-Propenoic acid, 3-(4-methoxyphenyl)-, 2-ethylhexyl ester	Acid	0.48	-	-	-
39.	Benzoic acid, pentadecyl ester	Acid	0.27	-	-	-
40.	3-Ethyl-2-heptanol	Alcohol	-	2.34	-	-
41.	Oxirane, (2-methylbutyl)-	Ether	-	0.91	-	0.83
42.	3-Heptanone	Ketone	-	4.34	4.26	1.80
43.	1,1,3,3,5,5,7,7-Octamethyl-7-(2-methylpropoxy) tetrasiloxan-1-ol	Alcohol	-	0.95	-	-
44.	Benzyl isocyanate	Benzene	-	0.65	-	-
45.	Benzenepropanoic acid, à-(hydroxyimino)-	Acid	-	2.26	-	-
46.	2H-Pyran, 2-(7-heptadecynyloxy)tetrahydro-	Cyclic	-	0.17	1.00	-
47.	2,2,7,7-Tetramethyloctane	Alkane	-	0.36	-	-
48.	2,5-Cyclohexadiene-1,4-dione, 2,6-bis (1,1-dimethylethyl)-	Cyclic	-	0.43	0.47	-
49.	Furan,2,5-dihydro-2,2-dimethyl-5-(1-methylethenyl)-3-(1 methylethyl)-	Cyclic	-	1.18	-	-
50.	Octadecane, 6-methyl-	Alkane	-	0.18	-	-
51.	1-Iodo-2-methylundecane	Alkane	-	3.17	0.40	-
52.	cis-11-Hexadecenal	Aldehyde	-	18.00	11.35	-
53.	Phthalic acid, 2-ethylbutyl isobutyl ester	Acid	-	1.16	-	-
54.	Tetradecane, 2,6,10-trimethyl-	Alkane	-	0.30	-	-
55.	Phthalic acid, butyl undecyl ester	Acid	-	1.70	0.98	1.02
56.	n-Hexadecanoic acid	Acid	-	0.20	-	-
57.	2-Decene, 5-methyl-, (Z)-	Alkene	-	0.63	-	-
58.	Cyclopentasiloxane, decamethyl-	Alkane	-	7.63	-	-
59.	Pentane, 2,2,3,4-tetramethyl-	Alkane	-	0.40	-	-
60.	Tridecane	Alkane	-	2.01	0.24	0.48
61.	Heptane, 1-nitro-	Alkane	-	-	2.12	-
62.	Cyclopropane, 2-bromo-1,1,3-trimethyl-	Cyclic	-	-	8.40	-
63.	Hexane, 3,4-dimethyl-	Alkane	-	-	0.40	-
64.	1-Hexene, 4-methyl-	Alkene	-	-	0.19	-
65.	1,3,6-Octatriene, 3,7-dimethyl-, (Z)-	Triene	-	-	0.11	-
66.	á-Ocimene	Terpene	-	-	29.27	-
67.	1,6-Octadien-3-ol, 3,7-dimethyl-	Alcohol	-	-	17.84	-
68.	Indolizine	Cyclic	-	-	0.43	-
69.	1H-Benzocycloheptene, 2,4a,5,6,7,8,9,9 a-octahydro-3,5,5-trimethyl-9-methylene-, (4aS-cis)-	Cyclic	-	-	0.29	-
70.	Indolizine	Cyclic	-	-	0.43	-
71.	1H-Benzocycloheptene, 2,4a,5,6,7,8,9,9a-octahydro-3,5,5-trimethyl-9-methylene-, (4aS-cis)-	Cyclic	-	-	0.29	-
72.	4-(1-Hydroperoxy-2,2-dimethyl-6-methylene-cyclohexyl)-pent-3-en-2- one	Ether	-	-	1.05	-
73.	Dibutyl phthalate	Ester	-	-	1.22	-

74.	Heptadecane, 2,6,10,15-tetramethyl-	Alkane	-	-	0.10	0.51
75.	Cyclobutane, 1,1-dimethyl-2-octyl-	Cyclic	-	-	-	0.34
76.	1-Hexanol, 2-ethyl-	Alcohol	-	-	-	0.45
77.	4-Bromoheptane	Alkane	-	-	-	0.12
78.	Naphthalene	Aromatic	-	-	-	0.19
79.	1-Hexanol, 2-(hydroxymethyl)-	Alcohol	-	-	-	0.19
80.	2,2,7,7-Tetramethyloctane	Alkane	-	-	-	0.11
81.	Longifolene	Terpene	-	-	-	0.16
82.	Menthol, 1'-(butyn-3-one-1-yl)-, (1S,2S,5R)-	Aromatic	-	-	-	1.36
83.	2-Piperidinone, N-[4-bromo-n-butyl]-	Cyclic	-	-	-	0.94
84.	Methoxyacetic acid, 2-tetradecyl ester	Acid	-	-	-	1.00
85.	Cholestan-3-ol, 2-methylene-, (3á,5à)-	Aromatic	-	-	-	0.30
86.	2-Methyl-Z-4-tetradecene	Alkene	-	-	-	0.97
87.	Octadecane, 6-methyl-	Alkane	-	-	-	1.53
88.	i-Propyl 14-methyl-pentadecanoate	Alkane	-	-	-	0.56
89.	Dodecane, 5,8-diethyl-	Alkane	-	-	-	0.26

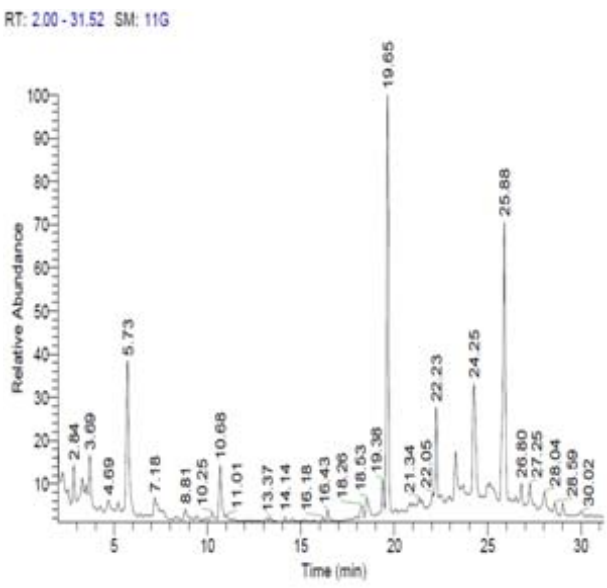

Fig. 4. Chromatogram of volatile compounds- mealybug infested tapioca leaves

Tapioca, in its healthy leaves was observed with three alcohols, one ketone, eleven alkanes, an alkene, an oxide, two acids, an aldehyde, a terpene, a benzene, six cyclic compounds, one triene and an ether group compounds. In these, heptane, pyran, á-ocimene, octadien-3-ol, decane, butylated hydroxytoluene, dibutyl phthalate (DBP) could be the ones repelling the mealybug from feeding. These findings derive support from Markovic *et al*. (1996) and Pare and Tumlinson (1999), and also report of DBP being used as an ectoparasiticide (Ali *et al.*, 2010).

After mealybug feeding, there was a decrease in the alcohol and acid compounds and an increase in the alkane group and benzene compounds in papaya: there were fourteen alkanes, five alcohols, six cyclic compounds, five acids, two alkenes, three benzene, an ether, a ketone, an oxide and an aldehyde. In tapioca, there was increase in alcohol and cyclic compounds, with eleven alkanes, seven alcohols, seven cyclic compounds, three acids, an alkene, a benzene, an ether, a ketone, an oxide an ester, two terpenes and an aldehyde. Thus it could be observed that the plants responded to insect feeding with release of a variety of volatiles, and the profile of the volatiles emitted were markedly different. These findings derive support from Louohrin *et al*. (1994) who reported that breakage of leaf glands due to insect feeding causes stored terpenes to be released in much higher levels, with increased emissions of lipoxygenase pathway green leaf volatiles. Oluwafemi *et al.* (2012) also reported that volatile organic compounds emitted from seedlings of seven African maize varieties when infested with *Cicadulina storeyi* varied.

Three common compounds were identified with the mealybug infested papaya and tapioca leaves- these include oxirane, (2-methylbutyl)-, phthalic acid, butyl undecyl ester, octadecane, 6-methyl. Although, similar volatile compounds were released in the mealybug

damaged leaves, the specific blends were quite distinct. The VOCs viz., benzyl isocyanate, pyran and furan were exclusively observed in papaya leaves after mealybug feeding, and these might cause increased population build up and feeding. Likewise, menthol, naphthalene, longifolene and cholestan-3-ol were exclusively observed in tapioca after feeding by mealybug, and these might cause repellence to mealybug.

Menthol, a monoterpenoid, has been registered for controlling *Acarapis woodi* (Rennie), the tracheal mites of the honey bees (Ellis and Baxendale, 1997). Erler (2005) found out that carvacrol, 1,8-cineole, menthol, g-terpinene, and terpinen- 4-ol were effective against the eggs of the Mediterranean flour moth, *Ephestia kuehniella*. Menthone from *Mentha arvensis* was found to be highly toxic (LC95 25 ml/l) to *Sitophilus oryzae* and had a relatively small inhibitory effect on AChE activity (Lee *et al*., 2001). Insecticidal activity of menthol against the vine mealybug, *Planococcus ficus* was reported by Karamaouna *et al.* (2013).

The current study on the quality of volatile signals revealed the specificity of volatile production (Dicke and Takabayashi 1991; Blaakmeer *et al*., 1994) and the parasitoid's ability to discriminate between odors (Agelopoulos and Keller 1994; Fritzsche-Hoballah *et al*., 2002). However, being able to discriminate between volatiles does not mean that predators and parasitoids will respond to specific plant volatiles in the wild. Many parasitoids have the ability to learn new signals based on past experience (Lewis and Martin, 1990). Additionally, there is heritable variation in parasitoids for responding to plant volatiles (Lewis and Martin, 1990; Wang *et al*., 2004). Puente *et al*. (2008) likewise reported the impact of herbivore-induced plant volatiles on foraging success of parasitoid *Cotesia rubecula*. Such differences in volatile compound blends often allow predators and parasitoids to discriminate between species of plants (Fritzsche-Hoballah *et al.* 2002), species of herbivores (Puente *et al.*, 2008), and even the age or density of herbivores (Gouinguené *et al.* 2003).

There is still much to learn about the chemical interactions between plants and insect herbivores that lead to the synthesis and release of volatiles by the plants. Further, damage of a plant by different herbivore species can induce the release of various volatile blends.

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EVALUATION OF *QUISQUALIS INDICA* AND *SAMADERA INDICA* GAERTN AS BOTANICAL PESTICIDES AGAINST *SPODOPTERA LITURA* (F.) IN POLYHOUSE

ANUSREE, S. S.*, NISHA, M. S. AND SHEELA, M. S.****

Department of Agricultural Entomology
College of Agriculture, Vellayani 695522, Thiruvananthapuram
***Department of Nematology*
**Email: anusreess777@gmail.com (corresponding author)*

ABSTRACT

The crude methanol and ethyl acetate extracts of *Quisqualis indica* L. and *Samadera indica* Gaetrn. were evaluated for their antifeedant and insecticidal action against third instar larvae of *Spodoptera litura* (F.) under laboratory condition. Maximum antifeedant activity was observed in crude methanol extracts of *S. indica* (45.62%) and *Q. indica* (31.87%) at 5% concentration. Significantly superior insecticidal action (93.51%) was noticed in *Q. indica* methanol extract 5%, while *S. indica* methanol extract 5% showed 73.55% larval mortality after three days of exposure. Results of pot culture study conducted under polyhouse revealed that crude methanolic extract of *Q. indica* and *S. indica* at 5% reduced the population to less than half with mean population of 3.2 and 3.8 larvae/plant two weeks after spraying. These reveal that these plants could be exploited as botanical pesticides in polyhouse.

Key words: *Quisqualis indica, Samadera indica,* methanolic and ethyl acetate extracts, antifeedant and insecticidal bioassay, pot culture, polyhouse

Protected cultivation of vegetables is getting popularized in India, and *Spodoptera litura* (F.) is a devastating pest of cowpea and salad cucumber grown under protected condition. The indiscriminative use of pesticides results in food contamination, environmental pollution and resistance buildup. Persistence of insecticides is more severe under polyhouse conditions resulting in residue problems. All these demand search for safer alternatives and botanical pesticides provide this.

Quisqualis indica L. (= *Combretum indicum* (L.) De Filipps), known as Rangoon creeper, is an evergreen creeping shrub with red flower clusters. It is used for treating various human ailments (Sahu *et al.,* 2012). *Samadera indica* Gaertn. (=*Quassia indica* (Gaertn.) Noot.) is an evergreen tree, belonging to family Simaroubaceae. The leaves of this tree possess many pharmacological properties including antimicrobial, antioxidant and anti-inflammatory activity (Viswanad *et al.*, 2011). Evaluation of the effect of these against insect pests are limited, and hence the present study on the potential of *Q. indica* and *S. indica*, as botanical pesticides against *S. litura* under polyhouse condition.

MATERIALS AND METHODS

Extraction of plant material: The fresh flowers of *Q. indica* were collected from in and around the Instructional Farm at College of Agriculture, Vellayani. The fresh mature leaves of *S. indica* were collected from the forest areas of Kulathuppuzha, Kollam district, Kerala. These were collected during morning hours from March-April 2015, and identification confirmed from the Department of Botany, Kerala University, Karyavattom, with the voucher specimens of *Q. indica* (KUBH- 6010) and *S. indica* (KUBH- 6011) deposited in the herbarium. These plant materials were shade dried at room temperature (28±2°C) and powdered coarsely. Each 18 g powder was soaked in 250 ml of ethyl acetate and methanol separately and stirred in a reciprocating shaker for 72 hr. Solutions obtained were filtered and evaporated to air dryness at room temperature and stored in refrigerator at 4°C till usage.

Collection and rearing of S. litura: The egg masses were collected from Instructional Farm, College of Agriculture, Vellayani, surface sterilized with 0.02% sodium hypochlorite, dried and allowed to hatch. After hatching the larvae were fed with tender castor leaves sterilized with 0.5% sodium hypochlorite until prepupal stage. Sterilized soil was provided for pupation at room temperature (28±2% RH) with 70±5% RH relative humidity in insectary. The moths emerged were transferred to oviposition chamber and maintained with

10% honey for egg laying. These laboratory reared larvae were used for bioassays.

Antifeedant bioassay: The antifeedant activity of extracts at concentrations of 1.25%, 2.5% and 5% was evaluated under no-choice method. One 3rd instar larvae prestarved for 4 hr was fed with crude extract coated leaf discs (5 cm dia) for 24 hr. Ten such replications were maintained for each treatment, and % antifeedant activity after 24 hr feeding calculated according to the formula given by Bentley *et al.* (1984).

Insecticidal bioassay: The insecticidal activity of extracts was evaluated at three concentrations *viz.*, 1.25%, 2.5% and 5%. 1 ml of the crude extract at various dosages was sprayed separately on freshly moulted third instar larvae of *S. litura* using TLC sprayer. Larvae sprayed with 1 ml of the distilled water and solvents alone served as control. A minimum of 20 larvae/ treatment were used and the experiments replicated thrice. The sprayed larvae were maintained with fresh castor leaves. Observations were recorded at 24 hr interval for 3 days after treatment. Corrected % mortality was calculated according to the formula given by Abbott (1925). Data were analyzed using ANOVA after angular transformation.

Pot culture evaluation: The pot culture experiment was conducted in the polyhouse of College of Agriculture, Vellayani. The cowpea variety Vellayani Jyothika was used, and seeds inoculated with rhizobium sown in pots of 30 x 25 cm dimension, filled uniformly with 1:2:1 potting mixture (sand: soil: cow dung). The crop was maintained following the KAU package of practice recommendations (2011) during February to May.

The significant treatments identified from laboratory studies, methanol extract (5%) of *Q. indica* flower, was compared with standard insecticide, quinalphos 0.05%, recommended biocontrol agent, *Beauveria bassiana* (Bals. - Criv.) Vuill. (Bb 5) 20 g/L and Neem Seed Kernel Extract (NSKE 5%) via pot culture. Sterile water served as untreated. As part of the study, 10 third instar larvae of *S. litura* were released on a plant on the previous day of treatment. Pre count of larvae was taken prior to giving treatments. Treatments were given early morning, and post treatment count of larvae observed at 24 hr interval till death or pupation. Data collected were analyzed using standard statistical procedures. Data on counts were analyzed using ANOVA after square root transformation.

RESULTS AND DISCUSSION

The antifeedant activity of crude extracts of *Q. indica* flower and *S. indica* leaf at 1.25, 2.5 and 5% concentrations against third instar larvae of *S. litura* are given in Table 1. Significantly higher activity of 45.62% was obtained with methanol extract of *S. indica* at 5% concentration. Crude methanolic extract of *Q. indica* 5% showed 31.87% feeding inhibition. The maximum antifeedant activity exhibited by the methanolic extracts of *Q. indica* flower and *S. indica* leaf could be attributed to the polar nature of the phytochemicals responsible for feeding inhibition. Similar findings were given by Sivaraman *et al*. (2014), who reported that the methanol extract of *Sinapis alba* L. seeds showed 71.42% antifeedant activity against third instar larvae of *H. armigera*. In all the treatments, antifeedant activity was directly proportional to concentration of the extract. Among the two plant parts compared, *S. indica* leaf extracts possessed more antifeedant action compared to *Q. indica* flower extracts. The potential of *S. indica* to impart feeding inhibition to *S. litura* derives support from Govindachari *et al.* (2001) on the quassinoid, indaquassin C, which exhibited 62.5% feeding inhibition at 5 µg/cm^2 concentration.

The insecticidal activity observed with the crude extracts of *Q. indica* flower and *S. indica* leaf against second instar larvae of *S. litura* are given in Table 2. The most effective one was with methanol extract of *Q. indica* flower at 5% concentration, which recorded 70, 86.99 and 93.51% larval mortality at 24, 48 and 72 hr after treatment, respectively. Crude methanol extract (5%) of *S. indica* showed 73.55% larval mortality at 72 hr of exposure. Among the two plant parts, *Q. indica* flower extracts possessed more larvicidal action compared to *S. indica* leaf extracts

Table 1. Antifeedant activity of crude extracts of *Q. indica* and *S. indica* on third instar larvae of *S. litura*

Treatments		Mean % antifeedant activity	
		Q. indica	*S. indica*
Ethyl acetate	1.25%	13.23±1.23^{e}	18.92±1.08^{d}
Ethyl acetate	2.5%	20.62±1.92^{cd}	28.39±1.62^{c}
Ethyl acetate	5%	27.24±2.54^{ab}	37.71±2.15^{b}
Methanol	1.25%	16.95±1.58^{de}	24.72±1.41^{c}
Methanol	2.5%	24.24±2.26^{bc}	36.16±2.06^{b}
Methanol	5%	31.87±2.97^{a}	45.62±2.60^{a}
Mean		22.36	31.92

Within columns, mean ± SD followed by the same letter do not differ significantly (Student t' test-CD 0.05)

Table 2. Insecticidal activity of crude extracts of *Q. indica* and *S. indica* against third instar larvae of *S. litura*

Treatments	Mean % mortality at different intervals					
	Q. indica Hours after treatment			*S. indica* Hours after treatment		
	24	48	72	24	48	72
Ethyl acetate 1.25%	25.00±1.76^{d}	33.26±5.77^{d}	39.96±5.00^{d}	16.67±2.89^{c}	28.11±7.64^{c}	33.18±7.64^{d}
Ethyl acetate 2.5%	41.67±1.70^{c}	55.02±5.00^{c}	61.69±2.89^{c}	23.33±2.89^{bc}	34.95±5.00^{bc}	44.98±5.00^{bc}
Ethyl acetate 5%	58.33±1.94^{b}	71.70±2.89^{b}	81.72±2.89^{b}	28.33±7.64^{b}	46.65±5.77^{b}	56.68±2.89^{b}
Methanol 1.25%	41.67±3.60^{c}	48.31±7.64^{c}	56.73±7.64^{c}	18.33±2.89^{c}	29.92±5.00^{c}	38.23±7.64^{cd}
Methanol 2.5%	60.00±1.29^{b}	70.34±10.00^{b}	76.98±7.64^{b}	30.00±5.00^{b}	43.27±7.64^{b}	55.02±5.00^{b}
Methanol 5%	70.00±1.48^{a}	86.99±5.00^{a}	93.51±2.89^{a}	38.33±2.89^{a}	61.77±7.64^{a}	73.55±7.64^{a}
Mean	49.45	60.94	68.43	25.83	40.78	50.27

Within columns, mean ± SD followed by the same letter do not differ significantly (Student t' test, CD 0.05)

giving mean larval mortality ranging from 49.45 to 68.43 and 25.83 to 50.27%, respectively. The toxicity of *Q. indica* flower against insect pests had been earlier reported by Song *et al.* (2014). They reported that the methanolic extracts obtained from the fruits of *Q. indica* exhibited significant insecticidal activity against four Coccoidea species (*Eriococcus lagerstroemiae* Kuwana, *Ceroplastes japonicas* Green., *Crisicoccus pini* Kuwana and *Planococcus citri* Risso). The toxic effect of methanol extracts of *S. indica* leaf against bacteria and fungi is known earlier (Viswanad *et al.*, 2011).

Pot culture evaluation in polyhouse revealed that the pre-treatment count ranged from 9.0 to 9.6 larvae/ per plant (Table 3). The crude methanol extract of *Q. indica* and *S. indica* at 5% concentration significantly reduced the larval population. *Q. indica* methanol extract 5% resulted in 65% mortality at two weeks after spraying (Fig. 1), and it became 58% mortality in *S. indica* methanol extract 5% after fourteen days of exposure. The check treatment, quinalphos 0.05% significantly reduced the population one week after spraying with 100% mortality two weeks after spraying. *B. bassiana* (Bb 5) did not exhibit satisfactory reduction.

The insecticidal action of extracts was significantly inferior to quinalphos 0.05% and superior to the biocontrol agent, *B. bassiana* (Bb 5). The superiority of insecticides over plant extracts against *S. litura* observed derives support from Suganthy and Sakthivel (2013). They reported that quinalphos 2ml/L caused 100% mortality of *S. litura*, while pungam oil 3% led to 1.63 larvae/plant one week after treatment. An incongruity was observed with the effect of *B. bassiana*

Table 3. Evaluation of plant extracts on *S. litura* on cowpea under polyhouse

Treatments	Number of larvae/plant					
	Pre-count	Days after spraying				
		1	3	5	7	14
Q. indica methanol extract 5%	9.2±0.84	6.2±0.84^{c}	4.8±0.84^{c}	4.2±0.84^{c}	4±0.71^{b}	3.2±0.84^{b}
S. indica methanol extract 5%	9±0.71	8±0.71^{b}	6.4±1.14^{b}	5.4±0.55^{b}	4.8±0.84^{b}	3.8±0.84^{b}
Quinalphos 0.05%	9.4±0.55	3.8±0.55^{d}	2.4±0.84^{d}	1.2±0.84^{d}	0.4±0.55^{c}	0±0.00^{c}
B. bassiana (Bb 5) 20g/L	9.4±0.55	9.2±0.45^{a}	8.8±0.44^{a}	8.8±0.45^{a}	8.6±0.55^{a}	7.2±0.84^{a}
Untreated	9.6±0.55	9.4±0.71^{a}	9±0.54^{a}	8.6±0.55^{a}	8.6±0.55^{a}	7.4±0.89^{a}
Mean	9.32	7.32	6.28	5.64	5.28	4.32
CD (0.05)	NS	0.19	0.22	0.26	0.23	0.22

Within columns, mean ± SD followed by the same letter do not differ significantly (Student t'test, CD 0.05).

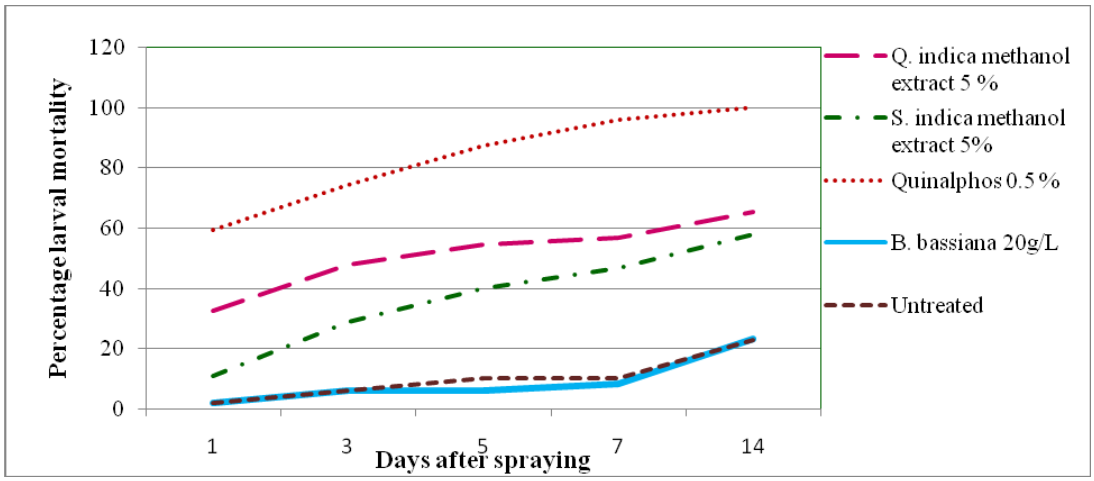

Fig. 1. Evaluation of plant extracts on *S. litura* on cowpea under polyhouse

reported by Gupta and Kumar (2014), who observed significant mortality in *S. litura* larvae with *B. bassiana*. This disparity might be due to the difference in isolates of the entomopathogen.

The present findings reveal that extracts of *Q. indica* flower and *S. indica* leaf were rich in potential molecules responsible for various bioactivities. Crude methanol extracts (5%) of both plant parts could reduce the population of pest to less than half under polyhouse condition. This highlights the potential of *Q. indica* and *S. indica* as ideal substitutes for chemical pesticides and it could be a solution for the pesticide residue problems prevalent under polyhouse cultivation.

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FIELD EFFICACY OF FLUBENDIAMIDE 480SC AGAINST BRINJAL SHOOT AND FRUIT BORER (*LEUCINODES ORBONALIS*)

SANDIP PATRA*, S. SARKAR, S. K. F. ALAM***, B. C. DAS***, P. P. DHAR*** AND A. SAMANTA*****

Division of Crop Protection, ICAR Research Complex for NEH Region
Umiam, Meghalaya 793103
***Krishi Vigyan Kendra, Uttar Banga Krishi Viswavidyalaya*
Pundibari, Coochbehar 736165
****Department of Agricultural Entomology*
Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia 741252
**Email: surajbckv2007@gmail.com (corresponding author)*

ABSTRACT

The field experiments were conducted at Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal during 2012 and 2013 to evaluate the field efficacy of flubendiamide 480SC against shoot and fruit borer (*Leucinodes orbonalis*) of brinjal. Seedlings of variety Muktakeshi were transplanted in plots of 25 m^2 area with a spacing of 60 x 45 cm. The experiment was designed in randomized block design (RBD) with four replications, and treatments *viz*., flubendiamide 480SC at 90 g, 72g and 60 g a.i./ha; thiodicarb 75 SP (750 g a.i./ha); quinalphos 20 EC (200 g a.i./ha); and water as untreated control. The insecticides were applied twice at 7 days interval. Results revealed that all the treatments gave significant reduction in infestation. It was evident that flubendiamide 480 SC @ 72 and 90 g a.i./ha was very effective with only 1.64 and 1.03% shoot, and 9.11 and 4.44% fruit infestation, respectively along with significant increase in yield.

Key words: Field efficacy, flubendiamide, thiodicarb, quinalphos, *Leucinodes orbonalis*, shoot and fruit infestation, fruit yield

Among the insect pests infesting brinjal, the major ones are shoot and fruit borer, *Leucinodes orbonalis* (Guenée), whitefly, *Bemicia tabaci* (Genn.), leafhopper, *Amrasca biguttula biguttula* (Ishida). Of these, shoot and fruit borer, *L. orbonalis* (Lepidoptera: Pyraustidae) is considered to be the main constraint. The yield loss due to this had been accounted to the tune of 70-92% (Rosaiah, 2001; Reddy and Srinivasa, 2004; Jagginavar et al., 2009; Chakraborti and Sarkar, 2011). To manage this many insecticides are being recommended, of which few result in hazards like pollution. This has necessitated the development of new, safer, quickly degradable insecticides. The present study evaluates the field efficacy of flubendiamide 480 SC (novel insecticide) against the shoot and fruit borer of brinjal and its effect on the natural enemies associated with brinjal ecosystem.

MATERIALS AND METHODS

The field experiments were conducted at Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal during 2012 and 2013. Brinjal (variety Muktakeshi) seedlings were transplanted in plots of 25 m^2 area with a spacing of 60 x 45 cm. The experiment was designed in randomized block design (RBD) with four replications with standard agronomic practices followed. Six treatments *viz*., flubendiamide 480SC (at 90, 72 and 60 g a.i./ha), thiodicarb 75 SP (750 g a.i./ha), quinalphos 20 EC (200 g a.i./ha) and water as untreated control were the treatments, with insecticides applied twice at 7 day interval (at the ETL of 5% shoot and fruit damaged) with knapsack sprayer @500 l/ha. Observations on the borer incidence on shoots were recorded from ten randomly selected plants/replication on 3rd, 5th and 7th day after each application and the number of infested and healthy fruits counted at each picking. The data were subjected to necessary transformation and the critical difference (CD) at 5% level of significance worked out.

RESULTS AND DISCUSSION

Observations obtained with shoot infestation presented in Table 1 reveal that the least infestation was in flubendiamide 480 SC @ 90 g a. i./ha with 1.30 and 0.75% infestation during 2012 and 2013, respectively; it is followed by its dose @ 72 g a.i./ha

Table 1. Effect of flubendiamide 480SC on shoot and fruit borer infestation, yield and natural enemies in brinjal (2012, 2013)

Treatments	Dose (g a.i. / ha)	Mean of infestation						Mean yield (q/ha)	Mean % reduction/ increase (+) of predators					
		Shoot infestation (%)			Fruit infestation (%)				*Menochilus* sp.			*Chrysoperla* sp.		
		2012	2013	Mean	2012	2013	Mean		2012	2013	Mean	2012	2013	Mean
Flubendiamide 480SC	60	3.65 (10.82)	2.54 (9.13)	3.10 (10.14)	20.09 (26.53)	7.82 (15.97)	13.96 (21.94)	33.25	2.40 (8.91)	4.44 (12.16)	3.42	3.28 (10.43)	6.04 (14.23)	4.66
Flubendiamide 480SC	72	2.08 (8.17)	1.20 (6.25)	1.64 (7.36)	13.74 (21.70)	4.47 (12.03)	9.11 (17.57)	36.88	2.84 (9.70)	4.96 (12.87)	3.90	3.84 (11.30)	6.96 (15.30)	5.40
Flubendiamide 480SC	90	1.30 (6.48)	0.75 (4.93)	1.03 (5.82)	6.19 (14.33)	2.70 (9.42)	4.44 (12.16)	38.88	3.60 (10.94)	5.92 (14.08)	4.76	4.04 (11.60)	7.92 (16.35)	5.98
Thiodicarb 75 SP	750	5.98 (14.00)	2.87 (9.69)	4.43 (12.15)	20.53 (26.74)	7.41 (15.52)	13.97 (28.95)	32.80	58.88 (50.12)	64.80 (53.61)	61.84	68.52 (55.87)	73.80 (59.21)	71.16
Quinalphos 20 EC	200	5.77 (13.74)	2.63 (9.27)	4.20 (11.83)	19.22 (25.77)	7.11 (15.18)	13.16 (21.27)	33.25	78.72 (62.53)	83.28 (65.86)	81.00	84.80 (67.05)	88.00 (69.73)	86.40
Untreated Control (Water spray)	-	16.78 (23.85)	11.43 (19.27)	14.11 (22.06)	35.28 (36.17)	17.49 (24.32)	26.38 (30.90)	24.63	+64.94 (0.00)	+49.20 (0.00)	+57.07	+24.84 (0.00)	+18.96 (0.00)	21.90
C.D. at 5%		0.19	0.13	0.16	0.22	0.16	0.17	0.14	0.23	0.22	-	0.10	0.15	-

Figures in parentheses angular transformed values

(2.08 and 1.20%, respectively); even at lower dose (60 g a.i./ha) it gave reductions in infestation (3.65 and 2.54%). In the the standard checks infestation was more: thiodicarb (5.98 and 2.87%) and quinalphos (5.77 and 2.63%) during 2012 and 2013, respectively. Cumulative values the least with flubendiamide @ 90 g a.i./ha (1.03%) followed by its next dose i.e. @72 g a.i./ha (1.64 %). Even at its lowest dose i.e. flubendiamide (@60 g a.i/ha) was observed to be at par with standard checks.

The perusal of data in Table 1 on the fruit infestation and yield reveal the following: During 2012, all the treated plots gave significant reduction in infestation; flubendiamide @ 90 g a.i/ha (6.19% fruit infestation) proved highly effective, and at 72 g a.i/ha also it was effective; both these treatments were significantly superior in terms of fruit damage as well as increasing yield (37.50 and 35.75 q/ha, respectively). Its lowest dose i.e. 60 g a.i/ha (20.09% infestation) was at par with those of standard checks (thiodicarb and quinalphos). Almost similar trend was noticed during 2013 too, with flubendiamide 480 SC @ 90 g a.i/ ha (2.70% fruit infestation) being the best. It is closely followed by its next higher dose @ 72 g a.i/ha (4.47% fruit infestation). Highest yield was obtained with flubendiamide @ 90 g a.i./ha (40.25q/ha) followed by its dose @ 72 g a.i./ha (38.00q/ha). Cumulative values also reveal that flubendiamide was highly effective.

As regards some important natural enemies associated with brinjal ecosystem, it was observed that flubendiamide was extremely safe to the two common predators, *Menochilus* sp., and *Chrysoperla* sp.. Reductions in their population @ 60-90 g a.i./ha were: *Menochilus* sp. -3.42-4.76% and *Chrysoperla* sp.- 4.66-5.98% (Table 1)

Flubendiamide is a selective chemical for lepidopterous insects and non-toxic to other beneficial insects (Latif et al., 2010). Flubendiamide proved to be an excellent insecticide against brinjal shoot and fruit borer with minimum shoot and fruit infestation and highest marketable fruit yield. These results are in agreement with Jagginavar et al. (2009) who reported that flubendiamide 480 SC @ 72 g a.i./ha could be efficiently used. The present findings are also in conformity with Latif et al. (2010) and Chakraborti and Sarkar (2011).

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POPULATION DYNAMICS OF BRINJAL FRUIT AND SHOOT BORER, *LEUCINODES ORBONALIS* (LEPIDOPTERA: PYRALIDAE) IN KASHMIR

AHMAD, S.I., PATHANIA, S.S.*, NEHRU, R.K. AND WANI, A.R.

Division of Entomology
Sher -e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar.
**Email: pathaniasjs@gmail.com*

ABSTRACT

Field surveys were carried out on the population dynamics of brinjal shoot and fruit borer, *Leucinodes orbonalis* at the University Experimental Farm, Shalimar Campus; Vegetable Farm, Habak and Wanganpora (Iddgah); and Bugam, Narkara and Gangbug from Budgam. Observations on the infestation were made at weekly intervals during kharif, 2014. The least shoot infestation was in the district Srinagar (Shalimar) at 13.03%, followed by Habak (14.47%) and Wanganpora (16.02%), whereas in the district Budgam it was 11.93% followed by Narkara (14.79%) and Gangbug (16.53%). Fruit infestation was also the least at Shalimar (14.57%) followed by Wanganpora (19.02%) and Habak (19.44%), whereas in district Budgam, the least infestation was 17.06% followed by Narkara (18.43%) and Gangbug (20.13%). Correlation coefficients between weather factors and adult catches at all the six locations revealed positive and significant relationships with minimum temperature, while maximum temperature, rainfall, relative humidity (evening), wind speed had positive and non significant ones; relative humidity (morning) had negative and non significant correlation. Multiple regression analysis too revealed that minimum temperature as the major weather factor followed by relative humidity (evening), wind speed, maximum temperature, and rainfall had the least effect.

Key words: Brinjal, *Leucinodes orbonalis*, Kashmir, Srinagar, Budgam, weather factors, shoot and fruit damage, correlation coefficients, multiple regression

The brinjal (*Solanum melongena* L.) is subjected to attack by number of insect pests right from nursery stage till crop harvest (Regupathy et al., 1997). Among these the major ones are shoot and fruit borer (*Leucinodes orbonalis* Guenee), white fly (*Bemisia tabaci* Gennadius), leafhopper (*Amrasca biguttula biguttula* Ishada) and non-insect pests like red spider mite (*Tetranychus macfarlanei* Baker and Pritchard) etc. Surveys in an agroclimatic zone provide the information about the status of pest which helps in developing efficient pest management strategies. Thus against brinjal shoot and fruit borer (BSFB), detailed information on the weather factors and the population dynamics is of great significance. The present study surveys the status and infestation level of BSFB in predominant brinjal growing areas in Kashmir.

MATERIALS AND METHODS

The surveys were done at Experimental Farm, Shalimar Campus, SKUAST-Kashmir and at farmers field during *kharif*, 2014. Two districts namely Srinagar and Budgam were surveyed with three locations from each i.e. University Experimental Farm- Shalimar Campus, University Vegetable Farm- Habak, Wanganpora (Iddgah) from Srinagar; and Bugam, Narkara and Gangbug (predominant brinjal growing areas) from Budgam. The observations were made at weekly intervals with three fields per location replicated thrice. In each replication, ten plants were randomly selected to observe wilted shoots and infested fruits, and % infestation worked out. The monitoring of adults was made using lure baited in a polyethylene funnel trap erected over the crop canopy. The observations were recorded after fifteen days of transplanting and continued till the crop attained senescence and harvest. The adult moth catch was recorded at weekly interval till the final harvest. Weekly meteorological data on temperature, rainfall, relative humidity and wind speed, was obtained from the Meteorological section, Division of Agronomy, SKUAST-K, Shalimar. The correlation and multiple regression coefficients between adult moth catch and weather factors were also worked out.

RESULTS AND DISCUSSION

Shoot infestation: Surveys revealed that infestation commenced from fourth week of June (25 SW) and gradually increased till 32 SW (2nd week of August), and again substantially increased till first fortnight of September with highest infestation being during 35 SW. Thereafter it decreased by the start of October and altogether became nil with harvest (Table 1). At Shalimar of district Srinagar, the infestation of 2.8% commenced from 25 SW which increased and reached a peak 33% in first week of September (35 SW); thereafter declined and became almost negligible with crop senescence. Similarly, in other two locations i.e., Habak and Wanganpura, 3.7 and 4.3% infestation was observed during 25 SW, and this increased to 32.06% and 38.33% in subsequent weeks with maximum of 33.0 and 42.0% being in first week of September (35 SW). Later it declined altogether by end of September. The highest of 16.02% was observed at Waganpura, among all the three locations of the district Srinagar.

Similarly, at all the three locations of district Budgam i.e., Bugam, Gangbug and Narkara; shoot infestation started in the fourth week of June (25 SW) which gradually increased till it peaked in the first week of September (35 SW). Gangbug was observed with highest infestation (16.53%), though cumulative value for district Budgam was 14.42%. Among all the locations surveyed, lowest infestation was recorded at Bugam (11.93%) followed by Shalimar (13.03%), Habak (14.47%), Narkara (14.79%) and Wanganpora (16.02%); and highest infestation was observed at Gangbug (16.53%). However, cumulative value at district Budgam (14.42%) does not differ much from 14.50% at Srinagar.

The present observations are more or less in accordance with those of Atwal and Verma (1972). Kushwaha (1983) recorded peak shoot infestation from 3rd week of August till the last week of September. The present findings are also in conformity with Panwar et al. (1986) who reported peak shoot infestation in 2nd week of September; though, Mehmood et al. (1992) observed incidence from 25 SW and highest infestation was during 34 SW, which is more or less in conformity with the present findings. Patnaik (2000) also found peak infestation during September and October. The present findings are also similar to those of Kumar and Singh (2013).

Fruit infestation: Fruit infestation started a week later i.e. on 26 SW, when compared to shoot, and increased from first week of July (26 SW) till 2nd week of August (32 SW), then attained peak during first fortnight of September, and thereafter it decreased and became nil by October. The least infestation (14.57%) was observed at Shalimar and at Bugam (17.06%), Narkara (18.43%), Wanganpora (19.0%) and Habak (19.44%). Maximum fruit infestation was observed at Gangbug (20.13%). The cumulative values revealed that at district Srinagar, it was 17.67% compared to that at Budgam (18.54%) (Table 2). The lowest fruit infestation at Experimental Farm, Shalimar could be due to timely plant protection measures. Highest infestation at Gangbug was possibly due to low temperature and humid conditions, and all along the canal adjoining the fields surveyed.

The present observations derive support from earlier ones of Dhamdhere et al. (1995) who reported maximum fruit infestation of 46.75%. The present results agree with Patnaik (2000) who reported peak infestation during September-October; however, Nayak et al. (2014a) reported that infestation started from last week of June and peaked during the first week of September. These above results are in agreement with Kaur et al. (2014) who reported maximum infestation during second week of October.

Moth catches: The trapping of moths revealed that moths start appearing during 24 SW at Shalimar, Wanganpora and Gangbug; at Habak and Narkara, appeared a week earlier (23 SW); however, at Bugam first moth was trapped a week later i.e. 25 SW (Table 3). Their number increased and highest peak was during 34 SW (last week of August) except for Shalimar, where the peak was in first week of September (35 SW). More or less a similar trend was observed at all the locations with minor variations. These observations are almost in accordance with Prasannakumar et al. (2009).

The correlation coefficients obtained revealed a positive and significant relationship with minimum temperature; maximum temperature, rainfall, relative humidity (evening), and wind speed had a positive but non-significant ones; and with relative humidity (morning) it was a negative and non-significant one (Table 4). These results are in conformity with Shukla and Khatri (2010) except for that on minimum temperature. Nayak et al. (2014b) also observed moth catch to be significant and positively correlated with both maximum and minimum temperature and

Table 1. Shoot infestation by *L. orbonalis* (Districts-Srinagar and Budgam, 2014)

Locations	% infestation (weekly interval)														Mean %	Cumulative mean %
	25SW	26SW	27SW	28SW	29SW	30SW	31SW	32SW	33SW	34SW	35SW	37SW	38SW	39SW		
Shalimar	2.80 (1.67)^{b}	4.56 (2.13)^{b}	7.00 (2.64)^{bc}	10.20 (3.19)^{cd}	12.06 (3.47)^{c}	13.00 (3.60)^{c}	14.03 (3.74)^{bc}	15.40 (3.87)^{a}	19.24 (4.38)^{a}	26.10 (5.10)^{a}	33.00 (5.74)^{a}	16.23 (4.02)^{ab}	8.30 (2.88)^{b}	0.50 (0.70)^{a}	13.03	
Habak	3.70 (1.92)^{c}	6.21 (2.48)^{d}	10.07 (3.17)^{d}	12.04 (3.46)^{d}	12.10 (3.47)^{d}	13.12 (3.62)^{c}	13.50 (3.67)^{c}	18.00 (4.24)^{bc}	25.10 (5.00)^{b}	32.06 (5.66)^{c}	33.00 (5.74)^{a}	16.13 (4.01)^{ab}	7.04 (2.64)^{a}	0.50 (0.70)^{a}	14.47	14.50
Wanganpora	4.32 (2.07)^{c}	4.30 (2.07)^{a}	7.10 (2.66)^{c}	8.21 (2.86)^{b}	12.22 (3.99)^{d}	14.02 (3.74)^{c}	14.15 (3.76)^{c}	16.00 (3.99)^{ab}	37.00 (6.08)^{d}	38.33 (6.19)^{e}	42.00 (6.48)^{b}	17.09 (4.13)^{bc}	9.03 (3.00)^{b}	0.50 (0.70)^{a}	16.02	
Bugam	1.33 (1.11)^{a}	4.20 (2.01)^{a}	5.54 (2.35)^{a}	5.10 (2.22)^{a}	7.09 (2.64)^{a}	7.30 (2.68)^{a}	10.99 (3.31)^{a}	16.50 (3.97)^{ab}	26.02 (5.09)^{b}	29.10 (5.36)^{b}	31.03 (5.55)^{a}	15.10 (3.87)a	7.30 (2.64)^{a}	0.50 (0.70)^{a}	11.93	
Gangbug	2.50 (1.57)^{b}	4.74 (2.17)^{bc}	6.30 (2.50)^{ab}	10.00 (3.16)^{bcd}	10.06 (3.21)^{b}	11.20 (3.33)^{b}	13.05 (3.60)^{b}	19.00 (4.35)^{c}	33.13 (5.74)^{c}	40.09 (6.32)^{e}	41.10 (6.32)^{b}	18.70 (4.24)^{c}	15.10 (3.87)^{c}	6.50 (2.64)^{b}	16.53	14.42
Narkara	3.20 (1.78)^{b}	5.04 (2.23)^{c}	6.23 (2.44)^{a}	9.11 (2.99)^{bc}	11.24 (3.31)^{b}	13.00 (3.60)^{c}	14.08 (3.71)^{bc}	16.05 (3.99)^{ab}	21.30 (4.58)^{a}	35.20 (5.91)^{d}	47.00 (6.85)^{c}	17.10 (4.12)^{b}	8.09 (2.82)^{ab}	0.50 (0.70)^{a}	14.79	
$C.D_{(P=0.05)}$	0.34	0.30	0.16	0.30	0.21	0.14	0.15	0.31	0.30	0.22	0.27	0.21	0.23	0.07	-	-

Values in individual columns superscripted by similar letter(s) do not differ significantly at p = 0.05; Figures in parentheses square root transformed values

Table 2. Fruit infestation by *L. orbonalis* (Districts-Srinagar and Budgam, 2014)

Locations	% infestation (weekly interval)													Mean %	Cumulative Mean %
	26SW	27SW	28SW	29SW	30SW	31SW	32SW	33SW	34SW	35SW	37SW	38SW	39SW		
Shalimar	0.5 (0.70)^{a}	2.00 (1.41)^{a}	8.21 (2.86)^{b}	12.00 (3.46)^{b}	13.03 (3.60)^{a}	14.08 (3.75)^{a}	18.22 (4.26)^{a}	24.00 (4.89)^{a}	29.21 (5.40)^{a}	39.00 (6.24)^{a}	16.00 (3.98)^{a}	9.20 (3.032)^{a}	4.01 (2.00)^{b}	14.57	17.67
Habak	6.02 (2.45)^{c}	11.30 (3.36)^{d}	13.04 (3.61)^{d}	15.00 (3.87)^{d}	17.00 (4.12)^{c}	18.10 (4.25)^{d}	21.11 (4.59)^{c}	33.00 (5.74)^{cd}	35.32 (5.94)^{b}	47.21 (6.87)^{b}	18.00 (4.24)^{c}	15.45 (3.929)^{c}	2.21 (1.47)^{a}	19.44	
Wanganpora	5.30 (2.29)^{c}	7.21 (2.68)^{c}	10.00 (3.16)^{c}	13.04 (3.61)^{c}	14.24 (3.77)^{b}	15.09 (3.88)^{bc}	18.90 (4.34)^{a}	38.00 (6.16)^{c}	45.00 (6.70)^{d}	47.24 (6.87)^{b}	18.06 (4.24)^{c}	11.21 (3.347)^{b}	4.00 (1.99)^{b}	19.02	
Bugam	4.03 (2.00)^{b}	5.13 (2.27)^{b}	7.00 (2.64)^{a}	10.20 (3.19)^{a}	14.12 (3.75)^{b}	15.20 (3.89)^{bc}	26.13 (5.11)^{d}	29.08 (5.39)^{b}	34.00 (5.83)^{b}	38.03 (6.16)^{a}	17.04 (4.12)^{b}	17.00 (4.122)^{d}	4.92 (2.21)^{b}	17.06	18.54
Gangbug	5.30 (2.29)^{c}	6.50 (2.54)^{c}	10.03 (3.16)^{c}	14.45 (3.80)^{d}	14.90 (3.85)^{b}	16.21 (4.02)^{c}	20.00 (4.47)^{b}	33.53 (5.79)^{d}	44.00 (6.63)^{cd}	49.00 (6.99)^{c}	19.80 (4.44)d	18.00 (4.242)^{d}	10.00 (3.16)^{c}	20.13	
Narkara	5.00 (2.23)^{bc}	7.05 (2.65)^{c}	10.03 (3.16)^{c}	13.01 (3.60)^{c}	14.00 (3.74)^{b}	15.12 (3.88)^{bc}	19.07 (4.36)^{ab}	31.00 (5.56)^{c}	42.31 (6.50)^{c}	50.01 (7.07)^{c}	18.10 (4.25)^{c}	10.80 (3.285)^{b}	4.00 (1.99)^{b}	18.43	
C.D$_{(P=0.05)}$	0.23	0.12	0.16	0.13	0.14	0.15	0.19	0.18	0.13	0.08	0.11	0.13	0.24	-	-

Values in individual columns superscripted by similar letter(s) do not differ significantly at p = 0.05; Figures in parentheses square root transformed value

Table 3. Adult catches of *L. orbonalis:* Districts-Srinagar and Budgam, 2014

Standard week (SW)	Catch/week/trap					
	Shalimar	Habak	Wanganpora	Bugam	Gangbug	Narkara
22	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.50	0.00	0.00	0.00	0.50
24	0.50	1.00	1.50	0.00	1.00	1.00
25	0.50	1.00	1.50	1.00	1.00	1.00
26	1.00	1.50	1.50	1.00	1.50	1.50
27	1.00	1.50	2.00	1.50	2.00	1.50
28	1.50	2.00	2.00	1.00	2.00	2.00
29	2.00	2.00	2.50	1.50	2.50	2.00
30	1.50	2.50	2.00	1.50	2.00	3.00
31	1.50	2.50	2.50	2.00	2.50	2.50
32	1.50	2.00	2.50	2.00	3.00	2.50
33	2.00	2.50	3.00	2.50	3.50	3.00
34	2.50	4.00	3.50	3.00	4.00	4.50
35	3.00	3.00	3.00	3.00	3.50	3.00
37	1.00	2.00	2.00	2.00	2.50	1.50
38	0.50	1.00	1.50	1.50	1.50	1.00
39	0.00	0.50	0.50	0.50	0.50	1.00
40	0.00	0.00	0.00	0.00	0.00	0.00

negatively correlated with relative humidity, whereas rainfall did not influence the trap catch significantly.

Multiple regression analysis revealed that both minimum temperature and relative humidity (evening) had a major contribution; it was followed by wind speed and maximum temperature; rainfall had the least effect; and relative humidity (morning) had a negligible effect. These results are in accordance with those of Nayak et al. (2014a), who concluded that both the temperature and relative humidity were the important factors.

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Table 4. Correlation and regression coefficients- weather factors vs moth catch of *L. orbonalis*

Location	Coefficient of determination	Prediction Equation	% contribution					Correlation coefficients* (r)						
			Max. temp. (ºC)	Min temp (ºC)	Rainfall (mm)	RH% (morning)	RH % (evening)	Wind speed (km/hour)	Max. temp. (ºC)	Min temp (ºC	Rainfall (mm)	RH% (morning)	RH % (evening)	Wind speed (km/hour)
Shalimar	0.6431	Y=-7.24+0.100X1+0.229X2+0.055X3-0.040X4+0.085 X5 +0.5809X6	7.04 (0.38)	40.39 (0.91)	0.95 (0.14)	4.99 (-0.32)	33.60 (0.83)	13.19 (0.52)	0.196 (0.42)	0.571* (0.01)	0.297 (0.30)	-0.015 (0.95)	0.098 (0.69)	0.137 (0.57)
Habak	0.5330	Y=-8.32+0.119X1+0.255X2+0.023X3-0.039X4+0.094 X5 +0.922 X6	8.06 (0.38)	40.36 (0.85)	0.15 (0.05)	3.77 (-0.26)	33.99 (0.78)	13.97 (0.50)	0.208 (0.39)	0.529* (0.01)	0.195 (0.42)	-0.021 (0.93)	0.073 (0.76)	0.122 (0.61)
Wanganpora	0.6713	Y=-8.71+0.143X1+0.264X2+0.096X3-0.054X4+0.106 X5 +1.02 X6	9.29 (0.45)	34.72 (0.87)	2.02 (0.21)	5.61 (-0.35)	34.72 (0.87)	13.87 (0.55)	0.199 (0.41)	0.567* (0.01)	0.335 (0.36)	-0.014 (0.95)	0.087 (0.72)	0.121 (0.62)
Bugam	0.5546	Y=-6.55+0.053X1+0.210X2+0.056X3-0.013X4+0.070 X5 +0.566 X6	2.96 (0.20)	49.80 (0.82)	1.67 (0.15)	0.89 (-0.11)	35.27 (0.69)	9.60 (0.36)	0.250 (0.91)	0.477* (0.03)	0.354 (0.38)	-0.217 (0.37)	0.255 (0.29)	0.133 (0.58)
Gangbug	0.6788	Y=-13.04+0.185X1+0.335X2+0.009X3-0.054X4+0.147 X5 +1.266 X6	9.53 (0.49)	34.32 (0.93)	0.01 (0.02)	3.57 (-0.30)	39.68 (1.00)	12.89 (0.57)	0.179 (0.46)	0.551* (0.01)	0.195 (0.42)	-0.068 (0.78)	0.155 (0.52)	0.110 (0.65)
Narkara	0.6395	Y=-9.07+0.146X1+0.253X2+0.042X3-0.040X4+0.101 X5 +0.807X6	11.17 (0.49)	37.67 (0.90)	0.45 (0.09)	3.65 (-0.28)	36.84 (0.89)	10.27 (0.47)	0.350 (0.37)	0.632* (0.003)	0.258 (0.87)	-0.051 (0.83)	0.091 (0.96)	0.228 (0.34)

Figures in parentheses standardized partial regression coefficient values, â *Significant at p=0.05; Y =Moth Catch; X1= maximum Temperature (ºC); X2 =Minimum Temperature (ºC); X3 = Rainfall (mm); X4 = % Relative Humidity (Morning); X5 =% Relative Humidity (Evening); X6 = Wind Speed (Km/hr)

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PHOSPHINE RESISTANCE IN CIGARETTE BEETLE *LASIODERMA SERRICORNE* (F.) (ANOBIIDAE: COLEOPTERA) IN MAJOR TURMERIC GROWING AREAS

A. RAJESH*, S. MOHAN AND S.J. NELSON

Department of Agricultural Entomology
Tamil Nadu Agricultural University, Coimbatore 641003
**Email: rajesh68.ag@gmail.com (corresponding author)*

ABSTRACT

Cigarette beetle, *Lasioderma serricorne* (F.) is a serious pest of stored turmeric causes huge losses by boring extensively through dry turmeric rhizomes. Stored turmeric is commonly disinfected by fumigation with phosphine gas as it leaves almost negligible amount of residue. *L. serricorne* is known to be resistant to phosphine due to its heavy and indiscriminate uses. No detailed information is available on current status of phosphine resistance in *L. serricorne* in major turmeric growing areas. This study investigated resistance level in twelve populations of *L. serricorne* collected from Tamil Nadu, Andhra Pradesh and Telangana. Samples collected were subjected to bioassay on the basis of the response of adults to discriminating concentration of 0.07mg L^{-1} for 24 hr exposure. The bioassay results showed that resistance was common in all the field collected populations of *L. serricorne* and the level of resistance ranged from 27.41 to 82.16%. The populations from Erode (82.16%), Salem (76.66%) in Tamil Nadu and Duggirala (80.23%) in Andhra Pradesh showed high level of resistance. The low level of phosphine resistance (27.41to 48.30%) was observed in populations from Tiruchengodu, Rasipuram, Athur, Namagiripettai in Tamil Nadu and Kadapa in Andhra Pradesh. The correlation between the number of aluminium phosphide fumigations and the resistance showed a correlation coefficient (r) of 0.534, indicating that indiscriminate use of phosphine and improper fumigation might lead to development of phosphine resistance in *L. serricorne* in turmeric storage.

Key words: Phosphine, *Lasioderma serricorne*, fumigation, turmeric warehouses, bioassays, Tamil Nadu, Andhra Pradesh, Telengana

India is the leading producer, consumer and exporter of turmeric in the world. India accounts for 78% in world production and 60% share in world export. Turmeric is stored in the form of dried rhizomes or powder in bag stacks in warehouses. Insect pests are one of the major constraints for quality deterioration of stored turmeric. The major insect pests attacking stored turmeric are cigarette beetle, *Lasioderma serricorne* (F.), drugstore beetle, *Stegobium panacium* L. and red flour beetle, *Tribolium castaneum* (Hbst.) etc. Among these, *L. serricorne* causes huge losses to stored turmeric to the extent of 39.8 per cent (Kavadia *et al*., 1978). It bores extensively through dry turmeric rhizomes, deteriorates rhizome quality and reduces the nutritional and medicinal value of stored turmeric. Female cigarette beetles attracted by the odor of stored products (Kohno *et al*., 1983) oviposit in these products. Hatched larvae feed on stored products and cause damage to them (Howe, 1957).

Fumigation with methyl bromide or phosphine has been the only means available to disinfest a commodity completely and rapidly. However, the use of methyl bromide is gradually being restricted because of its effect on depleting the ozone layer (Ryan, 1995). This has left phosphine as a monopoly fumigant in grain protection over the last five decades. However, continuous and indiscriminate use of phosphine resulted in the development of resistance to this fumigant in *L. serricorne*. Resistance to phosphine poses threat to effective control of this pest. Preliminary studies by Rajendran and Narasimhan (1994) revealed the emergence of phosphine-resistant cigarette beetles from tobacco storage in Andhra Pradesh. There is no detailed information on the status of phosphine resistance in *L. serricorne* in turmeric storage especially in India which is the world leading producer, consumer and exporter of turmeric. Hence, the present investigation was carried out to assess the current status of phosphine resistance in *L. serricorne* in major turmeric growing areas of three south Indian states.

MATERIALS AND METHODS

A random survey was conducted to collect samples of cigarette beetle (*L. serricorne*) from turmeric warehouses of Tamil Nadu State Regulatory Market (TNSRM), Central Warehousing Corporation (CWC) and Private Warehouses in 12 major turmeric growing areas across Tamil Nadu, Andhra Pradesh and Telangana (Table 1). Information on method of storage, duration of storage and frequency of phosphine fumigation was also collected from all the sampling sites. The collected *L. serricorne* samples were brought to Undergraduate Laboratory, Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore for mass culturing. The field collected *L. serricorne* samples were released separately in 2.0 kg plastic container along with 500 gm of wheat flour + 5% Yeast and kept for oviposition at room temperature of 30^{0}C and 60% relative humidity to obtain sufficient number of insects for resistance bioassay. The new batch of (next generation) adults was emerged from the culture after 35 - 40 days from the initial introduction and the adults with uniform age were used for the phosphine resistance bioassay. Phosphine gas was generated in a gas generation chamber and volume of dessicator was measured by following the procedure as described by Sonairajan *et al.,* (2015). The correct phosphine gas volume for injection was determined based on weight by volume basis which was previously described by FAO Method No. 16 (FAO, 1975):

$$d_l\ (\mu l) = \frac{298X\ x_1\ (mg/l)X\ v_1\ (l)X\ 22.414X1000X1000X100}{273X1000X33.9977(GMW\ phosphine)X86}$$

Where, x_1 (mg/l) = Required dose of phosphine in desiccators; and v_1 (l) = Volume of the desiccators.

The level of phosphine resistance was determined for the progeny of field collected populations using a modified FAO method (FAO, 1975). Adults were fumigated with a discriminating concentration of phosphine gas 0.07 mg L^{-1}over 24 hr exposure. The bioassay was performed at room temperature of 30^{0}C and 60% RH. Each resistance bioassay was replicated thrice along with control for each population and fifty adults were released per replication. After exposure, the insects were provided with small quantity of culture medium for a week and moved to recovery room. Adult mortality was determined after seven days from the end of the exposure period. The observation on number of insects responding i.e. insects showing any movements were considered to be alive and others as dead.

Mortality response data were calculated using Abbots formula (Abbot, 1925), to eliminate the influence of mortality, which was not greater than 10% in these experiments. The resistance percentage was worked out by the formula: Resistance percentage (R) = (100-CM) ± SE, where CM = Corrected Mortality; SE = Standard Error. Pooled binomial standard error was calculated by the formula- SE = Stdev / "*n.* Further, the % resistance was classified as low (0- 50%), medium (50 - 75%), and high (75-100%). To understand the relation between number of phosphine fumigations received and level of phosphine resistance,

Table 1. Phosphine resistance in *L. serricorne* from Tamil Nadu (TN), Andhra Pradesh (AP) and Telangana and fumigation details

Category of resistance	Locations	Warehouses	Stack details		Percent resistance (Mean ± SE)
			Period of storage (months)	No. of Aluminium Phosphide fumigations	
Low resistance (0 – 50%)	Kadapa, AP	CWC	42	12	48.30 ± 1.47
	Nandyal, AP	PRIVATE	10	3	41.26 ± 0.56
	Tiruchengodu, TN	TNSRM	11	2	27.41± 1.53
	Rasipuram, TN	TNSRM	12	4	42.76 ± 1.02
	Athur, TN	TNSRM	15	7	29.65 ± 0.96
	Namagiripettai, TN	TNSRM	17	6	38.83 ± 1.74
Medium resistance (50 – 75%)	Nandikotkur, AP	CWC	16	9	54.07 ± 1.67
	Coimbatore, TN	TNSRM	18	10	56.14 ± 0.83
	Nizamabad, Telangana	CWC	14	6	72.67 ± 0.56
High resistance (75 – 100%)	Erode, TN	PRIVATE	24	15	82.16 ± 1.71
	Salem,TN	TNSRM	8	2	76.66 ± 1.24
	Duggirala, AP	CWC	36	18	80.23 ± 1.92
			r = 0.534		

*TNSRM- Tamil Nadu State Regulatory Market; CWC- Central Warehousing Corporation

correlation coefficient (r) was calculated with MS-Excel.

RESULTS AND DISCUSSION

The results showed that all the populations of *L. serricorne* tested survived under discriminating dose of 0.07 mg L^{-1} over 24 h and exhibited varied level of resistance to phosphine. The level of resistance ranged from 27.41 to 82.16%. Of the 12 populations tested, 50% showed low resistance, 25% were medium and 25% exhibited high level of resistance to phosphine. The populations from Erode (82.16%), Salem (76.66%) in Tamil Nadu (TN) and Duggirala (80.23 %) in Andhra Pradesh (AP) recorded high level of (75 - 100%) resistance whereas the populations from Coimbatore (Tamil Nadu), Nandikotkur (Andhra Pradesh) and Nizamabad (Telangana) exhibited medium level (50 - 75%) of resistance. The least level (0 to 50.00%) resistance was observed in populations from Kadapa (AP), Nandyal (AP), Tiruchangodu (TN), Rasipuram (TN), Athur (TN) and Namagiripettai (TN) (Table 1). The correlation analysis between number of aluminium phosphide fumigations and % resistance showed a positive correlation with number of fumigations and level of phosphine resistance (r = 0.534) in *L. serricorne* populations collected from major turmeric growing areas.

The present study revealed that the resistance to phosphine was common in all the field collected populations of *L. serricorne* and this was in corroboration with the results of Rajendran and Narasimhan (1994) obtained in a study at the tobacco warehouses in Andhra Pradesh. Using a discriminating dosage of 0.03 g/m^3 and a 24 hr exposure period Zettler (1992) screened 10 strains of *L. serricorne* collected from tobacco storage premises in the USA and found one of them to be resistant to phosphine. However, the present one is the first record of occurrence of phosphine-resistant strains of *L. serricorne* in turmeric storage in India.

The results revealed that the level of phosphine resistance varied from 27.41 to 82.16% in the populations from turmeric warehouses in major turmeric growing areas of Tamil Nadu, Andhra Pradesh and Telangana. Resistance to phosphine among major stored product pests might be attributed to repetitive selection (fumigation) with high concentrations of phosphine over long period of time (Behnhalima et al., 2004; Collins et al., 2005), poor fumigation practices (Sartori et al., 1990; Lorini et al., 2007; Pimentel et al., 2007) such as use of sheets having holes, two or more sheets placed by simple overlap, improper sealing and operating procedures which led to rapid loss of phosphine gas and shorter exposure times (Rajendran, 1999; Benhalima et al., 2004).

Thus results of the present study reveal that there is varied level of phosphine resistance prevalent in populations of *L. serricorne* collected from turmeric warehouses of Tamil Nadu, Andhra Pradesh and Telangana. There exists a positive correlation between number of aluminium phosphide fumigations and degree of resistance. Hence, it is suggested that a detailed comprehensive study on characterization of resistance to phosphine in *L. serricorne* populations is essential for designing a resistance management strategy.

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EDIBLE INSECT RESOURCES AND THEIR USE AMONG THE DIMASA KACHARIS OF DIMA HASAO DISTRICT, ASSAM

SABINA LANGTHASA*, ROBINDRA TERON AND AJIT KUMAR TAMULI

Department of Life Sciences and Bioinformatics, Assam University, Diphu Campus
Karbi Anglong District 782462 Assam
**Email: sabinalangthasa@gmail.com (corresponding author)*

ABSTRACT

Entomophagy, the practice of eating insects and insect products as food is common among the Dimasa Kacharis of Dima Hasao district. The district constitutes a biodiversity rich area but largely remained unexplored particularly due to lack of road connectivity with remote villages. The present study documents the edible insect resources and their therapeutic uses among the Dimasa Kacharis. Group discussion and semi-structured interview methods resulted in documentation of 19 species belonging to 13 families, 16 genera and 6 orders out of which 11 species are known for their medicinal value. Edible insects are known to have high nutritive value while some are highly effective in therapeutic uses. The present study documents the Dimasa traditional knowledge system and their insect resources. This baseline information will be of use for researchers interested in undertaking ethnobiological research in Dima Hasao district.

Key words: Dimasa Kachari, Dima Hasao, Assam, entomophagy, therapeutic, nutrition, traditional knowledge

Dima Hasao (formerly North Cachar Hills) represents one of the hill districts (4890 sq km; $25^0$3' N to 25^0 47' N and 92^0 37' E to 93^0 17' E) (Fig. 1) of Assam in Northeast India. The district forms a rugged hilly country constituting the eastern flanks of the Jaintia Hills and northern flanks of the Barial range. On its eastern side are the states of Nagaland and Manipur, and Cachar district is towards the south. On the western side is Meghalaya. Nagaon and Karbi Anglong districts are located towards its north. The district is the home of several diverse ethnic tribes viz. Dimasa, Zeme naga, Hmar, Kuki, Biate, Karbi, Khasi, Hrangkhol, Vaiphes, Khelmas and Rongmei (Tapadar, 2007), each with its own rich social and cultural traditions distinctly different from each other. Dimasa Kacharis are regarded as the earliest inhabitants of the Brahmaputra valley. They inhabit the northern half of the Dima Hasao district and ravines of the Jatinga valley and the adjoining tract. The people remain close to nature and as a result the forest resources, including insects form an important part in their livelihood and well being.

Edible insects play an important role as part of human nutrition in many regions around the world such as Africa, Asia and Latin America (Aletor, 1995). More than one thousand insect species, edible at some stage of their life cycle, are reported worldwide as traditional food (Illgner and Nel, 2000). Bee products are by far the most common medical insect product both historically and currently (Srivastava et al., 2009). Insects are used by different cultures as source of remedies for various ailments but these had been relatively neglected as sources of modern drugs (Crane, 1983). Ronghang and Ahmed (2010) explored the traditional knowledge of eating different insects as food, medicines and their various uses in the culture and tradition among the people of Karbi Anglong district, Assam.

Insects form an important dietary supplement for the Dimasa Kacharis. Collecting various plants, animals and insects from forest for food has been an age old practice for them. Among other resources, insects constitute an integral part of sociocultural life of the Dimasas. Insects are utilized for varied purposes such as food, medicine and livelihoods. But till date no scientific study on any kind of ethnoentomology has been undertaken in the district. Acculturation and rapid loss of forest cover due to shifting agriculture and urbanization, compounded with lack of interest for cultural practices among the youths, pose serious threats to traditional knowledge systems of ethnic communities. The present study has been done with an aim to explore the utilization of insects both as food and medicine among the Dimasa Kacharis of the Dima Hasao district.

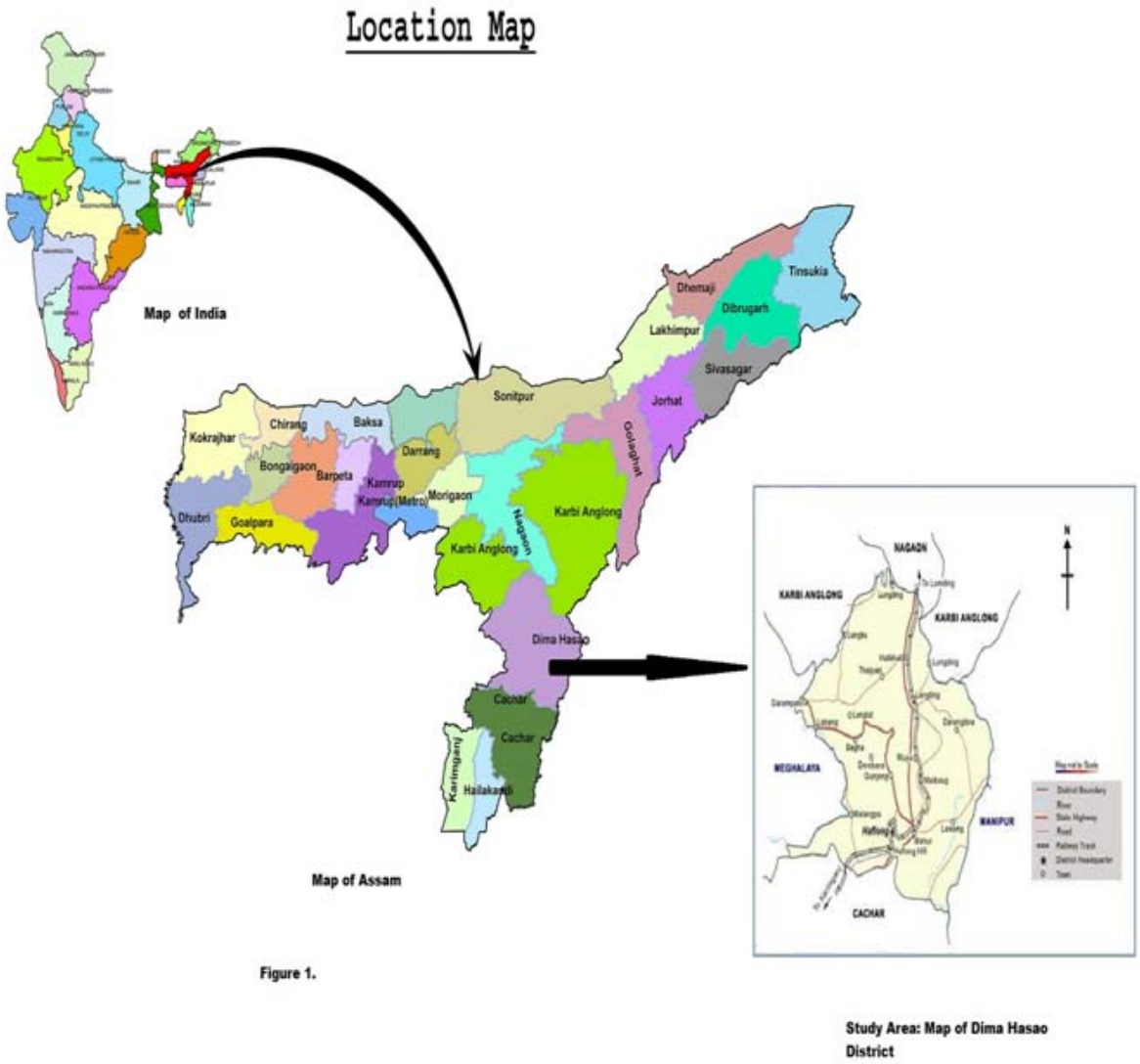

Fig. 1. Map of Dima Hasao district, Assam-study site

MATERIALS AND METHODS

The geographical boundary of Dima Hasao district, Assam and the natural relationship of insects with the people is the material of the study undertaken. Dima Hasao, a hill district in Assam, is established under Sixth Schedule of the Indian Constitution. The district occupies vast forest areas with three reserve forest areas *viz*. Borail RF, Krungming RF and Langting-Mupa RF. This region has proved to be a veritable paradise of valuable genes in a wide range of economic plants and animals including insects. The Dimasas of Dima Hasao district is mainly agriculturist, earning their livelihood by shifting or Jhum cultivation. They are said to be the earliest inhabitants of the Brahmaputra valley and called themselves as the 'Son of the Great River'.

Study was conducted during March 2015 to March 2017 in Dimasa Kachari villages. Eleven villages of more than 10 years of establishment viz., Narainpur, Harangajao, Miyungkhro (Jatinga valley), Choto Wapu, Thanalambra, (near Shifting agricultural field), Guliabra, Maibangsa, Langlai (near forests) and Maibang, Haflong and Umrangso (urban and semi-urban areas) were selected. Extensive field visits led to data through group discussion and semi-structured interview methods. Houses were selected randomly and questionnaires with simple questions like local names of insects, edible stage, seasons of their collection, mode of consumption, medicinal value and parts used. Informants (Fig. 2,3) included both elders and children as both the age groups are actively associated with collection of insects.

Fig. 2. Elderly Dimasa couple in traditional attire

Fig. 3. Traditionally knowledgeable Dimasa ladies-their weaving tool

Insects (both aquatic and terrestrial) were collected from ponds, beels, soils, trees, paddy fields and some from rearing households by traditional methods. Varied collecting equipments depending upon their habitat like insect net, sweep net, beating tray, water traps were used, and sometimes handpicked. These were then identified (Hahn Jeffrey, http://www.extension.umn.edu/) and preserved using standard methods (Singh et al., 2006-07; Srivastava, 2004). Terrestrial insects were preserved dry while aquatic insects were preserved in 70% alcohol. The specimens are maintained in the Department of Life Science and Bioinformatics Assam University- Diphu campus.

RESULTS AND DISCUSSION

The observations revealed a total of 19 species with food value (Table 1), belonging to 13 families, 16 genera and 6 orders. Eleven species were observed with medicinal value. Taxonomic distribution includes: Hymenoptera (7), Orthoptera (4), Lepidoptera (3), Hemiptera (3) and one each to Isoptera and Coleoptera.

As food: 19 species are used as food, and include *Oecophylla smaragdina, Apis mellifera indica, Apis dorsata, Apis florea, Apis cerana indica, Acheta domesticus, Reticulitermes flavipes, Antheraea assamensis, Philosamia ricini,* bamboo weevil *Cyrtotrachelus dux, Hieroglyphus banian* (F.), *Schistocerca gregaria,* cinnamon bug *Ochrophora montana, Okanagana viridis, Gryllotalpa africana, Vespa orientalis, Lethocercus indicus, Tetragonula iridipenis and Dytiscus marginalis.*

It was found that the winged termites, *Reticulitermes flavipes*, Cinnamon bug *Ochrophora montana* , locally called as '*Thanglang*', house cricket, *Acheta domesticus* (Fig. 4) and pupae of silkworm viz. *P. ricini* and *A. assamensis* were the most preferred and widely consumed by the Dimasas. These serve as a delicacy and are exploited in large numbers, especially the Eri pupae (Fig. 5). Eri culture too, is an important occupation of the Dimasas, and eri pupae are eaten and/or sold for cash generation (@ Rs 80/ 500gm) in local markets (Fig. 6), and cocoons are spun into yarns for weaving clothes, especially by the elders (Fig. 7) or sold in return for cash. Cinnamon bug *O. montana,* according to the Dimasas is a precious food available profusely only after 50 years during the gregarious bamboo flowering season. Besides, oil is also extracted

Fig. 4. Cricket, *Acheta domesticus*, a delicacy

Fig. 5. Dried eri pupae served in a tray

Table 1. Edible insects of the Dimasa Kacharis

Insects	Family	Vernacular Name	Edible Stage	Mode of Consumption
Oecophylla smaragdina	Formicidae	Keresma	Adult, eggs	Raw, chutney, dry fry
Apis mellifera indica	Apidae	Berega	Honey, larva, pupa	Raw, chutney, dry fry
Apis dorsata	Apidae	Bereyung	Honey, larva, pupa	Raw, chutney, dry fry
Apis florea	Apidae	Bereship	Larva, pupa	Raw, chutney, dry fry
Apis cerana indica	Apidae	Berekhaosha	Larva, pupa	Raw, chutney, dry fry
Acheta domesticus	Gryllidae	Khlamphu	Adult, nymph	Chutney, dry fry, paste
Reticulitermes flavipes	Rhinotermitidae	Thelem	Adult, winged form	Raw, dry fry
Antheraea assamensis	Saturniidae	Lodama	Pupa	Raw, dry fry, chutney, paste
Philosamia ricini	Saturniidae	Lodama	Pupa	Raw, dry fry, chutney, paste
Cyrtotrachelus dux	Curculionidae	Yungairing	Larva	Raw, deep fry, boiled
Hieroglyphus banian	Acrididae	Gu	Adult, nymph	Roasted
Schistocerca gregaria	Acrididae	Guyung	Adult, nymph	Raw, roasted, dry fry Ochrophora montana
Ochrophora montana	Pentatomidae	Thanglang	Adult	Edible, fried, chutney or raw, stored after fermentation
Okanagana viridis	Cicadidae	Grayungma/ Yengyengma	Adult	Eaten roasted or fried.
Gryllotalpa africana	Gryllotalpidae	Jijaima	Adult, nymph	Edible roasted and fried
Vespa orientalis	Vespidae	Bere	Larva	Edible, larva, eggs deep fry
Lethocercus indicus	Belostomatidae	Yungkangkrai/ Gangjema	Adult	Edible eaten roasted or raw
Tetragonula iridipenis	Apidae	Khusmaima	Honey, Larva, eggs	Raw or dry fry
Dytiscus marginalis	Dytiscidae	Dsi jagai	Adult	Eaten roasted, fry

Fig. 6. Eri pupae along with other vegetables sold in the local market of Haflong town.

Fig. 7. Old Dimasa ladies spinning the eri cocoon onto a '*Spool*' to make into fine thread.

from the bugs using traditional processing. This oil has high market value in spite of its bad smell and the pure oil is believed to cure many health problems (Lalsiamliana, 2006).

Honey and larva from bees viz. *A. mellifera indica* and *A. dorsata* are very common and consumed highly by the Dimasas, with *A. dorsata* yielding the highest quantity of honey. Honey from stingless bee, *T.*

iridipenis is the best for therapeutic use, while its propolis too has economic importance. Honey from *A. mellifera indica* are sold at Rs. 200-250/ 500 ml.

Apitherapy and culturing and rearing of silkworm are thereby much encouraged among the Dimasas. These have economic importance, in addition to livelihood opportunities for the rural villagers, especially women. *R. flavipes* or winged termites (Fig. 8) are considered revered food. Locust *S. gregaria* and bamboo weevil *C. dux* are extensively consumed. Larvae and eggs of *O. smaragdina* (Fig. 9*)*, larvae of *V. orientalis, L. indicus, H. banian, O. viridis* and *D. marginalis* too have food value among the Dimasas.

Fig. 8. Fried winged termites, *Reticulitermes flavipes*

Fig. 9. Larvae of *Oecophylla smaragdina*, after the harvest

Apart from food value, *O. smaragdina* are even used in culture by the Dimasa people in their traditional wedding ceremony as a sort of game to annoy the groom's party. As part of the tradition, the latter is stopped at the gate and the bride's party sprinkle handful of weaver ants and enjoy the moment of how members of the groom's team get rid of the ants. The larvae are even used as fish bait in ponds and its nest are sometimes introduced in orchard as it acts as effective biological control agents against various insect pests.

Stages and mode of consumption: Insects are consumed at every stages *viz*. immature stages like nymph, larva, pupa, eggs including adults. Mode of consumption varies, some are consumed raw, roasted, deep fry, boiled, chutney, curry or sometimes made into paste and stored by fermentation for future use (Table 2). Adult insects are prepared for consumption simply by removing the wings, hindlegs, forelegs and mouth. The cinnamon bug is either taken raw or fried in oil and is stored by fermentation for future use as they have high nutritive value and also found to alleviate hunger. Insects such as, *G. africana, L. indicus and R. flavipes* are mostly taken raw.

As medicine: Insects had been extensively used all over the past for therapeutic uses and arthropods represent a rich and largely unexplored source of new medicinal compounds (Dossey,2010). Entomotherapy is found to be quite common among the Dimasas of Dima Hasao district. Eleven species were identified for therapeutic use (Table 2). Therapeutic use of insects to cure various ailments is based on their traditional knowledge and transmitted through word of mouth.

Ochrophora montana or *Thanglang* in local dialect, is a delicacy and is used as medicine to alleviate hunger. This cinnamon bug is sold in huge amount in local markets during its availability and is a valuable dietary supplement for the poor people during famine (Thakur et al., 2012). Eggs of weaver ants *O. smaragdina* are used to treat throat pain in babies and children suffering from boils. The eggs are also used to cure breathing problem i.e., *asthma* in adults and for treatment of malaria. The formic acid of these insects are being used in connection with scabies, malaria, tooth aches, stomach disorders, blood pressure anomalies etc. (Chakravorty et al., 2011).

Honey from bees is used for relieving chest pain, cold, cough, fever and sore throat. Some consider it as a best natural remedy in gastritis or gastric ulcer; women use it as an ointment for dry skin. Honey from *T. iridipenis* is by far considered the best. Species of

Table 2. List of insects and their medicinal/therapeutic use

Insect	Parts used	Therapeutic, other uses
Oecophylla smaragdina	Adult, eggs	For babies suffering from throat pain, Boils, breathing problem and for malaria treatment
Apis dorsata	Honey	Preventive against cold, cough, fever and sore throat
Apis cerana indica	Honey	Cold, cough, fever and sore throat
Apis mellifera indica	Honey	Cold, cough, fever and sore throat
Tetragonula iridipenis	Honey, propolis	Cold, cough, fever and sore throat, economic importance
Reticulitermes flavipes	Whole body	Health benefit, Dietary supplement
Philosamia ricini	Cocoon, Pupae	Prevention against increase flow of in babies, protection from evil spirit, health benefit, dietary supplement
Antheraea assamensis	Pupae	Health benefit, dietary supplement
Ochrophora montana	Whole body	Alleviate hunger
Acheta domesticus	Whole body	Preventive against child suffering from chest pain, cold and cough
Lethocercus indicus	Whole body	Cold and cough

bees and wasps are considered to be poisonous. The chemical substance released from their abdomen as defensive mechanism against predators is found to be very poisonous which causes skin irritation. Winged termites, *R. flavipes* are considered as dietary supplement and health benefit. Different species of termites are used to treat various diseases that affect human health. For example *M. exiguus* is used for asthma, bronchitis, influenza, whooping cough, flu (Alves et al., 2009; 2011). The smaller winged termites that appear before rainy season are generally not edible and if consumed cause deafness and goiter in the neck as believed by the Dimasas.

Silkworm species viz. *A. assamensis* and *P. ricini* are very nutritive with high protein content, thereby consumed for health benefit. These are found to contain huge amount of fats too (Deori et al., 2014**)**. Silkworms had been used for detoxification and treating bacterial infections causing sore eyes, swollen throat and loss of speech, as well as for impotence (Ahn et al., 2008). Eri cocoon is used as traditional medicine for babies suffering from increase flow of saliva. Local prescription called *Maduli*, is prepared with eri cocoon and tied onto the neck of babies (Fig. 10) to prevent flow of saliva and to protect them from influence of evil spirits. House cricket, *A. domesticus* and *L. indicus*, giant water bug, too serve as remedies for children suffering from chest pain, cold and cough.

Fig.10. Local prescription '*Maduli*' prepared with eri cocoon tied onto baby's neck, prevent flow of saliva

The study concludes edible insects as valuable natural resource for the Dimasa Kacharis of Dima Hasao district. This tribe uses a wide variety of insects in traditional food practices and as remedies for curing different ailments. Besides nutritional and medicinal benefits, insects also serve as a good source of income for the tribe, especially for the women. Further, scientific investigations on their chemical contents will provide reliable source of nutrition to the people for better health, because of their nutritive value and ubiquitous presence (Kato et al., 2009).

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COW URINE AS A CHEMOTHERAPEUTIC IN COMBATING EUROPEAN FOUL BROOD IN HONEY BEE, *APIS MELLIFERA* L.

MOHAMMED M. IBRAHIM*, R. K. THAKUR, K. M. KUMARANAG**, UJMA MANZOOR**, SUBHASH CHANDER AND DEBJANI DEY**

Division of Entomology, ICAR- Indian Agricultural Research Institute, New Delhi 110012
***ICAR-AICRP on Honey Bees and Pollinators, New Delhi 110012*
**Email: mrmustafa1982@gmail.com (corresponding author)*

ABSTRACT

Investigations were carried out at few apiaries in Himachal Pradesh and Haryana to gather relevant data on the antioxidant and antimicrobial activities of cow urine and terramycin against bacterial disease, European Foul brood (*Melissococcus plutonius*) in honey bee, *Apis mellifera* colonies. Seventy colonies were selected for experimentation and equalized for colony strength, food stores and assured to have same aged queen. Observations were recorded on disease infection level on 3, 7, 15 and 21 days after 1st and 2nd spraying and % recovery of infection worked out. It is concluded that the spray of cow urine showed a rapid significant reduction in the infection within 21 days and also improved brood growth and health as well as hygienic colonies. Moreover, there was no contamination in the hive products. Whereas, terramycin treatments showed high reduction in the infection below the detectable level in 15 days only but left residues in hive products. Thus the study reveal that the cow urine could have a potential as a therapeutic against bacterial disease supporting the claim of traditional management practice. Cow urine could be used as alternative to chemotherapeutic for the management of European Foul Brood in honey bee colonies.

Key words: European foul brood, cow urine, spray, alternative control, terramycin, residues, Himachal Pradesh, Haryana

Honey bee brood and adults are hosts a number of entomopathogens such as bacteria, fungi, protozoa, viruses and parasitic mites (Aronstein and Murray, 2010; Forsgren, 2010; Genersch, 2010). A number of strategies are available to protect honey bees against these pathogens. These include a broad range of chemotherapeutic compounds that have been tested, but unfortunately none of the tested compounds achieved a complete control of the diseases (Lodesani and Costa, 2005). European Foul Brood (EFB) was reported in Himachal Pradesh and Dharwad during 1998 (Singh and Garg, 2000). Later on, the disease killed about 25% of the colonies in Punjab (Gatoria et al., 2000; Singh and Garg, 2000). A variety of indigenous methods for managing such diseases are being carried out. There is a need to develop alternative control methods to prevent the development of resistant strains of diseases. The present study investigates the efficiency of cow urine along with terramycin for controlling EFB in European honey bee, *Apis mellifera* L.

MATERIALS AND METHODS

The present study on the efficacy of cow urine and terramycin against EFB in honey bee *A. mellifera* colonies was carried out at apiaries located at Himachal Pradesh and Haryana, during 2015-17. Seventy colonies were selected and prepared in terms of equalization of strength, food stores and by maintaining same aged queen. For confirmation of the presence of *M. plutonius*, the screening test or rapid method was done. Meanwhile, five young larvae were collected from each infected colony and kept in clean and closed containers. These were brought in the laboratory of Division of Entomology, Indian Agricultural Research Institute, New Delhi for further study. Samples of young dead larvae (5- 6th day of life) were collected and smeared on microscope slides, abdominal part was dissected and the mid gut contents mixed with 5% aqueous nigrosin, dried gently over a flame and then examined under sterozoom microscopy connected with Leica Application Suite Version 3.6.0.

Infested colonies were subjected to test the efficacy of cow urine. 10 - 15 ml of cow urine at different concentration (50%, 75%, and 100%) and terramycin sugar syrup (125, 150 and 175 mg/l sugar syrup/ colony) per replication were sprayed on the selected

and marked highly infected area (100 cm^2) (taken as 100% infection) in triplicate with a plastic sprayer (applied gently on the infected brood). Control colony was sprayed with 10 ml of distilled water. Observations on disease infection were taken on 3, 7, 15 and 21 days after first and second spraying. Whereas two feedings of terramycin sugar syrup was given to the infected colony. The recovery in infection calculated according to Tiwari (2015) by the following formula:

$$\% \text{ Recovery of infection } X\ 100 \frac{\text{No. of recovered cells after spraying}}{\text{Total number of infected cells}}$$

The data was subjected to statistical analysis using RBD (Two Factorial) design after suitable transformations using SAS System and Tukeys HSD Softwares.

RESULTS AND DISCUSSION

Diagnosis of European Foul Brood: Visible symptoms of EFB were seen in the young freshly dead larvae, which appeared dull white dead becoming yellow and finally dry to brown, coiled and flaccid. These observations agree with those of Bailey (1960), Singh (1962), OIE, (2008) and Forsgren (2010). In the laboratory, the non-spore of *M. plutonius* was seen easily as opaque chalk white clump, with lanceolate cocci occurring singly and in cluster as also reported by Hornitzky and Wilson (1989) and Hornitzky and Smith (1999).

Efficacy of cow urine and terramycin against EFB: The observations revealed significant differences in controlling the disease at Himachal Pradesh and Haryana (Figs.1, 2). Terramycin showed highly significant

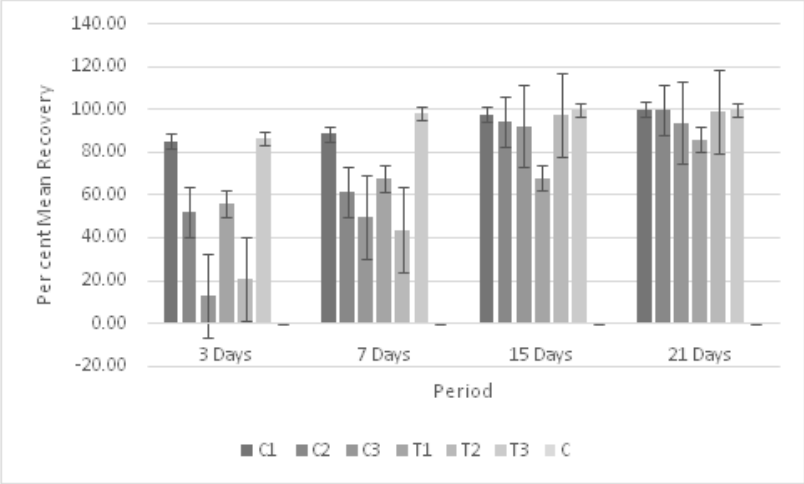

Fig. 1. Efficacy of cow urine and terramycin (Haryana, 2015-16)

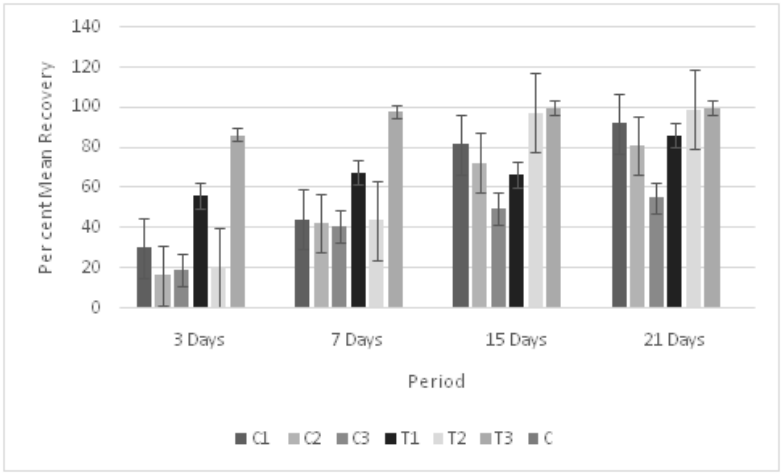

Fig. 2. Efficacy of cow urine and terramycin (Himachal Pradesh, 2016-17)

difference after 1st and 2nd spraying in comparison to control; rapid significant reduction in the % recovery of infection was observed in 1ststpray (86.42%) @ 175mg/l followed by cow urine (85.36%)@ 50%. The lowest means recovery were observed for terramycin (56.14%) @ 125m/l followed by (20.74%) @ 150mg/l but with cow urine it was more (52.20% and 13.03%) for concentration @ 75% and 100%, respectively. The results were positive for all treated colonies after 7 days of the 1st spray.

In case of terramycin, treatments have shown better recovery at 98.27%, 67.72% and 43.91% @ (175, 125 & 150) mg/l, respectively. Cow urine treatments obtained high mean recovery (88.72%, 61.52% and 49.86%) for different concentrations 50%, 75% and 100%, respectively. After 15days of the 2nd spray a rapid decrease in infection was observed with terramycin (100%, 97.56% and 68.08%) @ (175, 150 and 125) mg/l, respectively. For cow urine equally high values (97.56%, 94.40 and 92.25) @ 50%, 75% and 100%, respectively were observed. After 21 days of 2ndspray, % recovery was markedly high with cow urine (100%)@ 50% and (100%) @ 75% followed by (94.09%)@ 100%. The low values (86.12%), were observed with terramycin @ 125mg/l. Whereas, colonies treated with terramycin recoded per cent recovery of infection(99.29% and 100%) for concentration(150 and 175) mg/l, respectively. No honeybee hive product showed any sign of cow urine contamination.

Results on the efficacy of cow urine and terramycin at Himachal Pradesh during 2016-17 are given in Table 2; the least values were obtained after 3 days of the 1st spray in all treatments in comparison to control. Highest recovery mean (84.78%) was obtained with terramycin @ (175mg/l) followed by (52.35%) and (25.76%) for colonies treated with (150 and 125) mg/l, respectively. With cow urine there was lowest recovery of infection (30.36%, 16.66% and 19.17%) for different concentrations 50%, 75% and 100%, respectively. After 7 days of the 1st spray, with terramycin (175 and 150) mg/l there was maximum recovery of infection (95.89% and 64.61%, respectively). Terramycin 125mg/l resulted in less recovery of infection (39.84%). Data obtained after 2nd spray revealed again that terramycin treatments are the best with maximum recovery, compared to cow urine treated ones. After 21 days of the 2nd spray, terramycin resulted in 69.18% and 64.09% recovery. Meanwhile, the colony fed with 175mg/l showed 100% recovery. Colonies sprayed with cow urine 50% gave highest recovery (92.23%) followed by 75% and 100% (81.11% and 55.12%), respectively.

Table 1. Effect of cow urine (ml/colony) and terramycin sugar syrup (mg/l/colony) against European foul brood in *A. mellifera* (2015-16)

Treatments	I Spray (% recovery of infection)		II Spray (% recovery of infection)		
	3 Days	7 Days	15 Days	21 Days	Means
C_1 Cow urine (50%)	#67.59cd	#70.61bc	#82.81ab	#90.00a	#77.75b
	*85.36	*88.72	*97.56	*100.00	*92.91
C_2 Cow urine (75%)	#46.26ef	#51.68ef	#77.15abc	#90.00a	#66.27c
	*52.20	*61.52	*94.40	*100.00	*77.03
C_3 Cow urine (100%)	#20.84g	#44.96ef	#76.76abc	#78.52abc	#55.27e
	*13.03	*49.86	*92.25	*94.09	*62.31
T_1 Terramycin sugar syrup (125 mg/l)	#48.60ef	#55.50de	#55.66de	#68.32cd	#57.02de
	*56.14	*67.72	*68.08	*86.12	*69.51
T_2 Terramycin sugar syrup(150 mg/l)	#27.08g	#41.45f	#82.65ab	#86.06a	#59.31d
	*20.74	*43.91	*97.56	*99.29	*65.37
T_3 Terramycin sugar syrup(175 mg/l)	#68.38cd	#83.82ba	#90.00a	#90.00a	#83.05a
	*86.42	*98.27	*100.00	*100.00	*96.17
Control	#00.00h	#00.00h	#00.00h	#00.00h	#00.00f
	*0.00	*00.00	*00.00	*00.00	*00.00
Means	#39.82d	#49.72c	#66.43b	#71.84a	
	*44.84	*58.57	*78.55	*82.78	

* Value original means; #means in angular transformed values; Mean with same superscript letters not significantly different and other letters grouping given as per Tukey's HSD; S.E. (Days) = 0.95; S.E. (Treatments) = 1.25; S.E. (Days x Treatments) = 2.51; CV = 7.64; CD (Treatments) = 3.56; CD (Days x Treatments) = 25.32

Table 2. Effect of cow urine (ml/colony) and terramycin sugar syrup (mg/l/colony) against European foul brood , *A. mellifera* (2016-17)

Treatments	I Spray (% recovery of infection)		II Spray (% recovery of infection)		
	3 Days	7 Days	15 Days	21 Days	Means
C_1 cow urine (50%)	#32.66ijk	#41.82hij	#64.80cde	#74.21abc	#53.37c
	*30.36	*44.53	*81.74	*92.23	*62.22
C_2 cow urine (75%)	#24.04k	#40.57hijk	#58.55dcefg	#64.28cdef	#46.86d*53.22
	*16.66	*42.50	*72.61	*81.11	
C_3 cow Urine (100%)	#25.43jk	#39.44hijk	#44.74hig	#47.95fhig	#39.39e
	*19.17	*40.82	*49.53	*55.12	*41.16
T_1 Terramycin Sugar Syrup (125 mg/l)	#29.98jk	#39.25hij	#60.32defhg	#57.58bcd	#57.575bd
	*25.76	*39.84	*70.85	*69.18	*69.18
T_2 Terramycin Sugar Syrup(150 mg/l)	#45.20efhig	#53.90defhg	#79.03ab	#58.96a	#58.9775b
	*52.35	*64.61	*92.89	*64.09	*64.09
T_3 Terramycin Sugar Syrup(175 mg/l)	#66.75bcd	#85.29ab	#92.98a	#95.72a	#85.26a
	*84.78	*95.89	*92.00	*100.00	*95.1675
Control	#00.00l	#00.00l	#00.00l	#00.00l	#00.00f
	*00.00	*00.00	*00.00	*00.00	*00.00
Means	#46.10d	#57.62c	#78.18b	#85.81a	
	*52.25	*66.74	*89.99	*96.81	

* Value original means; # means in angular transformed values; Mean with same superscript letters not significantly different and other letters grouping are given as per Tukey's HSD; S.E. (Days) = 1.14; S.E. (Treatments) = 1.51; S.E. (Days x Treatments) = 3.01; CV= 10.80; CD (Days) = 3.23; CD (Treatments) = 4.47; CD (Days x Treatments) = 36.50

Beekeepers often rely on antibiotics for control of various pathogens leading to short and long term impacts on the ability of bees to evolve resistance toward pathogens and favour the spread of more virulent strains (Desneux et al., 2007), increase in cost of chemical use and risk of contamination of hive equipments and products (Lauro et al., 2003), and affecting its quality for human consumption (Martel et al., 2006).

It is necessary to develop effective, sustainable and ecofriendly strategies for the control of bee enemies and diseases *viz.*, selection, integration and implementation of a mixture of control strategies (biological, cultural and chemical). The cow urine evaluated now against EFB reduced the disease infection below detectable limit, showed rapid recovery, and promoted growth of brood. Chand and Tiwari (2012) in their survey showed that with 25-100% cow urine spray, there was recovery of EFB infection within 10-12 days after application whereas with terramycin only 40-50% recovery was observed.

The present study revealed that the spray of cow urine gave a rapid and significant reduction in the % infection in 21 days. Similar results were obtained by Tiwari (2015), and Tiwari and Mall (2007) with cow urine inhibiting bacterial growth of *M. plutonius* in *A. mellifera* colonies under in vitro conditions. Antioxidant and antimicrobial activities of cow urine had been studied by Jarald et al. (2008) and Ganaie et al. (2010). These observations also showed its potential therapeutic value. Terramycin treatments also resulted in high level of reduction in the disease infection within 15 days only which corroborates earlier work but it persists longer in the hive (Thompson et al., 2007). Besides these, there is more chance for selecting resistant bacteria (Amani et al., 2012).

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A NEW RECORD OF TERMITE *AMITERMES BELLI* (DESNEUX) FROM HIMACHAL PRADESH

G. K. MAHAPATRO*, SACHIN KUMAR AND MURARI KUMAR*****

Division of Entomology, ICAR- Indian Agricultural Research Institute, New Delhi 110012
**Current address: ICAR-IARI Regional Station, Pune 411067*
**Email: gagan_gk@rediffmail.com*

ABSTRACT

This paper deals with first report of termite *Amitermes belli* (Desneux) from Himachal Pradesh. Currently 23 species under five families (Termopsidae, Kalotermitidae, Stylotermitidae, Rhinotermitidae and Termitidae) and ten genera are known from Himachal Pradesh. As a member of the highly specialized termite family Termitidae, *A. belli* is unique among other termites found in India, due to backwardly directed tooth. This species had been reported from Delhi, Haryana, Madhya Pradesh and Rajasthan earlier; and this study sample is collected from cow dung from Renuka village, Sirmour district, Himachal Pradesh.

Key words: *Amitermes belli*, Himachal Pradesh, Termitidae, Delhi, Haryana, Madhya Pradesh, Rajasthan, cow dung, Sirmour district

Termites of Himachal Pradesh are poorly known. The earliest records of termites from Himachal Pradesh are those of Holmgren and Holmgren (1917), Roonwal (1953) and Chatterjee and Thakur (1964, 1967). Chhotani (1997) discussed the taxonomic status and geographical distribution of the termites known so far from this region. Thakur (2007) reported 22 species under five families (Termopsidae, Kalotermitidae, Stylotermitidae, Rhinotermitidae and termitidae) and nine genera from Himachal Pradesh. As a result of present survey we identified *Amitermes belli* (Desneux), which had not been reported so far.

Genus *Amitermes* is cosmopolitan in nature, and represented by nearly 114 species of which five occur in the Oriental region. In Indian region this genus is represented by three species (*i.e. A. baluchistanicus*, *A. belli* and *A. paradentatus*); and from India only single species *A. belli* had been reported (Chhotani, 1997). As a member of the highly specialized termite family Termitidae, *A. belli* is unique among other termites found in India (backwardly directed tooth-Fig. 1). This species had been also reported from Delhi, Haryana, Madhya Pradesh and Rajasthan (Kumar, 2010). The present report is from a sample collected from cow dung (non-damaging stage) from Renuka village, Sirmour district, Himachal Pradesh. Current survey shows that species continues being introduced in many states despite the efforts of harbour quarantines. Till date, 23 termite species had been reported from Himachal Pradesh (Table 2), which amounts to 11.86% of the Indian termite fauna (Mahapatro and Kumar, unpublished).

Systematic Account

1906. *Termes belli* Desneux, *Ann. Soc. Ent. Belg.*, Brussels, 49(12): 352-354. Im. S. and W.

Type-locality: Pakistan: Karachi (Sind).

1949. *Amitermes belli* Snyder, *Smiths. misc. Coll.*, 112: 114.

1972. *Amitermes belli* Chaudhry, Ahmad, Malik, Akhtar and Arshad, *Termites of Pakistan*

(Final Tech. Rep. PL 480): 55.

1997. *Amitermes belli* Chhotani, *Zool. Surv. India, Publ.*, Vol. II, pp. 108-113.

Castes known: imago, soldier and worker.

MATERIALS AND METHODS

Three samples of termites were collected from Renuka village, Sirmour district, Himachal Pradesh. The specimens were preserved in 75% ethyl alcohol, with proper label containing details of the locality, date of collection etc. For taxonomic studies, Roonwal's (1970) monograph "Measurements of termites (Isoptera) for taxonomic purpose" was followed. The specimens were studied under a stereozoom microscope fitted with ocular micrometer and the measurements of various body parts (such as head, mandibles, pronotum, etc.) were taken.

RESULTS AND DISCUSSION

Key to species of *Amitermes* from India (based on soldier)

1(2) Tooth of mandibles laterally directed .....*A. paradentatus* (Ahmad)

2 (1) Tooth of mandibles posteriorly or postero-laterally directed

3 (4) Posterior margin of head round. Mandibles thinner; tooth on mandibles directed posteriorly.....*A. belli* (Desneux)

4(3) Posterior margin of head weakly convex. Mandibles thicker; tooth on mandibles directed postero-laterally.....*A. baluchistanicus* (Akhtar)

Diagnostics

The soldiers are very small (4.41-5.31mm); possess

Table 1. Body measurements (in mm) of soldiers of *Amitermes belli* (n=5)

S. No.	Body parts	Range	Mean ±SD
1	Total body-length	4.41-5.31	4.63±0.37
2	Head		
	Head- length with mandibles	1.80-2.07	1.94±0.12
	Head- length to lateral base of mandibles	1.24-1.41	1.25±0.07
	Maximum width of head	0.96 -1.13	1.05±0.08
	Length of mandibles		
	Left mandible	0.63-0.67	0.64±0.01
	Right mandible	0.64-0.68	0.65±0.01
	Mandibular tooth index	0.50-0.57	0.52±0.02
3	Thorax		
	Length of pronotum	0.33-0.35	0.34±0.00
	Maximum width of pronotum	0.67-0.77	0.71±0.04

Table 2. List of termites from Himachal Pradesh

Family	Genus/species
Termopsidae,	*Archotermopsis wroughtoni* (Desneux)
Kalotermitidae,	*Neotermes bosei* Snyder
Rhinotermitidae	*Coptotermes heimi* (Wasmann)
	Coptotermes kishori Roonwal & Chhotani
	Heterotermes gertrudae Roonwal
	Heterotermes indicola (Wasmann)
Stylotermitidae	*Stylotermes faveolus* (Chatterjee & Thakur)
Termitidae	*Speculitermes cyclops* Wasmann
	Amitermes belli (Desneux)
	Angulitermes bhagsunagensis Thakur
	Odontotermes assmuthi Holmgren
	Odontotermes bhagwatii Chatterjee and Thakur
	Odontotermes distans Holmgren &Holmgren
	Odontotermes giriensis Roonwal and Chhotani
	Odontotermes gurdaspurensis Holmgren & Holmgren
	Odontotermes lokanandi Chatterjee & Thakur
	Odontotermes microdentatus Roonwal & Sen-Sarma
	Odontotermes obesus (Rambur)
	Odontotermes redemanni (Wasmann)
	Microtermes incertoides Holmgren
	Microtermes mycophagus (Desneux)
	Microtermes obesi Holmgren
	Microtermes unicolor Snyder

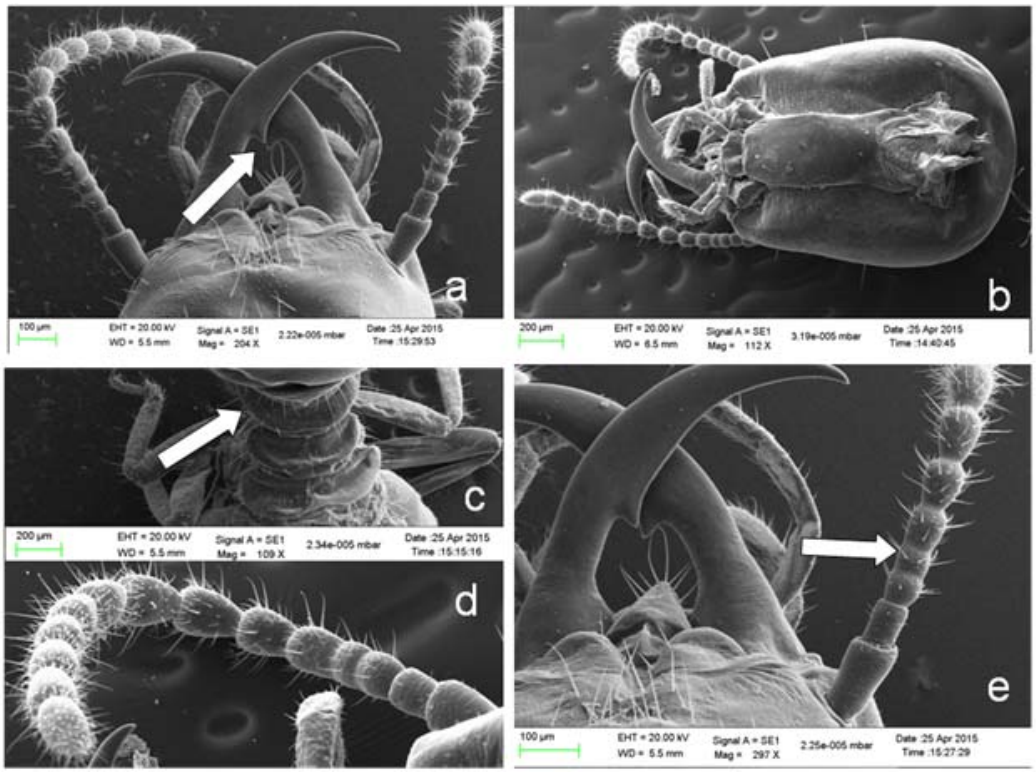

Fig. 1. SEM images: *Amitermes belli* soldier: a. Mandibles sickle-shaped with a backwardly directed sharp tooth, antenna 14 segmented; b. Postmentum fairly arched, sub-rectangular; c. Pronotum saddle-shaped; d. 14 segmented antenna; and e. 4th shortest antennal segment.

pale yellow heads and sickle shaped mandibles and basally wide and reddish. Antenna with 14 segments, 4th the shortest. Mandibles thin, long and strongly incurved in distal half. This species differs from other subterranean termites by having a prominent sharp dent directed backwardly at about middle in both the mandibles (Fig. 1). Postmentum fairly arched subrectangular, sides weakly narrowed and pronotum saddle shaped.

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FITNESS COSTS OF RESISTANCE TO CRY1AC TOXIN IN *HELICOVERPA ARMIGERA* (HÜBNER)

VINOD S. KUKANUR, T.V.K. SINGH AND K.R. KRANTHI*****

Department of Entomology, College of Agriculture, Rajendranagar
Prof. Jayashankar Telangana State Agricultural University, Hyderabad 500030
Emeritus Scientist - ICAR;Central Institute for Cotton Research, Nagpur*
***Email: prof.tvksingh@yahoo.com (corresponding author)*

ABSTRACT

Transgenic cotton producing a *Bacillus thuringiensis* is widely used for controlling *Helicoverpa armigera* (Hubner). Increasing adoption of Bt cotton expressing *cry* genes from *Bacillus thuringiensis* run under high risk for development of resistance. Fitness costs can greatly influence the rate of resistance evolution and also aids in delaying resistance. In the present study fitness costs in resistant *H. armigera* were evaluated by comparing biological performance to susceptible insects when reared on untreated diet. Parameters monitored includes larval survival, larval and pupal weights, pupal malformation, developmental time (larval and pupal) and reproductive traits (fecundity and fertility). From the results, it was found that fitness costs reduced survival of resistant strain on untreated diet by 12-25%. Significant weight differences were recorded between resistant and susceptible on untreated diet. Slower growth and development of resistant insects on untreated diet was also observed. Resistant insects took 2-4 days more for larval development, which led to emergence asynchrony between susceptible and resistant adults.

Key words: *Helicoverpa armigera*, Cry1Ac, resistance, larval and pupal weight, periods, malformation, fecundity, fertility, emergence asynchrony

Transgenic crops producing proteins from *Bacillus thuringiensis* (Bt) are the most efficient tool for pest management (Gao et al., 2009). However, sustainability of Bt crops may be compromised due to development of resistance by pests. Many target pests of Bt crops have shown resistance in both the lab and field (Tabashnik et al., 2014). The widely accepted strategy to delay the evolution of resistance in target pests is high-dose and refuge strategy (Alstad and Andow, 1995). The theory underlying the high dose-refuge strategy is to reduce heritability of resistance by providing numerous susceptible moths emerging from refuge to mate with resistant moths emerging from Bt crops (Gould, 1998). Various mathematical models had been demonstrated that the growing of refuge crops around Bt crops can aid in delaying evolution of insect resistance to Bt crops (Tabashnik et al., 2014). The effectiveness of refuge strategy depends on many factors such as, low initial resistance allele frequency, recessive inheritance, chances of mating between susceptible insects from refuges and resistant insects from Bt crops and fitness costs associated with resistance.

Fitness costs is one of the crucial factor that influence resistance evolution in target pest (Gassman et al., 2009). Fitness costs of resistance to *Bacillus thuringiensis* (Bt) crops occur in the absence of Bt toxins, when individuals with resistance alleles are less fit than individuals without resistance alleles (Carriere et al., 2010). Fitness costs are the results of negative pleotropic effects of genes that confer resistance (Groeters et al., 1994). Fitness costs associated with resistance genes can be substantial, affecting survival and development (Lisa and Akhurst, 2005), diapause (Lisa and Akhurst, 2004) and mating success (Groeters et al., 1994).

Pest susceptibility is considered as a valuable natural resource (Mallet, 1989), on which most of resistance management strategies are built. Fitness costs are capable of inhibiting the evolution of resistance to Bt toxins and may contribute to the delay or either prevention of resistance to Bt toxins (Carriere et al., 2001 and Raymond et al., 2007). The evolution of insect resistance to crops producing toxins from *B. thuringiensis* (Bt) requires heritable resistance and consistent selection favouring individuals with resistance alleles (Falconer, 1989). Ascertaining the fitness of individuals with resistance alleles in absence of selection i.e on non-Bt cotton or refuges crops helps

to understand resistance evolution (Carrière and Tabashnik, 2001). The existence of fitness costs is determined in two ways, either by comparing life cycle traits, such as survival, developmental rate, weights and fertility parameters between Bt-resistant and susceptible strains in the absence of Bt toxins or evaluating stability of resistance in the absence of Bt toxins (Bird and Arkhust, 2006). In the present study an attempt has been made to study fitness costs by comparing life history parameters of resistant, susceptible and F1 hybrid on toxin free diet (untreated diet) and results are presented below.

MATERIALS AND METHODS

Fitness parameters of homozygous resistant, homozygous susceptible and their F_1 hybrid (heterozygous) of *H. armigera* were compared on diet containing the Cry1Ac toxin and on Cry1Ac toxin free diet (Untreated).

Insect rearing: Larvae were collected from pigeonpea crop in Palem, Telangana during 2014. These were reared individually in 50-well bioassay trays on semisynthetic diet up to fifth instar. Rearing techniques were followed as per Kranthi (2005). After fifth instar, larvae entering pre-pupation were left in plastic tubs (9 x 9 cm) partially filled with sand and saw dust (1:1 ratio). After three to four days of pupation, all the pupae were removed and surface sterilised using 2% sodium hypochlorite. Pupae were sexed based on the differences on the ventral side of abdomen (Navarajan et al., 1979). Male and female pupae were maintained separately in 1 l plastic jars (15 x 13 cm) for adult emergence. Two days old females were paired with one day old males and provided with 10% honey mixed with 0.2 g L-ascorbic acid + 0.2 g methyl paraben+ vit-E tablet as feed in 1000 ml translucent plastic jars with a top covered with muslin cloth as a substrate for egg laying. Jars were kept in a room maintained at 27±2°C, 80±5% RH and a photoperiod of 14:10 L: D h.110 crosses were established from the adult's derived from field collected larvae. The neonates from each single pair family were maintained separately on semisynthetic diet up to F_2 generation.

Cry toxin diet and discriminating dose: The F_2 neonates of each single pair family lines were shifted to semisynthetic diet, larvae reaching white stage (second instar) were subjected to discriminating dose of Cry1Ac toxin incorporated at the rate of 1µg/ml of diet. Larvae that reached 3rd instar on 6th day were considered as resistant and reared up to pupation, pupae were weighed and those of approximately the same weight kept for emergence. The toxin diet was prepared following the procedure given by Kranthi (2005). The diet (1200 ml) was prepared with all the ingredients, and after mixing in agar, diet was allowed to cool to around 50°C-55°C prior to mixing the Cry1Ac toxin. Cry1Ac toxin was obtained in the form of MVP II (Pseudomonas encapsulated with 19.7% Cry1Ac toxin containing 1 ml of 2% MVP II + 1 ml of 1X PBS) from the Central Institute for Cotton Research, Nagpur. Later, 1ml of toxin diet was poured into the 25-well trays and cooled to room temperature.

Insect strains: Resistant and susceptible strains were isolated using the methodology described by Andow and Alstad (1998) and Kranthi et al. (2006). Strains were isolated from F_2 population obtained by single pair isolines derived from field collected larvae on pigeonpea during 2014 in Palem, Telangana. Resistance to the Cry1Ac toxin had been ascertained to be a recessive trait (Kaur and Dilwari, 2011) and discriminating dose @ 1µg/ml of diet precisely differentiates resistant (RR) from susceptible individuals (both SS and RS) from the treated population. Hence, using discriminating dose and F_2 methodology, both resistant and susceptible strains were isolated. The F_1 hybrid was developed by crossing resistant with susceptible strain in a reciprocal manner (SS@&XRRB&, RR@&XSSB&).

Life history traits on treated and untreated diets: The performance of all the three strains (resistant, susceptible, and their F_1 progeny) were compared on two diets (Cry1Ac incorporated semi-synthetic diet and untreated diet). Observations on larval survival, larval duration, larval weights, pupal weights, prepupal and pupal duration, adult emergence and % egg laying were recorded; and weights were recorded daily for each instar starting from 3rd day till pupation. After pupation, malformed pupae were separated and counted. Healthy pupa were sexed and kept separately in 1 l jars for emergence.

Fecundity and intrinsic rate of increase: The net replacement rate (R_0), the average number of female offspring produced by each female during its entire lifetime was calculated for a resistant, susceptible and F_1 hybrid. Adults emerged were paired with opposite sex within the insect strain. Whereas, reciprocal crosses were made with resistant and susceptible insect strain to obtain F_1 heterozygotes. Lifetable was constructed from ten single pairs in each insect strain. The number of eggs laid on each day was counted using stereozoom

microscope till death. Due to variable hatch rate of eggs laid by females of different ages, eggs that hatched on a single day were used to study the lifetable. Newly hatched larvae were transferred individually into 30 ml plastic vials containing semisynthetic diet. Observations on larval hatching, larval development, prepupal and pupal development and successful emergence of adult and fecundity were recorded daily. Age specific mortality in different developmental stages like egg, larva, pupa and adult was also recorded. The formulae given by Birch (1948), Howe (1953) and Bilapate et al. (1980) were used to construct life and fertility tables.

Data analysis: Larval survival, developmental time, larval weights, prepupal weights and pupal weights were analysed by analysis of variance (ANOVA) and pairwise comparisons among strains were made using a Tukey-Karmer multiple comparison test (Hochberg and Tamhane, 1987).

RESULTS AND DISCUSSION

Population growth parameters: The net reproductive rate (R_0) of three strains (resistant, susceptible and F_1 hybrid) were far greater than 1 (ranging from 58.77 to 218.22) on two different diets tested. However, R_0 was affected in Cry1Ac resistance strain. Lowest R_0 was recorded in resistance strain reared on untreated diet. Comparison of R_0 among resistance and susceptible strain on untreated diet showed reduced net reproduction values from 181.45 to 89.68 in F_3 generation, 191.66 to 58.77 in F_4 generation and 135.03 to 80.32 in F_5 generation, respectively. The fitness measured by relative fitness (*w*) showed reduced fitness of resistant strain on untreated diet. Relative fitness (w) of resistant strain on untreated diet was 0.49 in F_3, 0.31 in F_4 and 0.60 in F_5 generations compared to susceptible strain; also, net reproductive rate of F_1 hybrid (218.22) was higher compared to resistant and susceptible strain; and relative fitness (w) (1.14) of F_1 hybrid was higher compared to susceptible strain (Table 1).

Intrinsic rate of increase (*r*) showed similar trend as R_0 (Table 1). The *r* values for the Cry1Ac resistant *H. armigera* on the two diets (Cry1Ac incorporated and untreated diet) were >0, ranging from 0.095-0.160. The resistant strain showed reduced *r* values compared to susceptible strain on untreated diet, possibly indicating association of fitness costs with Cry1Ac-resistance (Table 1). Mean generation time (T) for all the strains on two diets ranged from 33.07 to 47.18 days. Comparison among strains on untreated diet, showed that resistant strain and F_1 hybrid took longer days than susceptible strain to complete generation; resistant strain completed in 46.94 days in F_3 generation, 38.11 days in F_4 generation and 39.39 days in F_5 generation.

Larval and pupal weight: The mean weight gained during development by larvae and pupae of resistant, susceptible and F_1 hybrid during three generations on two diets is given in Table 2. Significant larval weight differences existed between susceptible, resistant and F_1 hybrid in all the larval instars on two diets tested. Resistant and F_1 heterozygotes gained least weight on both Cry1Ac and untreated diets. Resistant strain larvae were smaller and weighed 37.35mg compared to susceptible strain (118.05mg) on untreated diet. Weight during third instar differed significantly between resistant and susceptible strain on untreated diet. Resistant strain weighed 1.82-3.97 times less compared to susceptible strain on untreated diet, indicating possible association of fitness costs. Similar trend was observed during 4th and 5th larval instars, wherein resistant larvae weighed significantly less compared to susceptible strain. F_1 hybrid also showed similar trend as resistant strain, larvae gained 1.17-5.45 times less weight compared to susceptible strain. In pre-pupal and pupal stages similar trend was observed when comparing between the three

Table 1. Net reproduction, rate of increase and generation time-strains and their F_1 hybrid of *H. armigera* (treated & untreated diets)

Parameters	F_3 generation		F_4 generation		F_5 generation		
	Susceptible	Resistant	Susceptible	Resistant	F_1 hybrid	Susceptible	Resistant
Net reproduction rate (R_0)	181.45	89.68	191.66	58.77	218.22	135.03	80.82
Intrinsic rate of natural increase (r_m)	0.112	0.095	0.160	0.141	0.141	0.124	0.128
Mean generation time (T_c)	46.50	47.18	33.07	38.39	39.33	34.34	39.57
Corrected mean generation time (T) in days	46.28	46.94	32.78	38.11	38.11	34.11	39.39

strains on untreated diet. Pre-pupal and pupal weights of resistant and F_1 hybrid differed significantly from susceptible strain (Table 2).

Developmental time: In all three generations susceptible strain resulted in 100% mortality when released on diet containing Cry1Ac, however, a small proportion of F_1 hybrid were able to survive upto 4th instar. The average time to pupation in the susceptible strain on untreated diet was 14.55 days. The larval duration in F_1 hybrid was 15.40 days. Resistant strain showed a significant increase in larval duration on untreated diet compared to susceptible strain. In F_3 generation, resistant strain required two additional days on the untreated diet, and four days in F_4 and three additional days in F_5 generation on untreated diet. This increase in larval duration in resistant strain compared with susceptible strain on untreated diet may be due to presence of fitness cost. Pupal duration did not vary much among the strains on treated and untreated diets. No significant difference was observed between the strains on both the diets. All the three strains took 8.73-9.22 days for adult emergence (Table 2).

Larval mortality: Susceptible strain and F_1 heterozygotes showed 100% mortality on Cry1Ac diet and only resistant strain was able to survive and complete larval period on a Cry1Ac diet. Furthermore, high larval mortality was recorded in resistant strain on a Cry1Ac diet (30-38.75%) and mortality did not differ on a non-Bt diet between resistant strain and susceptible strain during F_3 and F_5 generation. Whereas, resistant strain showed significantly higher mortality (25.00%) compared to susceptible strain (7.38%) on untreated diet during F_4 generation. F_1 hybrid showed 5.50% mortality on untreated diet (Table 2).

Malformed pupae: Malformation in the larvae entering to pupal stage when observed with the three strains on both the diets, significantly more

Table 2. Larval and pupal weights, duration and mortality in strains and their F_1 hybrid of *H. armigera* (treated & untreated diets)

Life history parameters	Generation	Susceptible strain	Resistant Strain		F_1 hybrid
		Untreated Diet (n =20)	Untreated Diet (n =20)	Cry1Ac-diet (n =20)	Untreated Diet (n =20)
3rd instar larval weight (mg)	F_3	118.05±6.00^{a}	37.35±3.41^{bc}	27.00±3.13^{c}	NA
	F_4	115.45±7.13^{a}	34.15±1.95^{b}	27.6±2.00^{cd}	24.85±1.83^{d}
	F_5	113.50±4.19^{a}	35.90±1.24^{b}	27.95±2.92^{c}	NA
4th instar larval weight (mg)	F_3	303.25±5.80^{a}	181.05±9.76^{b}	134.90±7.84^{c}	NA
	F_4	328.35±3.90^{a}	150.85±4.29^{c}	135.60±6.73^{d}	164.20±6.29^{b}
	F_5	317.90±4.51^{a}	178.60±5.29^{b}	133.70±4.91^{c}	NA
5th instar larval weight (mg)	F_3	406.50±6.86^{a}	271.70±7.50^{b}	201.20±3.14^{b}	NA
	F_4	409.05±6.82^{a}	279.80±8.10^{c}	267.41±4.86^{d}	283.05±7.99^{b}
	F_5	382.20±5.09^{a}	281.40±4.89^{b}	277.00±3.84^{c}	NA
Larval duration (days)	F_3	15.05±0.15^{a}	17.20±0.26^{c}	20.05±0.20^{b}	NA
	F_4	14.05±0.20^{a}	18.40±0.11^{c}	19.40±0.11^{d}	15.40±0.11^{b}
	F_5	14.55±0.11^{a}	17.60±0.28^{b}	18.35±0.34^{b}	NA
Larval mortality (%)	F_3	12.63±0.95^{a}	12.88±1.01^{a}	37.38±1.04^{b}	NA
	F_4	7.38±1.64^{a}	25.00±1.16^{c}	38.75±4.79^{b}	5.50±0.46^{d}
	F_5	17.70±1.20^{a}	17.38±0.83^{ac}	30.00±1.57^{b}	NA
Pre-Pupal weights (mg)	F_3	376.00±7.26^{a}	297.50±9.84^{b}	251.70±3.29^{a}	NA
	F_4	363.00±9.60^{a}	292.75±8.19^{b}	262.65±5.26^{c}	294.00±4.71^{b}
	F_5	373.50±7.85^{a}	285.31±8.83^{a}	270.55±4.36^{a}	NA
Pupal weights (mg)	F_3	297.60±4.49^{c}	305.65±9.41^{b}	320.30±3.22^{a}	NA
	F_4	343.35±7.69^{a}	262.05±10.58^{c}	317.50±4.32^{bd}	321.25±7.48^{d}
	F_5	303.30±5.23^{a}	300.75±4.80^{ac}	315.10±7.59^{b}	NA
Pupal duration (days)	F_3	10.35±0.29^{a}	13.15±0.20^{c}	10.90±0.14^{a}	NA
	F_4	6.50±0.11^{a}	6.60±0.13^{ab}	7.00±0.23^{ab}	9.30±0.15^{c}
	F_5	7.35±0.26^{a}	8.90±0.20^{a}	8.85±0.26^{a}	NA
Malformed Pupa (%)	F_3	0.00±0.00^{a}	22.53±1.88^{c}	12.00±0.00^{b}	NA
	F_4	0.00±0.00^{a}	20.00±0.28^{c}	15.08±0.38^{b}	10.00±0.45^{d}
	F_5	4.96±0.14^{a}	22.38±0.45^{b}	5.00±0.22^{a}	NA

malformation was noticed in resistant and F_1 hybrid. Highest malformed pupae were noticed in resistant strain on untreated and treated diets in F_3, F_4 and F_5 generation (5- 22.53%) and F_1 hybrid recorded 10% malformed pupae compared to susceptible strain.

From the present study of fitness parameters of susceptible and resistant strains, and their F_1 hybrids, it was apparent that some lifehistory parameters viz., larval weights, larval duration, pre-pupal weights and malformed pupae have significant differences. This reveals the fitness costs associated with resistance gene. Significantly lower weight gain was noticed in resistant strain when reared on toxin free diet (untreated diet) compared to susceptible strain that gained higher weight at 3rd instar, at 4th instar, and at 5th instar. Significant difference in larval duration as depicted in Table 2 reveal that susceptible strain developed in 14.5 days from larva into pupa compared to the 17.26 days (17.84% longer) for resistant strain when reared on untreated diet. However, the trend shows the reduction in larval duration of resistant strain on Cry1Ac toxin diet over the generations. Cry proteins have unanticipated nutritionally favourable effects that might have increased fitness of resistance strain on Cry diet (Sayyed et al., 2003).

A higher % of malformed pupae were noticed in resistant strain developed on untreated diet, whereas, resistant strain developed on Cry1Ac toxin diet recorded less malformed pupae. This could be due to elimination of individuals that are less fit on Cry1Ac toxin diet, as evidenced by prolonged larval stages and death of such individuals in late instars and mortality of resistant individuals due to accumulation of deleterious mutations in the absence of selection (Vassilieva et al., 2000). Similar comparisons had been shown between resistant and susceptible strain in terms of life history parameters by other workers who reported delayed larval development in resistant strain by 4.7 days on non-Bt cotton, 1.5 days on sorghum and no delay on pigeon pea compared to susceptible strain (Lisa and Akhurst, 2004), apart from increased larval mortality, lower larval weights, lower pupal weight, longer pupal duration and high pupal mortality (Liu et al., 1999., Carriére et al., 2001 and Storer et al., 2001), high per cent of abnormal adults were also recorded in resistant strain when reared on toxin free diet compared to susceptible strain (Janmaat and Myers, 2005., Carrière et al., 2006., Gassmann et al., 2009 and Anilkumar et al., 2008).

Net replacement rate reduced drastically in resistance strain developed on untreated diet, compared to susceptible strain during three generations. The delay in the development time during larval period and delayed adult eclosion in resistant strain has resulted in reduced intrinsic rate of increase (r_m) (Lewontin, 1965). As a result, r_m for resistant strain was 15.96% lower during F_3 generation, 12.59% lower during F4 generation compared to susceptible strain on toxin free diet. Whereas, the r_m for resistant strain increased by 3.37% during F_5 generation compared to susceptible strain. The r_m for heterozygotes was 12.59% lower than the susceptible strain on toxin free diet.

Fitness costs to Bt resistance is known in many targeted pests of Bt crops viz., *H. armigera* (Hübner) (Lisa and Akhurst, 2004, 2005 and Guangchun et al., 2014), *Helicoverpa zea* (Boddie) (Anilkumar et al., 2008), *Pectinophora gossypiella* (Saunders) (Carriere et al., 2006), *Plutella xylostella* (L.) (Raymond et al., 2011), *Plodia interpunctella* (Hübner) (Oppert et al., 2000). *Chrysomela tremulae* F. (Wenes et al., 2006), *Diatraea saccharlis* (F.) (Wu et al., 2007), *Ostrinia nubilalis* (Hübner) (Andre et al., 2010), *Trichoplusia ni* (Hübner) (Alida and Judith, 2011) and *Anticarsia gemmatalis* Hübner (Gomez and Miranda, 2012). However, in other studies significant fitness costs were not associated with Bt resistance and no differences in survival or larval weight were found between resistant and susceptible, *Heliothis virescens* in the absence of Bt (Gould and Anderson, 1991). The Cry1Ab resistant and susceptible *D. saccharalis* had similar larval growth, development and pupal weights when not exposed to the Bt toxin (Wu et al., 2009), suggesting the lack of major fitness costs associated with Bt resistance.

The fitness of heterozygotes in refuge crops is key determinant factor that impacts strongly on the early dynamics of resistance evolution (Roush, 1997) and the potential for delays in resistance evolution increases as the magnitude and dominance of fitness costs increases (Carrière and Tabashnik, 2001). The resistant individuals show lower fitness than susceptible individuals when fitness costs are recessive but fitness of heterozygotes do not differ with susceptible, whereas, when fitness costs are dominant both resistant and the heterozygote (F_1) insects display lower fitness in the absence of toxin than the susceptible insects, which favours a decline in frequency of resistance alleles in the refuge crops (Gassmann et al., 2009). The success of refuges in resistance management depends on ability to produce large numbers of susceptible individuals over a long period (Roush, 1997), mating compatibility between resistant and

susceptible individuals (Tabashnik, 1994) and development synchrony between resistant and susceptible insects favouring mating among them. The temporal separation caused due to developmental asynchrony between resistant and susceptible insects might threaten the very concept of refuge strategy (Liu et al., 1999). From the present study similar developmental delay was noticed in resistant strain which could contribute to mating asynchrony. However, this effect may not pose problem as *H. armigera* is multigenerational pest and overlapping generations may nullify the effect (Wu et al., 2002) and might aid in effective dilution of resistant alleles.

Reducing the heritability of resistance by manipulating the concentration of Bt toxins and the distribution of host plants with and without Bt toxins has been the main focus of resistance management strategies (Gould 1998., Carrie‘re et al., 2004 and Tabashnik et al., 2004). A reduction in fitness of resistant individuals has been implicated as possible reason for decline in the frequency of resistance to insecticides in *H. armigera* (Daly and Fisk, 1995) and *P. gossypiella* (Tabashnik et al., 2003). Many models have predicted the delay in resistance development due to fitness costs (Caprio 2001., Storer et al. 2003 and Gustafson et al., 2006). Similar reports in laboratory-selected Cry1Ac-resistant insects such as *P. gossypiella*, *H. armigera*, and *P. xylostella* support these model predictions by documenting fitness costs and incomplete resistance to Bt crops (Liu et al., 1999., Carrie´re et al., 2006., Lisa and Akhurst, 2005 and Higginson et al. 2005). From the present investigation, the fitness costs associated with resistant strain has demonstrated the potential to reduce population growth of both resistant and heterozygotes in Cry1Ac and toxin free diets which might aid in reduction of resistance alleles.

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FIELD BIOLOGY AND SEM STUDY OF SUGARCANE WOOLY APHID, *CERATOVACUNA LANIGERA* ZEHNTNER

CHERALU, N., T.V.K. SINGH* AND VINOD S. KUKANUR

Department of Entomology, College of Agriculture, Prof. Jayashankar Telangana State Agricultural University, Hyderabad 500030
**Emeritus Scientist, ICAR*
**Email: prof.tvksingh@yahoo.com (corresponding author)*

ABSTRACT

Field biology, morphometrics and SEM study of body parts of sugarcane woolly aphid, *Ceratovacuna lanigerum* Zehntner are included in this study. Twenty morphological characters were measured. The line diagrams of body, head, abdomen, the arrangement of antennae, rhinaria, wax glands, wax gland plates, spiracles, subanal plate, cauda, frontal horns, wing venation of forewing and hindwing are given. The data on the field biology reveal that the aphid lifecycle is completed in 20 days with four moults, and it reproduces parthenogenetically, and exhibit morphological variations.

Key words: *Ceratovacuna lanigera*, field biology, apterae, alatae, adults, morphometrics, body parts, line diagrams, SEM images

Sugarcane is attacked by about 288 species of insects and other pests (James and Leslie, 2007). Among these, aphid species cause heavy losses in terms of quantity and quality. As many as 17 species are associated, of which seven belong to subfamily Aphidinae; five to Pemphiginae; two to Drepanosiphinae and three to Hormaphidinae (Raychaudhuri, 1984). Among the three hormaphidine species, *Ceratovacuna lanigera* Zehntner is the most notorious, as it is a serious pest of cane in Eastern states viz., Assam and Nagaland (Tripathi, 1995). Apart from sugarcane, it is also reported to feed on plants belonging to family Poaceae, Bixaceae and Combretaceae (Joshi and Viraktamath, 2004). During past *C. lanigera* caused heavy yield losses and threatened the sugarcane cultivation and sugar industry in Maharashtra and Karnataka (Chakravarthy and Thyagaraj 2005). Though the pest was reported as early as 1958 from Cooch Behar, West Bengal (Basu and Banerjee, 1958), it gained more attention during 2004 due to its severe incidence and outbreak in the southern states. It is a sap feeder, suck the sap from phloem tissues and excrete honey dew onto foliage leading to the development of sooty mould. The infestation reduces the sugar quality and yield.

Members of Aphididae are much diverse who exhibit a high degree of host specificity except for the few polyphagous and show adaptations in relation to host plants (Blackman and Eastop, 2000). Many aphid taxa have a biological complexity in their life cycle which develops several distinct morphs during their lifecycle making their identification difficult (Dohlen et al., 2005). The members within the genus *Ceratovacuna* are difficult to identify because of their reduced morphology, wooly matter and also their association with different host plants. The literature pertaining to its morphology is inadequate and morphometrics on populations from India not available. The aim of this work is to study morphometrics using electron microscope and determine the stadial period of each instar of *C. lanigera*.

MATERIALS AND METHODS

Lifecycle: The samples of *C. lanigera* were drawn from farmer's field surveyed in and around Sangareddy, Medak district in Telangana and released on sugarcane plants maintained under shade net in College Farm, University campus (Lat: 17.32049897; Lon: 78.42089832). Plants were maintained under shade net to provide a congenial environment for quick multiplication and protection from natural enemies. Lifecycle studies began with the release of five pairs of flocculent apterous viviparous females/leaf and such five releases were made on five plants as a replication. Females after release settled along the ventral surface of the leaf along the midrib. A day after the release, observations were made at every 12 hrs till the completion of the final instar. The observations on larval

instars, duration, reproductive period, young ones produced by each female and fecundity were made. A total of eight lifecycles in the field were studied and means worked out and presented.

Morphometrics: The population samples drawn from the fields were utilized. Various nymphal instars along with alate and apterous adults were collected and preserved in 70% alcohol (Radke et al., 1972). All the stages were cleaned with xylol and mounted in Canada balsam on microscopic slides (Heikinheimo, 1983). Later these were identified based on the character described by Ghosh (1988) and Patil (2002). The characters scored are given in Table 1. All measurements were made using a phase contrast microscope fitted with a calibrated micrometer eyepiece. The figures of body, head, abdomen, antennae, rhinaria, wax glands, wax gland plates, legs, siphunculi, subanal plate, caudal, dorsal sclerotization on the abdomen of alate adults, frontal horns, wing venation were drawn using camera lucida from the same slides which were used for morphometrics. The measurements of ten insects with respect to each character were recorded and mean values and the standard deviation (SD) (Radke et al., 1972) depicted in Table 2 and 3. For measurements of taxonomically important body parts Radke et al. (1972) and Ghosh (1988) were followed.

Studies using scanning electron microscopy: Electron microscopic photographs of different instars and adults (alate and apterous) were taken. The slides were prepared by mounting different stages over the stubs using double-sided carbon tape and fixed by treating with four per cent aqueous osmium tetraoxide vapours. Finally, a thin layer of the platform (palladium) metal was applied to the sample slide using an automated sputter coater (JOEL JFC-1600) for about two min (Bozzola and Russell, 1985). The samples were then scanned under scanning electron microscope (Make: JEOL-JSM 5600) at various magnifications at RUSKA Labs, Sri P.V. Narasimha Rao Telangana State University for Veterinary, Animal and Fishery Sciences, Rajendranagar, Hyderabad.

RESULTS AND DISCUSSION

Lifecycle

From 25 apterous viviparous females released/leaf, on an average 59% females (range 13-17) established and started the colony (Table 1). A day after females established on a leaf near midrib, these started producing the nymphs. There were four nymphal (Fig 1, a-d) instars (Shankar and Shitole, 2004); apterous females reproduced parthenogeneti-cally giving birth directly to nymphs (Joshi and Viraktamath, 2004). The nymphs were observed to emerge early in the morning and fecundity of females ranged from 20.50- 43.00 with an average of 30.01± 9.7/female (mean ± SE). Further nymphs produced/female/day ranged from 1.10-2.00 (1.68±0.64). No female produced >4 nymphs/ day, with all nymphs being developing into females.

The first instar (Fig 1a): Very active and found to move fast on the leaf surface when exposed to sunlight, and yellowish/greenish yellow; lasted 4.20 ± 0.44 to 5.75 ± 0.50 days (5.20 ± 0.51), decreased with an increase in the temperature. Second instar (Fig 1b): Less active and settled on a leaf near midrib, turned from yellowish to brownish with black marking on the body; duration varied from 4.10 ± 0.43 to 4.75± 0.50 days (4.49 ± 0.23). Third instar (Fig 1c): Sedentary, partially covered with white wooly filaments, filaments dense at the posterior end of the abdomen and covered only up to thorax; these filaments were very soft, dry, non-polar and hydrophobic; duration 4.10 ± 0.45 days to 5.25 ± 0.50 days (4.56 ± 0.38); Fourth instar (Fig 1d): body completely covered with wooly filaments including head; duration was between 4.30 ± 0.45 days to 5.50 ± 0.57 days. Fecundity ranged between 18.59 to 43.00/female, with lifecycle completed in 19.11±1.3 days (Table 1). Shankar and Shitole (2004) also reported the nymphal duration of around 20 days.

Morphometrics

Adult females from field samples were measured and details are as follows:

Apterous females: Body length ranged from 2.10-2.50 mm, and width from 0.78-0.88 mm (across thorax) and 0.96-1.50 mm (across abdomen); head and pronotum distinctly pale brown, and 0.62±0.07 mm wide; dorsal cephalic hairs fine and acute at apices, less than ten anterior to the level of eyes; frontal horns acute, 0.07 to 0.09 mm long, divergent, bearing 6-10 very short hairs. Antennae five segmented, usually pale brown with apical segments darker, total length ranged between 0.32-0.37 mm; mean length of the I, II, III, IV and V segments were 0.024, 0.046, 0.118, 0.044 and 0.106 mm, respectively; flagellum gradually more distinctly imbricated, with imbrications often spinulose apical; primary rhinaria present on all the five antennal segments which are round and protuberant.

Table 1. Lifecycle of sugarcane wooly aphid (field population)

No. of life cycle	No. of insects released	No. of insects established	Total No. of young ones produced/ female	Ave. No. of young ones produced/ day	Max. No. of young ones produced/ day/ female	Duration of different instars (days)				Total duration (days)
						I	II	III	IV	
1st	25	15	43.00	2.00	4	5.75±0.50	4.75±0.50	5.25±0.50	5.50±0.57	21.25
2nd	25	17	33.00	1.70	3	5.50±0.57	4.75±0.50	4.75±0.50	5.25±0.50	20.25
3rd	25	14	26.03	1.40	3	5.57±0.78	4.57±0.53	4.85±0.37	5.00±0.81	19.56
4th	25	13	37.00	1.75	3	5.50±0.57	4.25±0.50	4.50±0.57	5.00±0.81	19.25
5th	25	16	41.00	2.20	3	5.20±0.44	4.40±0.54	4.60±0.54	4.80±0.44	19.00
6th	25	15	21.00	1.14	2	5.20±0.83	4.60±0.54	4.20±0.44	4.80±0.44	18.80
7th	25	15	20.50	1.20	3	4.75±0.50	4.50±0.57	4.25±0.50	4.50±0.57	18.00
8th	25	13	18.59	1.10	3	4.20±0.44	4.10±0.43	4.10±0.45	4.30±0.45	16.90
Average			30.01±9.74	1.68±0.64	3.00±0.53	5.20±0.51	4.49±0.23	4.56±0.38	4.89±0.38	19.11±1.35

*Mean of five replications

Table 2. Morphometrics of females of sugarcane woolly aphid

Character No.	Character		Apterous viviparus female*		Alate viviparus female*	
			Range (mm)	Mean ± SD	Range (mm)	Mean ± SD
1.	Body length		2.10-2.50	2.200 ± 0.040	2.30-2.60	2.30 ± 0.03
2.	Body width	Across thorax	0.78 – 0.88	0.810 ± 0.030	0.87-1.04	1.015 ± 0.03
3.		Across abdomen	0.96 – 1.50	1.030 ± 0.050	0.90-1.28	1.21± 0.04
4.	Frontal horns		0.07 – 0.09	0.080 ± 0.007	NA	NA
5.	Antennal segments	I	0.02 – 0.03	0.080 ± 0.007	NA	NA
6.		II	0.04 – 0.05	0.024 ± 0.005	NA	NA
7.		III	0.04 – 0.05	0.118 ± 0.017	0.30-0.35	0.32 ± 0.01
8.		IV	0.10 – 0.14	0.044 ± 0.005	0.14- 0.17	0.16 ± 0.01
9.		V	0.10 – 0.11	0.106 ± 0.005	0.13-0.17	0.15 ± 0.01
10.	Antenna (total)		0.32 – 0.37	0.338 ± 0.024	0.62-0.67	0.64 ± 0.01
11.	No. of rhinaria on	III	NA	NA	20-22	21 ± 1.09
12.		IV	NA	NA	6-8	7 ± 0.70
13.		V	NA	NA	4-5	5 ± 2.14
14.	Head		0.52 – 0.72	0.62 ± 0.07	0.60-0.67	0.63 ± 0.02
15.	Legs	I	1.12 – 1.20	1.14 ± 0.03	1.2-1.44	1.28 ± 0.09
16.		II	1.16 – 1.21	1.17 ± 0.01	1.52-1.60	1.53 ± 0.03
17.		III	1.15 – 1.40	1.29 ± 0.09	1.84-1.92	1.88 ± 0.02
18.	Cauda		0.56 – 0.62	0.59 ± 0.02	0.54-0.62	0.58 ± 0.03
19.	Forewing	Length	-	-	3.20-3.50	3.28 ± 0.19
20.		Width	-	-	1.40-1.48	1.45 ± 0.03

*n=10; NA: not attempted.

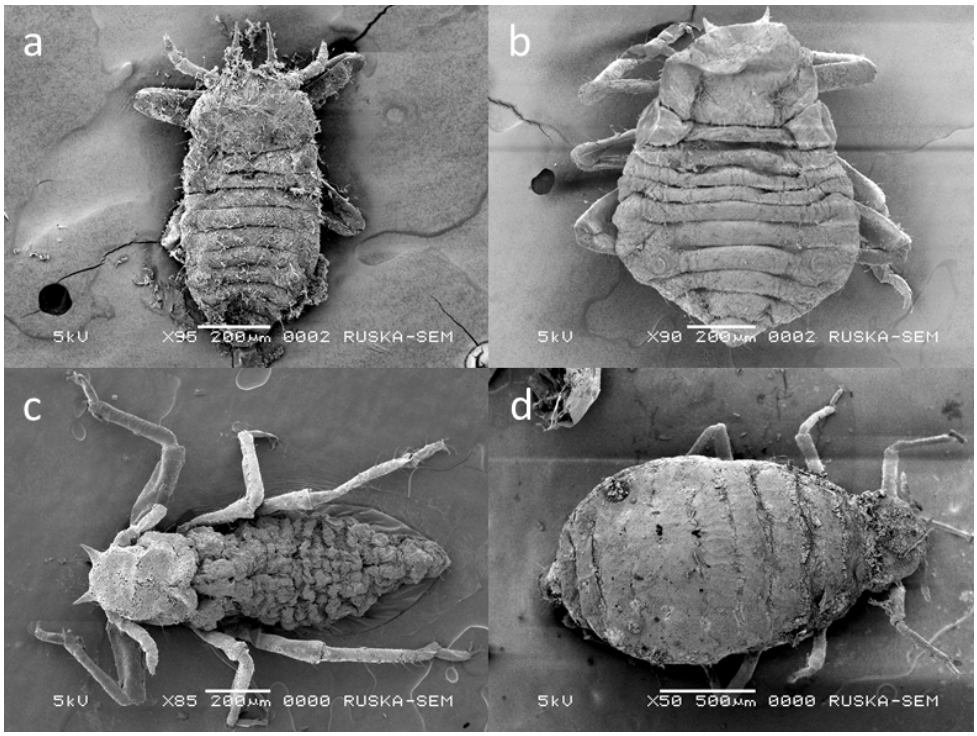

Fig. 1. SEM images of larval instars of sugarcane wooly aphid: a. first, b. second, c. third and d. fourth

Table 3. Morphometrics of instars of sugarcane wooly aphid

Character No.	Character		Instars* I		II		III		IV	
			Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
1.	Body length		0.76-0.89	0.81±0.05	0.89-1.00	0.95±0.04	1.07-1.26	1.17±0.07	1.76-2.11	1.95±0.14
2.	Body width	-Across thorax	NA	NA	NA	NA	NA	NA	0.76-0.88	0.80±0.04
3.		- Across abdomen	0.27-0.38	0.33±0.01	0.30-0.46	0.46±0.03	0.62-1.07	0.75±0.02	0.96-1.12	1.07±0.06
4.	Frontal horns		0.12-0.16	0.14±0.02	0.12-0.15	0.15±0.01	0.08-0.11	0.09±0.01	0.08-0.09	0.09±0.01
10.	Antenna		0.19-0.24	0.21±0.02	0.20-0.24	0.22±0.01	0.22-0.25	0.23±0.01	0.27-0.33	0.30±0.02
14.	Head		0.22-0.32	0.27±0.04	0.32-0.38	0.34±0.02	0.46-0.52	0.49±0.02	0.48-0.56	0.52±0.04
15.	Legs	I	0.52-0.57	0.55±0.02	0.56-0.62	0.60±0.02	0.63-0.67	0.64±0.01	0.67-0.73	0.70±0.02
16.		II	0.54-0.59	0.56±0.02	0.63-0.72	0.66±0.03	0.67-0.78	0.72±0.04	0.81-0.91	0.84±0.05
17.		III	0.64-0.75	0.69±0.04	0.72-0.78	0.74±0.02	0.80-0.88	0.83±0.03	0.89-0.97	0.93±0.03
18.	Cauda		0.16-0.19	0.17±0.01	0.24-0.33	0.29±0.03	0.43-0.49	0.47±0.02	0.48-0.54	0.50±0.02

* All in mm; n=10; NA: not attempted.

Apterous adult possess crenulated margins of wax glands arranged in a row up to the seventh and eighth tergites. Abdominal dorsum pale, bearing some fine irregular sculpturing. Wax glands are present laterally at meso and meta-notum and are almost always present on 1st- 7th tergites; when fully developed composed of two to six round or irregularly shaped cells; and 8th tergite with a median wax gland on the pale brown spinopleural area. Siphunculi with slightly elevated cones, usually with a sclerotic rim and is surrounded by a few hairs. Mean caudal width ranged from 0.56-0.62 mm, bearing 11-12 hairs including two long and two thick hairs. The subanal plate is bilobed. All the three pairs of legs smooth, pale brown, possessing long and fine hairs; longest hairs were observed on hind tibiae. The length of the first, second and third pair of legs are 1.14, 1.17 and 1.29 mm, respectively. First tarsal chaetotaxy (f.t.c) is 4, 3, 2 hairs, and occurrence of dorso apical hairs on second tarsal segment expanded at apices (Fig. 2.).

Alate females: Body length ranged from 2.30-2.60 mm long with width ranging 0.87-1.04 (across thorax) and 0.90-1.28 mm (across abdomen). Head brownish black on anterior portion and darker on posterior portion. Dorsal cephalic hairs fine. The mean head width ranged from 0.62-0.67 mm. Frontal horns were short and much reduced. Antennae five segmented, with total length 0.64 ± 0.01 mm. Spinulose imbrications on segment III, hairs on the flagellum were fine and sparse, III antennal segment with 20-22 and IV with 6-8 and V 4-5 annular secondary rhinaria was noticed. Abdominal dorsum pale, bearing a transverse sclerotic bands on 6th, 7th and 8th tergites. The length of fore wing ranged from 3.20 to

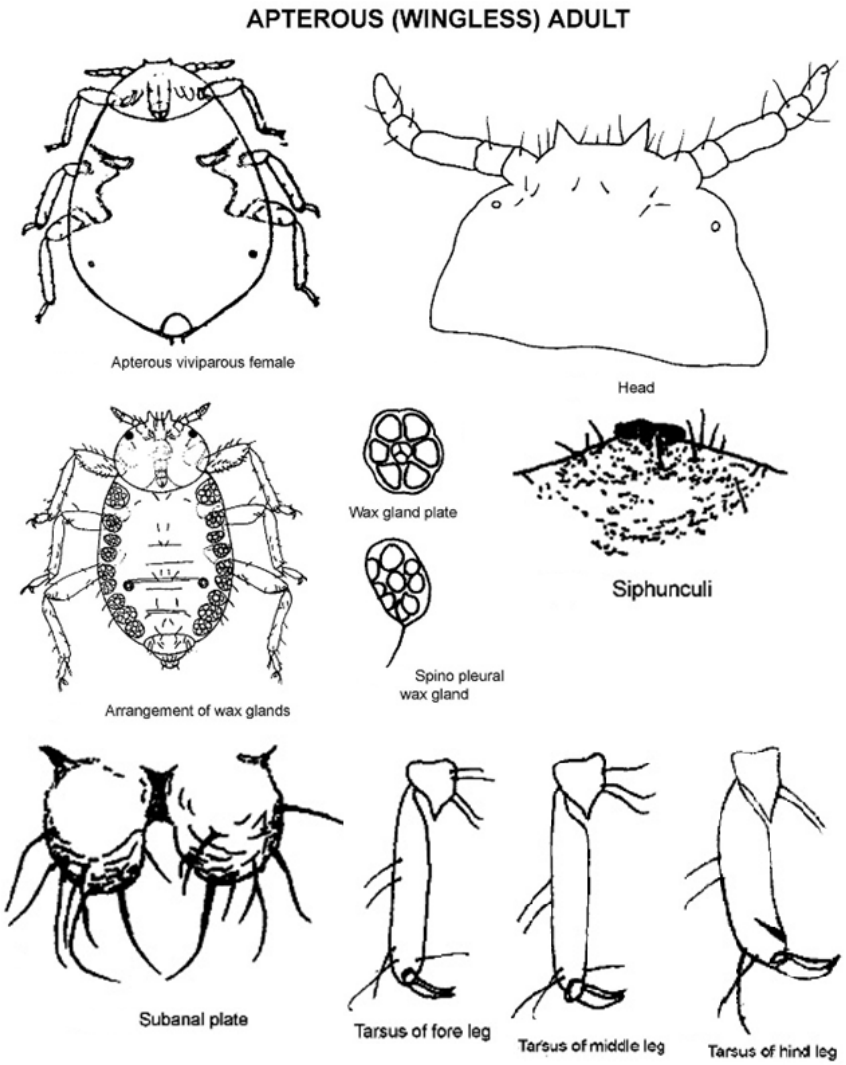

Fig. 2. Apterous adult and body parts of sugarcane wooly aphid

3.50 mm and width ranged 1.40-1.48 mm. Wing venation was normal (Fig. 3).

Forewings venation consist of two longitudinal veins, one; costa (C) which is a weak vein running along the frontal edge of the wing and the second; strong main vein (SC+R+M+Cu) which runs just behind the coxa formed by the fusion of subcosta (SC), radius (R) and the basal parts of the media (M) and cubitus (Cu); both veins run apically into the pterostigma; cubitus has two branches Cu_{1a} and Cu_{1b} which have a common base; two branches separate and appear as two veins running independently from the main vein; median is branched twice. From the pterostigma arises a short vein, the radial sector (RS) which runs towards the wing apex. The venation of hind wing consists of a longitudinal vein, and two oblique veins, which are usually separated from each other. Cauda semioval with many long hairs measuring 0.54-0.62 mm. Femoral pale of legs are brown near base, rest dark brown. The mean length of the I, II and III pair of legs are 1.28, 1.53 and 1.88 mm, respectively (Fig 3.).

Nymphs: First instar 0.81 ± 0.05 mm long and 0.33 ± 0.01 mm wode (Table 3). Head is fused with prothorax, and its width ranged from 0.22-0.32 mm; dorsal cephalic hairs were fine; frontal horns divergent, acute at apex, and 0.14 ± 0.02 mm long. Antennae were 4-segmented, and 0.21±0.02 mm long; segment I, II and IV each with single fine hair while segment III with two similar hairs. Abdominal dorsum pale, dorsal hairs fine and acute, always long on posterior tergites. Siphunculi pore like with thick rims. Cauda with 2 long hairs, and measured upto 0.17±0.01 mm in length. legs pale bearing many fine hairs on femora and tibiae. First tarsal chaetotaxy (f.t.c) is 3, 3, 2 hairs, which are fine. The mean length of I, II and III pair of legs is 0.55 ± 0.02, 0.56 ± 0.02 and 0.69 ± 0.04 mm, respectively. Dorso apical hairs on second tarsal segments were distinctly expanded at apices (Fig. 4).

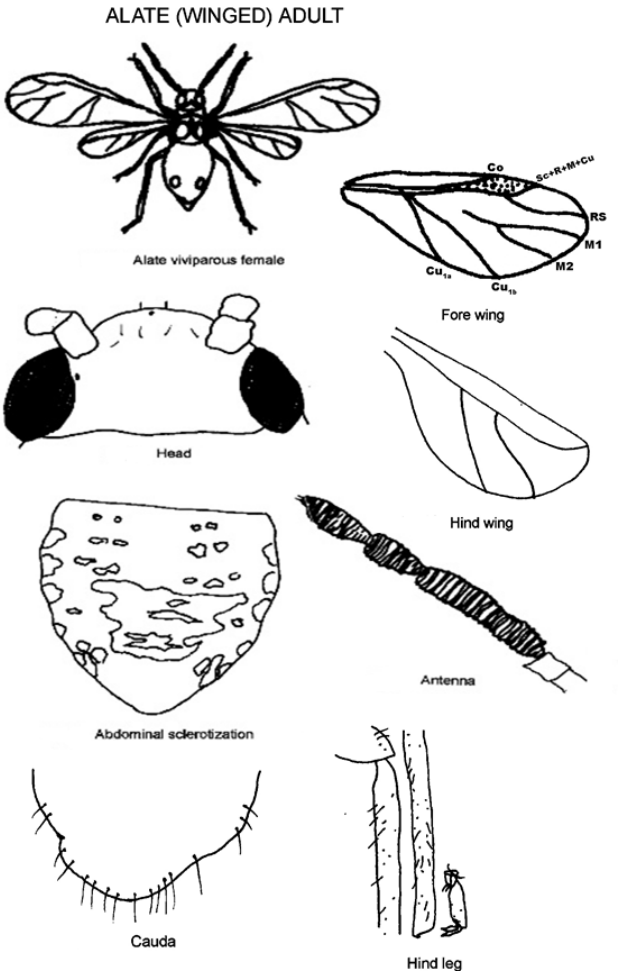

Fig. 3. Line diagram of SWA Alate (winged) adult and its body parts

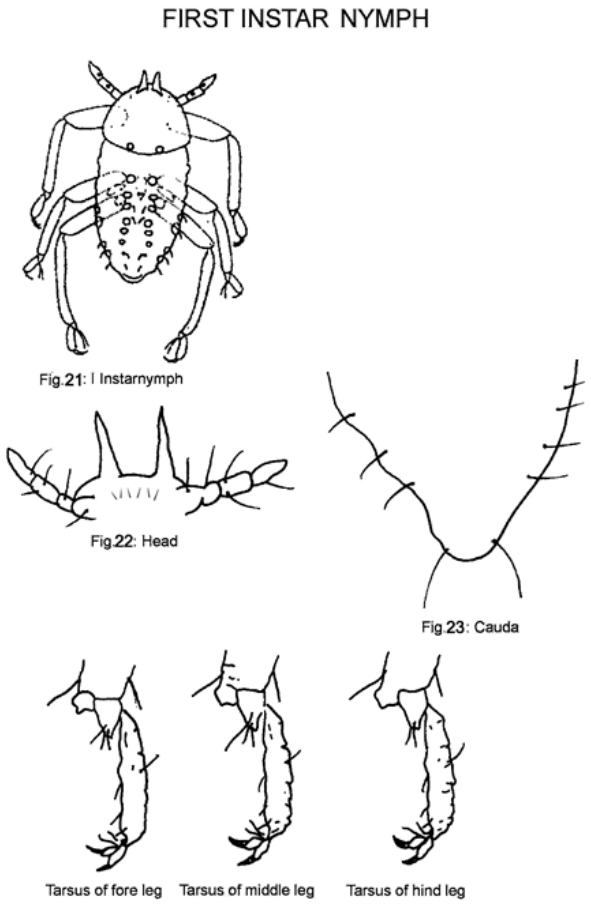

Fig. 4. Line diagram of SWA first instar nymph and its body parts

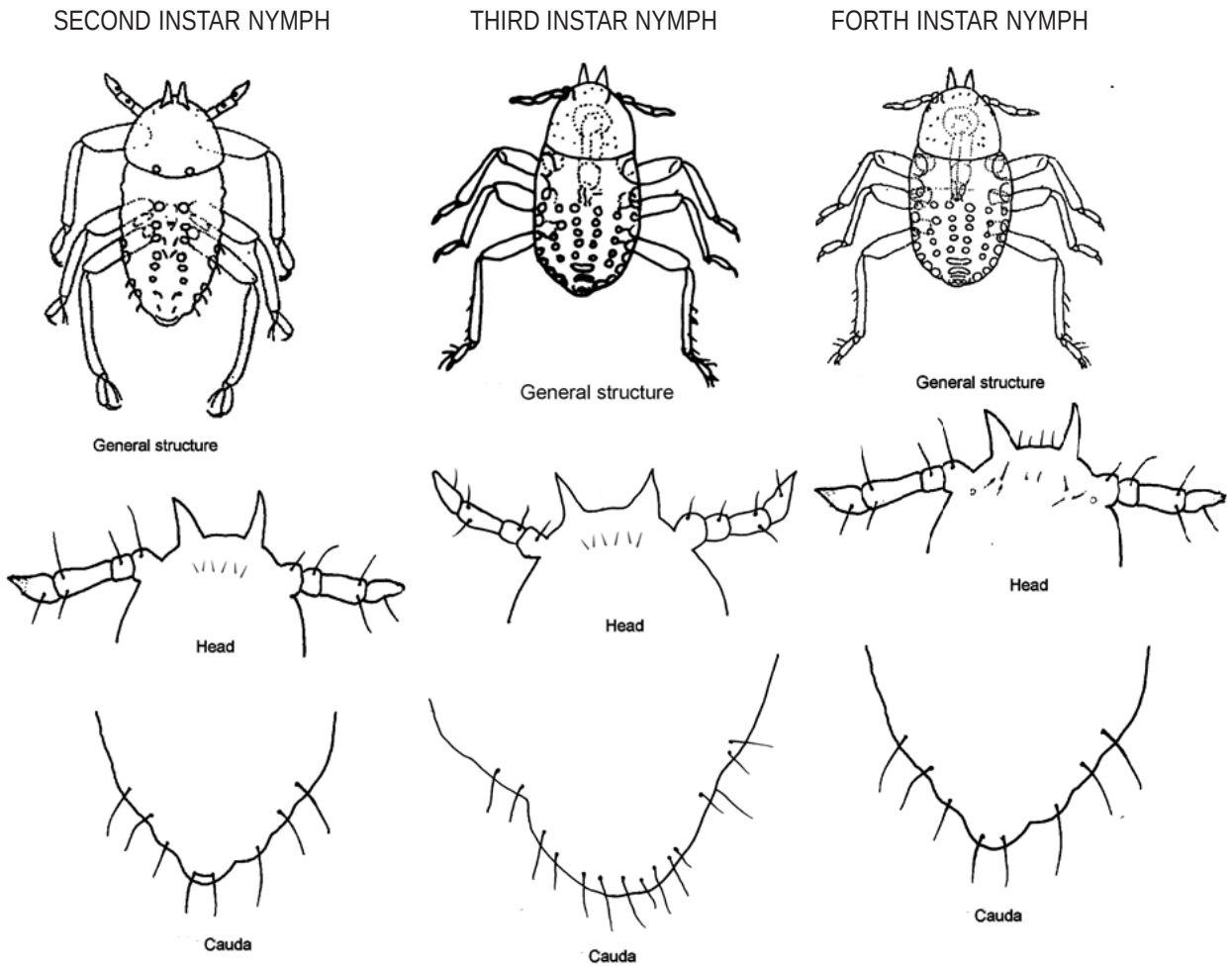

Fig. 5. Line diagram of SWA second, third and fourth instar nymphs and body parts

Second instar measured 0.95 ± 0.04 mm long and 0.46±0.03 mm wide. Head is fused with prothorax, with width of 0.34±0.02 mm. Frontal horns divergent measuring 0.15±0.01 mm. Antenna is four-segmented, with mean length of 0.22±0.01 mm; segment I, II and IV have one fine hair while segment III have two fine hairs. Caudal width ranged from 0.24 to 0.33 mm (Fig 5.).The mean length of the I, II and III pair of legs is 0.60 ± 0.02, 0.66 ± 0.03 and 0.74 ± 0.02 mm, respectively (Table 3).

Third instar measured 1.17±0.07 mm long and 0.75±0.02 mm wide. Head fused with prothorax; frontal horns short measuring about 0.09±0.01 mm; width ranged from 0.46-0.52 mm; with hair arrangement similar to second instar with I, II and IV antennal segment bearing one single fine hair and segment III with two fine hairs; mean antennal length measured 0.23±0.01 mm. The length of the I, II and III pair of legs is 0.64 ± 0.01, 0.72 ± 0.04 and 0.83 ± 0.03 mm, respectively. Cauda is oval with many long hairs (Fig 5.) and width ranged from 0.43-0.49 mm with a mean of 0.47±0.02 (Table 3).

Fourth instar was 1.95±0.14 mm long and 0.80±0.04 (across thorax) mm and 1.07±0.06 mm wide (across abdomen). Head and pronotum fused; frontal horns short measuring about 0.09±0.01 mm; width of the head ranged between 0.48-0.56 mm. Antenna four segmented with mean length of 0.30±0.02 mm; I, II and III pair of legs measured 0.70±0.02, 0.84±0.05, 0.93±0.03 mm, respectively. Cauda oval with many long hairs and 0.50±0.02 mm (Fig 5; Table 3).

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IMPACT OF NUMBER OF SPRAYS OF INSECTICIDES ON MANAGEMENT OF SHOOT GALL PSYLLA *APSYLLA CISTELLATA* BUCKTON IN MANGO

S. S. SINGH*, SANJAY SACHAN AND V. PANDEY**

G.B. Pant University of Agriculture and Technology
Krishi Vigyan Kendra, Dhakrani 248142, Dehradun, Uttarakhand
***Horticultural Science Division, KAB-II, ICAR, Pusa, New Delhi 110012*
**Email: sssindia02@gmail.com*

ABSTRACT

Field investigations were conducted during 2014-15, 2015-16 and 2016-17 to evaluate the impact of number of sprays of insecticides on management of shoot gall psylla *Apsylla cistellata* Buckton in mango cv. Dashehari. Two sprays of thiamethoxam+ profenophos during second fortnight of August to first week of September resulted in maximum yield, gross and net returns, and gave tremendous impact with reduction of incidence of shoot gall psylla and drying of branches. Neverthless, one spray of thiamethoxam + profenophos exhibited maximum C:B ratio i.e. 3.33 during 2015-16 and 2.44 during 2016-17 which was superior over all other treatments including two sprays, and with less expenditure. Thus either one or two sprays of thiamethoxam+ profenophos gave almost similar result in terms of yield, gross and net returns and reduction in incidence. Therefore, single spray helped the farmers in effective, economical and ecofriendly management of shoot gall psylla in mango. These results also reveal that the three sprays of monocrotophos, quinalphos and dimethoate recommended earlier neither provide satisfactory results nor cheaper, as compared to one or two sprays of thiamethoxam + profenophos.

Key words: Shoot gall psylla, mango, thiamethoxam, profenophos, incidence, single and two sprays, cost effectiveness, monocrotophos, quinalphos, dimethoate, farmers' practice, adoption

Mango (*Mangifera indica* L) is one of the commercially important fruit crops grown in India, including the subtropical regions of Uttarakhand, with productivity of 3.66 t/ha. The terai regions of North India, despite having one of the most fertile soils and excellent climate for mango cultivation have only 43% of national level productivity (8.44 t/ha). In addition to alternate bearing, the incidence of shoot gall psylla (*Apsylla cistellata* Buckton: Psyllidae: Homoptera) infesting shoots is one of the major constraints attributed to low productivity in Uttarakhand. Mango shoot gall psylla is the most devastating pest in the *terai* region, spread over Uttarakhand, Uttar Pradesh, north Bihar and West Bengal. Its nymphs suck the sap and exude whitish sticky droplets, which gradually dries up later on. The affected buds get converted into hard conical galls inside which the nymphs develop into adults.

Feeding of nymphs and subsequently secretion of certain chemicals results in the formation of hard conical green shoot galls in place of apical and axillary buds, in which they later enter, feed, develop and grow till adulthood (Shukla and Mishra, 2005; Srivastava et al., 1982). Due to transformation of apical/terminal reproductive and vegetative buds into galls, the affected branch becomes unfruitful. The galls are generally observed during October-November and continue up to March-April when the adults emerge out of the galls. Its incidence adversely affects the flowering and fruit setting, as the infested branches later dry up. Depending on the severity, this causes loss of fruit yield to the tune of 20 to 60%. Heavily infested trees might yield only 10-40 kg fruits/tree against a potential normal yield of 250-300 kg (Singh and Yadav, 2007). More than 3000 ha of orchards are estimated to be badly affected at Dehradun, Nainital and Udham Singh Nagar districts of Uttarakhand, leading to an economic loss of Rs. 700-800 million annually (Singh et al., 2015).

The surveys conducted in the mango growing areas of Dehradun and discussion held with farmers revealed that due to lack of knowledge about the pest, most of the farmers do not resort to any management including application of insecticide. It was also observed that some farmers are using monocrotophos, quinalphos or dimethoate, but even with three

applications of these, there is not sufficient relief. As a result, cost of application of insecticides increases year after year, leading to poor management causing serious problem to the farmers. The infestation of mango orchards in the study area has attained alarming severity resulting in significant reduction in fruit yield (40-50 kg/tree) as against the potential fruit yield of 250-300 kg/tree. This results in huge economic loss, and insufficient knowledge on the nature and severity of the problem aggravates the problem. Hence, the present study evaluates the impact of intervention made to assess and validate the effect of insecticides as is being used by the farmers currently along with sprays of other insecticides and their economics.

MATERIALS AND METHODS

The field trials were laid out in Dehradun district, Uttrakhand during 2014-15, 2015-16 and 2016-17. The incidence of shoot gall psylla on mango and impact of insecticides used by the farmers were compared with number of sprays of other insecticides viz., thiamethoxam + profenophos in cv. Dashehari. Surveys were conducted in five randomly selected villages namely Badwala, Jassowala, Jamnipur, Lakhanwala and Dobri. The study area is a leading producer of Dashehari cultivar of mango. Initially, 10 farmers were identified for discussion and their views on incidence of shoot gall psylla recorded. A questionnaire designed upon the popular farming in the targeted villages was utilized to minimize bias and uncontrolled error.

Accordingly, to disseminate the technology for large scale adoption and benefit to mango growers, interventions were made through participation of the farmers. In order to mobilize the farmers, campaign on management was organized in the 5 selected villages, where pest incidence was comparatively more serious. During campaign, farmers were educated on various aspects of the pest such as nature of damage, life cycle, symptoms, effectiveness of insecticides used earlier, use of thiamethoxam and profenophos, their dosage, time of application etc. These insecticides were recommended for one and two applications during second fortnight of August to first week of September 2015 and 2016. Demonstration was conducted with two sprays of thiamethoxam + profenophos in 35 year old, mango orchards covering 21 ha at Village: Badwala, Block: Vikasnagar, District: Dehradun found most effective during 2013. Further assessment of these and validation of number (one and two) of sprays of thiamethoxam + profenophos in five randomly selected villages in comparison of three applications of insecticides carried out currently by the farmers were done.

The incidence of shoot gall psylla was recorded on 10 randomly selected trees in each village with the help of farmers. Similarly, data on drying of branches in the same 10 trees was recorded. Farmers were trained to ensure participatory approach in recording these observations, during May- June 2016 and 2017. Observations on the number of fully formed galls/10 twigs were taken during November-December 2015 and 2016, as galls in the leaf axils were visible only by October- November. The fruit yield (kg/tree) was also recorded from these 10 randomly selected trees during June-July 2016 and 2017, and mean worked out.

One and two sprays of thiamethoxam+ profenophos were followed by the farmers in the selected villages during second fortnight of August to first week of September, 2015 and 2016. The observations on number of galls/10 twigs, drying of branches/10 trees, and yield kg/ha were computed along with gross and net returns, and the impact of insecticides on economics brought out. Randomized Block Design was used to analyze the data obtained during 2014-15, 2015-16 and 2016-17.

Details of treatments are as follows:

Treatments	Details
Treatment 1	Three sprays of monocrotophos, quinalphos and dimethoate at 12 days interval during second fortnight of August to first week of September
Treatment 2	Two sprays of thiamethoxam+ profenophos at 12 days interval during second fortnight of August to first week of September
Treatment 3	One spray of thiamethoxam+ profenophos during second fort night of August to first week of September
Treatment 4 (Farmers' practice)	One spray of monocrotophos during second fort night of August
Treatment 5 (Control)	No insecticide used

RESULTS AND DISCUSSION

Incidence of shoot gall psylla

Before intervention: The surveys in the five selected villages and observations on the incidence during November-December 2014, revealed that it ranged from 178.30 to 212.06/10 twigs in cv. Dashehari (Table 1). The maximum incidence (212.06/10 twigs) was found in Lakhanwala village, while the minimum (178.30/10 twigs) was from Jassowala village. The observations revealed maximum number of branches dried (124.20/10 trees) in Lakhanwala village, and minimum (94.82/10 trees) at Badwala village.

After intervention: During November-December, 2015 and 2016, with three sprays of monocrotophos, quinalphos and dimethoate and one and two sprays of thiamethoxam+ profenophos revealed that the least incidence was in treatment 2, with two applications of thiamethoxam+ profenophos. This was followed by treatment 3 with only one spray of thiamethoxam+ profenophos. Both these treatments were at par as regards incidence. The incidence of shoot gall psylla i.e. 9.48/10 twigs recorded in 2015 while it was 7.22/ 10 twigs in 2016. In treatment 3, three sprays of monocrotophos, quinalphos and dimethoate were given and this along with treatment 2 was significantly superior over others (Table 2,3). The maximum incidence (227.72/10 twigs) was observed in the treatment 5 (2015) and 237.05/10 twigs (2016) in which no insecticide was applied; while in treatment 4 (farmers' practice), 191.04 galls /10twigs were observed during 2015 and 212.82/10 twigs in 2016. As regards, drying of branches same pattern was found as in case of incidence of number of galls.

The field evaluation trials of insecticides in which two sprays of thiamethoxam 0.75g/l of water + profenophos 2 ml/l of water + sticker @ 1.0 ml/l of water were given during the second fortnight of August to first week of September was found the most promising against the pest. Singh et al. (2015) recommended these two sprays of thiamethoxam + profenophos, and it was the most effective.

Table 1. Incidence of shoot gall psylla, yield & economics in mango- before intervention (2014-15)

Treatment	Mean No. of galls formed/ 10 twigs	Drying of branches/ 10 trees	Yield (kg/tree)	Yield (kg/ha)	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	C:B ratio
Badwala	187.46	94.82	44.52	4452	28000	44520	16520	1.59
Jassowala	178.30	104.13	49.08	4908	28000	49080	21080	1.75
Jamnipur	196.83	112.76	40.26	4026	28000	40260	12260	1.43
Lakhanwala	212.06	124.20	34.45	3445	28000	34450	6450	1.23
Dobri	204.88	107.92	37.60	3760	28000	37600	9600	1.34
SEM	5.660395	5.456173	3.206058	220.6824	-	-	-	-
CD (5%)	12.334	11.889	6.986	480.867	-	-	-	-

Table 2. Impact of insecticides on incidence of shoot gall psylla, yield and economics in mango- after intervention (2015-16)

Treatment	Mean No. of galls formed/ 10 twigs	Drying of branches/ 10 trees	Yield (kg/tree)	Yield (kg/ha)	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	C:B ratio
T1	9.48	3.75	234.30	23430	92250	257730	165480	2.79
T2	7.26	1.08	272.84	27284	94600	300124	205524	3.17
T3	8.78	2.50	255.62	25562	84420	281182	196762	3.33
T4 (Farmers practice)	191.04	116.19	52.25	5225	32000	57475	25475	1.79
T5 (Control)	227.72	130.80	36.44	3644	18400	40084	21684	2.17
SEM	0.754933	0.815512	9.790271	138.2405	-	-	-	-
CD(5%)	1.645	1.777	21.333	301.226	-	-	-	-

Table 3. Impact of insecticides on incidence of shoot gall psylla, yield and economics in mango-after intervention (2016-17)

Treatment	Mean No. of galls formed/ 10 twigs	Drying of branches/ 10 trees	Yield (kg/tree)	Yield (kg/ha)	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	C:B ratio
T1	7.22	2.36	166.58	16658	94385	199896	105511	2.11
T2	5.46	0.90	194.70	19470	96190	233640	137450	2.42
T3	6.38	1.45	181.02	18102	88765	217224	128459	2.44
T4 (Farmers practice)	212.82	132.07	48.95	4895	32000	58740	26740	1.83
T5 (Control)	237.05	145.33	32.89	3289	18400	39468	21068	2.14
SEM	0.46168	0.413492	5.000459	412.6283	-	-	-	-
CD (5%)	1.006	0.901	10.896	899.117	-	-	-	-

Fruit yield

Before intervention: The observations indicate that due to high incidence of shoot gall psylla in all the 5 villages, production of mango was very low. The highest yield i.e. 49.08 kg/tree was obtained at Jassowala village, and the lowest (34.45 kg/tree) at Lakhanwala village (Table 1). This low yield was mainly due to high incidence of shoot gall psylla and poor adoption of control measures by the farmers. Although farmers spent @ Rs 28000/ha in spraying of insecticides mainly monocrotophos, dimeathoate and quinalphos and other management practices there was no impact. Gupta and Joshi (1985), Monobrullab and Singh (1997) and Kumar et al. (2007) also observed that heavily infested trees yield only 10-40 kg of fruits against a normal yield of 250-300 kg.

After intervention: In first year, it was observed that maximum yield i.e. 272.84 kg/tree was obtained with treatment 2 (2015-16), while it was 194.70 kg/ tree in 2016-17; treatment 3 was the next best with high yield (255.62 kg/tree in 2015-16; 181.02 kg/tree during 2016-17) (Table 2,3); treatment 1 showed yield of 234.30 and 166.58 kg/tree, 2015-16 and 2016-17, respectively. However, in farmers practice (treatment 4) only 52.25 and 32.89 kg/tree yield was obtained which was at par during 2015-16 and significantly superior to control (treatment 5) in 2016-17. The least yield was 36.44 kg/tree in 2015-16 while it was 32.89 kg/tree during 2016-17 with untreated control.

Gross and net return

The estimation of gross and net income calculated indicate that both i.e. one and two applications of thiamethoxam + profenophos during second fort night of August to first week of September had tremendous impact.

Before intervention: Results reveal that in the farmer's participatory management, maximum gross and net returns were Rs 49080/ha and Rs 21080/ha, respectively during 2014-15 at Jassowala village followed by Rs 44520/ha and Rs 16520/ha, respectively at Badwala village; the least gross return of Rs 34450/ ha and net return of Rs 6450/ha was at Lakhanwala village. The poor gross and net returns were mainly because of very high incidence and non adoption of any econtrol measures by the farmers.

After intervention: In 2015-16, economics reveal that maximum gross return (Rs. 300124/ha) was obtained with treatment 2 closely followed by treatment 3 (Rs. 281182/ha) with lowest of Rs. 40084/ha with untreated control plot; similarly, maximum net return i.e. Rs. 205524/ha was from treatment 2 closely followed by treatment 3. In 2016-17, again maximum gross returns of Rs. 233640/ha was from treatment 2 closely followed by treatment 3 (Rs. 217224/ha); it was Rs. 199896/ha in treatment 1, and Rs. 58740/ha in treatment 4 (farmers practice) and Rs 39468/ha from treatment 5 (control plot). Similarly maximum net returns i.e. Rs 137450/ha was obtained with treatment 2 followed by treatment 3; net returns from other treatments were Rs. 105511/ha in treatment 1 Rs. 26740/ha in treatment 4 (farmers practice) and Rs. 21068/ha from treatment 5 (control).

Effects of intervention: Although two sprays of thiamethoxam + profenophos during second fortnight

of August to first week of September gave maximum yield, gross returns, net returns and received less incidence and drying of branches, one spray of these fetched maximum C:B ratio i.e. 3.33 during 2015-16 and 2.44 during 2016-17. It happened due to low cost involved in one spray, as reflected in Table 2 and 3. The earlier recommendations of three sprays of monocrotophos, dimethoate and quinalphos did not work efficiently, as the continuous deployment of these insecticides have adversely affected their efficacy, also these are more hazardous as compared to thiamethoxam and profenophos.

In the modern era of IPM, we have to advocate the need based and judicious measures in horticultural crops particularly fruits and vegetables. Excessive pesticides pose serious threats of undesirable residues. Keeping these in view, it will be appropriate and meaningful for all the stakeholders including farmers to adopt one spray of thiamethoxam + profenophos for effective, economical and ecofriendly management of shoot gall psylla in mango.

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RED SPIDER MITE *TETRANYCHUS CINABARINUS* (BOISD.) ON WATERMELON CULTIVARS

Watermelon *Citrullus lanatus var. lanatus* (Thunb.) is mainly cultivated in Maharashtra, Karnataka, Tamil Nadu, Punjab, Rajasthan, Madhya Pradesh and Uttar Pradesh. With less genetic diversity amongst cultivars, many are susceptible to pests and diseases (Lopez et al., 2005). The red spider mite (RSM), *Tetranychus cinabarinus* (Boisd.) is a polyphagous mite reported from over 150 host plants including the cultivated watermelon (Zhang, 2003; Jeppson et al., 1975). Watermelon with its prostrate growth habit makes the acaricides penetrating the leaf canopy difficult (Mansour and Karchi, 1994). Also, chemical control leads to resistance and is harmful to the beneficial parasitoids and predators (Zhang, 2003). Host plant resistance might be used to enhance chemical control, resulting in reduced rates and frequency of acaricide application (Smith, 1989).

With restricted genetic diversity, several pests have made watermelon vulnerable and information on the variations in mite incidence in its cultivars is of importance in IPM. Therefore, nine watermelon cultivars were evaluated under greenhouse condition in RBD with three replications during summer 2014-15 at Chilli and Vegetable Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola. The cultivars included are as in Table 1. These were sown in three lines of 2m each at spacing 45x30 cm and university recommended practices with drip irrigation followed. Incidence of mite was first recorded in third week of April 2015 from Vidarbha. Hence, the glasshouse grown cultivars were subjected to red spider mites and the damage evaluated. The weather parameters viz., maximum and minimum temperatures and morning and evening relative humidity were also recorded. During April 9-15, 2015, the ambient temperatures were 35.17 ^{o}C and 20 ^{o}C and RH in the morning and evening were 77.86 and 32.14%, respectively. Observations on damage were rated in the scale 0 to 4 in a sample of five plants each (Singh and Dhooria, 2008) and observed at 13 and 18 days after infestation (DAI)- Grade 0: leaves exhibiting no or negligible damage, 1: leaves exhibiting about 25% yellowish white symptoms, 2: leaves exhibiting about 50 % yellowish white symptoms, 3: leaves exhibiting about 75% yellowish white symptoms and 4: leaves exhibiting about >75% yellowish white symptoms to drying up or falling off of leaves.

Table 1. Damage in watermelon by red spider mite

S.No.	Cultivar	Mean Mite injury Rating		
		13 DAI	18 DAI	Mean
1.	WMHYS-15-01	3.47	3.87	3.67
2.	WMHYS-15-02	2.67	2.93	2.80
3.	WMHYS-15-03	2.47	2.87	2.67
4.	WMHYS-15-04	2.27	2.73	2.50
5.	WMHYS-15-05	1.53	1.93	1.73
6.	WMHYS-15-06	1.80	2.07	1.93
7.	WMHYS-15-07	1.73	2.00	1.87
8.	WMHYS-15-08	2.67	3.07	2.87
9.	Sugarqueen	1.40	1.60	1.50
	SE (m±)	0.156	0.166	0.158
	CD (5%)	0.467	0.497	0.473
	CV (%)	12.14	11.21	11.43

DAI- days after infestation

The damage was observed ranging from 1.40 to 3.47 at13 days after infestation (Table 1). The minimum damage was in the cultivar sugarqueen (1.40) followed by WMHYS-15-05 (1.53), WMHYS-15-07 (1.73) and WMHYS-15-07 (1.80); maximum damage was recorded in WMHYS-15-02 and WMHYS-15-08 (3.67). At 18 days after infestation, damage score ranged from 1.60- 3.87, with WMHYS-15-01 showing more damage. Two hundred and nineteen watermelon collections were evaluated for broad mite infestation in field planting (Kousik et al., 2007); on nine accessions there was no visible mite injury. Further, 14 selected plant introductions evaluated in green house and noted six plant introductions viz., PI 357708, PI 500354, PI 386015, PI 386016, PI 525082 and PI 449332 with low broad mite injury rating.

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Chilli and Vegetable Research Unit
Dr. Panjabrao Deshmukh Agricultural University
Akola 444104
***Department of Entomology*
**Email: vinodsonalkarpdkv@gmail.com*

V.U. Sonalkar*,
S.M. Dadmal and**
S. M.Ghawade

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HEALTHY MANAGEMENT OF HONEY BEES *(APIS MELLIFERA)* WITH WINTER PACKING OF HIVES IN KASHMIR

Honey bees employ fairly sophisticated thermal management strategies to prepare the nest and protect the colony from freezing at subzero temperature. Foraging activities generally stop around 10°C and survive the winter even at as low as -29°C through many other ways. As the ambient temperature drops below -10°C to 14°C in winter in Kashmir, heat retention is insufficient to keep cluster warm. At this point the adult bees begin to generate their own heat by consuming carbohydrate (in the form of honey) and exercising their powerful flight muscles while remaining clustered inside the hive. The packing of bee hives with packing material supplement the bee have management and the present study explores its effects in the Kashmir valley during peak winter.

The study was undertaken at the SKUAST-Kashmir at an apiary of Division of Entomology during 2008-2013. In the first week of October colonies were grouped into six lines with three colonies in each line, with each colony forming a replication. The colonies of each line/ yard were given different packing material. These clonies were of equal strength with seven frames each in order to keep space available for packing material. Sufficient stores (honey) were left for feeding during winter. Entrance of all colonies were minimized with mud. All colonies were checked for the presence of healthy queen, store and bee strength before giving winter packings. The treatments described include (1) the colony in the unprotected hive without packings referred to as check colony (2) the colony with hive wrapped with insulation/ packing material referred as packed colony. The swarming, absconding, disease incidence and the cost benefit of each treatment was observed.

The survey at district Ganderbal revealed both the *A. mellifera* and *A. cerana* in the apiaries of fanners. Results revealed that 63.48% fanners used gunny bags as winter packing material in the hives, while 34.99% used rice straw. The strength of these colonies were exceptionally good. In the district Srinagar, it was 73.56% for gunny bags and 26.43% using rice straw; at Ananthnag, it was 80.62% and 19.39%, respectively; overall it was 72.55% for gunny bags and 26.93% for rice straw as wintering material (Table l). In the managed bee colonies in Kashmir, the winter mortality varied considerably in different regions- from 12.00 to 12.66 9 (Table 2).

With *Apis mellifera* at the apiary in SKUAST-Kashmir Shalimar, cost benefit was also worked out, which revealed highest expenditure of Rs. 305.40 was with treatment 1 (paper+ rice straw+ gunny bags) with 3.5 kg honey harvested/colony, which worked out to

1:2.48 as cost: benefit (C:B ratio). Lowest expenditure of Rs. 283.40 was in the treatment having gunny bags+ rice straw+ thermocol, with C:B ratio of 1:1.16. Highest (1:3.08) C:B ratio was obtained in treatment having thermocol+ dry leaves+ gunny bags as packing material (Table 3).

Table 1. Winter management practices of honey bee hives adopted by beekeepers in Kashmir (2008-10)

District	Type of packing	Type of bees 2008-13	% Farmers adopting 2009-13	Mean (%)	Position of colony	
Ganderbal	Gunny bags	1 &2	66.66	60.30	63.48	+++
	Rice straw	1 &2	33.33	36.66	34.99	+++
	No packing		—	—	—	
Srinagar	Gunny bags	1&2	71.42	75.71	73.56	+++
	Rice Straw	1&2	28.59	24.27	26.43	+++
	No packing					
Anantnag	Gunny bags	1 &2	87.50	73.75	80.62	+++
	Rice Straw	1 &2	12.52	26.26	19.39	+++
	No packing		—	—		
Mean	Gunny bags Rice Straw No Packing		72.55	26.93	0.00	

1&2 = *Apis mellifera & Apis cerana;* +++ = Strong condition

Table 2. Winter mortality loss of managed honey bees in Kashmir

District	% Loss of colonies					
	2008	2009	2010	2011	2012	2013
Ganderbal	14.00	12.00	8.00	14.00	10.00	14.00
Srinagar	12.00	14.00	12.00	14.00	8.00	16.00
Ananthnag	14.00	8.00	16.00	12.00	14.00	12.00
Pooled (winter mortality % loss)						12.44

Table 3. Effect of winter packaging materials (2008-2013, non migrated colonies)

Colony No.	No. of Bee Frames during autumn (Before Packing)	Treatment	Observations recorded (After opening winter packing) % Survival of Bee frames in spring	Swarming/ Absconding	Incidence/ Discase/ insects	Robbing	Expenditure on feeding, packing, treatment (Rs)	Yield	C:B Ratio
1	5.0	Paper+Rice straw+ Gunny Bags	80.0	S+	-	-	305.40	3.5	1:2.52
2	5.5	Paper+thermocole+ Rice straw	72.72	S+			300.40	2.5	1:1.79
3	6.0	Gunny bags+Rice straw+Thermocole	50.00	s+	D+,I	-	283.40	1.5	1:1.16
4	5.5	Paper+Gunny Bags	54.54	s+		R+	285.00	M.J	1:2.27
5	6.5	Thermocole+Dry Leaves+Gunny Bags	69.23	s+	_ _	-	285.40	4.0	1:3.08
6	6.5	Control	10.00	-tive	+tive	-Hive	300.0	0.5	1:0.5

Rate of honey = Rs 220/kg; S+ = Swarming, D+ = Disease, 1+ = Mite and R+ = Robbing

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Division of Entomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar 191121
Email: muneerento@yahoo.co.in

MUNEER AHMAD

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EFFICACY OF NEWER INSECTICIDES AGAINST POD BORER COMPLEX OF PIGEONPEA

The pigeonpea (*Cajanus cajan* (L.) Millsp.) is infested by a number of insect pests, and among the factors responsible for its low yield, the damage by insect pests is important. It is attacked by several insect pests from seedling stage till harvesting. The pod borer complex comprises of *Helicoverpa armigera*, *Grapholita critica*, *Maruca testulalis*, *Lampides boeticus*, *Exelastis atomosa* and *Melanagromyza obtusa*. Among these, the pod borer *H. armigera* (Hubner) and pod fly *M. obtusa* (Malloch) are major limiting factors. A number of insecticides had been found effective against this pest, but *H. armigera* has developed resistance against most of these due to its injudicious use. The present field trial evaluates the efficacy of some newer molecules.

The field experiment was carried out at the College Farm, N. M. College of Agriculture, N. A. U., Navsari during *kharif* 2014-15, in a randomized block design, with three replications. The cultivar 'Vaishali' was sown during second fortnight of July with spacing of 90 x 20cm and plot size of 4.0 m x 4.5 m. All the recommended agronomical practices were adopted for raising the crop. Commercially available formulations of insecticides were sprayed with knapsack sprayer with hollow cone nozzle, with spray volume at 600 l/ha. The first spray was applied at 50% flowering and second 50% pod formation stage.

As regards pod borer, larval populations of H. armigera from five plants were recorded from each treatment before and 7 days after sprays (DAS). At the time of maturity 5 plants were selected randomly per plot and 50 pods/plant plucked, thus 250 pods observed for pod infestation, and % infestation worked out. The data were subjected to square root and arcsine transformation, respectively prior to statically analysis. As regards pod fly, at maturity 5 plants were selected randomly/plot and with 50 pods/plant 250 pods were observed for grain damage, with 750 grains observed for damage, and % grain damage worked out. These were subjected to arcsine transformation prior to statistical analysis.

After harvest, pods were dried under sun light and healthy seeds obtained were weighed with electronic top pan balance, and the grain yield thus obtained was converted/ha before subjecting to ANOVA. To assess the economics, Incremental Cost Benefit Ratio (ICBR) was worked out with net realization being worked out for all the treatments by deducting the cost of protection from the gross realization of produce. Net gain over control was calculated by deducting the realization of control from realization of each treatment. ICBR for each treatment was calculated by dividing net gain over control by total cost of plant protection.

The pooled data presented revealed that all the treatments were significantly superior over control (Table 1); lowest pod borer population was observed with chlorantriniliprole 0.006% (0.79 larvae/plant) and it was at par with all the treatments except control. The order of effectiveness was: chlorantriniliprole

0.006% (0.79) <indoxacarb 0.01% (0.87) <spinosad 0.009% (0.87) <flubendiamide 0.0096% (0.97) <emamectine benzoate 0.002% (1.05) < (trizophos 35% + deltamethrin 1%) @ 0.036% (1.12) <difenthiuron 0.05% (1.17) <control (2.39). These findings corroborate with those of Anonymous (2012) and Sreekanth et al. (2013), who reported that *Helicoverpa* larvae population were lowest in plot treated with chlorantriniliprole.

The pod damage by *H. armigera* at harvest indicated that significantly least damage was with chlorantriniliprole @ 0.006% (4.98%) (Table 2); next effective was indoxacarb @ 0.01% (5.51%) followed by spinosad @ 0.009% (5.51%), flubendiamide @ 0.0096% (6.21%), emamectin benzoate @ 0.002% (6.73%), (trizophos 35% + deltamethrin 1%) @ 0.036% (7.17%) and difenthuron @ 0.05% (7.57%). Similar observations had been reported by Gowda et al. (2003),

Table 1. Larval population of *Helicoverpa armigera* in insecticidal treatments

Sr. No.	Treatment	Before Spray	Larvae/ plant 7 DAS at 50% flowering stage	Larvae/ plant 7 DAS at 50% pod formation	Mean
1	Emamectin Benzoate 5 WSG @ 0.002%	1.60 (2.08)	1.17 (0.88)	1.31 (1.23)	1.24 (1.05)
2	Spinosad 45 SC @ 0.009%	1.65 (2.24)	1.10 (0.72)	1.23 (1.01)	1.17 (0.87)
3	Indoxacarb 14.5 SC @ 0.01%	1.64 (2.19)	1.10 (0.72)	1.23 (1.01)	1.17 (0.87)
4	Trizophos 35% + Deltamethrin 1%) @ 0.036%	1.68 (2.32)	1.20 (0.93)	1.34 (1.31)	1.27 (1.12)
5	Flubendiamide 48 SC @ 0.0096%	1.59 (2.05)	1.14 (0.80)	1.28 (1.15)	1.21 (0.97)
6	Chlorantraniliprole 18.5 SC @ 0.006%	1.60 (2.08)	1.06 (0.64)	1.19 (0.93)	1.13 (0.79)
7	Difenthiuron 50 WP @ 0.05%	1.67 (2.29)	1.21 (0.96)	1.37 (1.39)	1.29 (1.17)
8	Control	1.69 (2.37)	1.61 (2.08)	1.79 (2.69)	1.70 (2.39)
	S.Em±	0.07	0.05	0.05	0.05
	C. D. at 5%	NS	0.15	0.17	0.16
	C.V.%	7.70	6.98	7.03	6.99

Figures outside parentheses $\sqrt{x + 0.5}$ transformed values

Table 2. Pod borer and pod fly damage and grain yield in insecticidal treatments

S. No.	Treatment	% pod damage by *H. armigera*	% Seed damage by pod fly	Yield (kg/ha)	% Yield increase over control
1	Emamectin Benzoate 5 WSG @0.002%	15.04 (6.73)	22.56 (14.72)	2784	30.29
2	Spinosad 45 SC @ 0.009%	13.57 (5.51)	19.57 (11.23)	3363	42.28
3	Indoxacarb 14.5 SC @ 0.01%	13.57 (5.51)	19.57 (11.23)	3672	47.14
4	(Trizophos 35% + Deltamethrin 1%) @ 0.036%	15.53 (7.17)	23.44 (15.83)	2616	25.81
5	Flubendiamide 48 SC @ 0.0096%	14.43 (6.21)	21.53 (13.47)	2841	31.67
6	Chlorantraniliprole 18.5 SC @ 0.006%	12.89 (4.98)	18.57 (10.15)	3745	48.16
7	Difenthuron 50 WP @ 0.05%	15.90 (7.51)	24.20 (16.91)	2378	18.37
8	Control	23.10 (15.39)	33.15 (29.91)	1941	-
	S.Em±	1.02	1.64	175.5	-
	C. D. at 5%	3.11	4.98	532.43	-
	C.V.%	11.45	12.46	10.42	-

Figures outside parentheses *arc sin* transformed values

Table 3. Economics of insecticides treatments on pigeonpea

S. No.	Treatment	Quantity of insecticide/ha (2 spray)	Cost of insecticides Rs/ha (2 spray)	Labour cost Rs/ha (2 spray)	Total Cost of Pl. Prot. (Rs/ha)	Grain Yield (kg/ha)	Gross realization of produce (Rs/ha)	Net realization (Rs/ha)	Net gain over control (Rs/ha)	ICBR
1.	Emamectin Benzoate 5 WSG @ 0.002%	480 gm.	4080	1712	5792	2784	167040	161248	44788	1:7.73
2.	Spinosad 45 SC @ 0.009%	240 ml.	3840	1712	5552	3363	201780	196228	79768	1:14.37
3.	Indoxacarb 14.5 SC @ 0.01%	820 ml.	2706	1712	4418	3672	220320	215902	99442	1:22.51
4.	(Trizophos 35% + Deltamethrin 1%) @ 0.036%	1200 ml.	660	1712	2372	2616	156960	154588	38128	1:16.07
5.	Flubendiamide 48 SC @ 0.0096%	240 ml.	3720	1712	5432	2841	170460	165028	48568	1:8.94
6.	Chlorantraniliprole 18.5 SC @ 0.006%	360 ml.	5160	1712	6872	3745	224700	217828	101368	1:14.75
7.	Difenthuron 50 WP @ 0.05%	1200 gm.	4080	1712	5792	2378	142680	136888	20428	1:3.53
8.	Control					1941	116460	116460		

Anonymous (2006), Halder et al. (2006), Tamboli and Lolage (2008), Nishantha et al. (2004), Babariya et al. (2010), Anonymous (2012) and Sreekanth et al. (2013). Thus chlorantriniliprole, indoxacarb and spinosad were the most effective against pod borer.

As regards seed damage by pod fly, significantly least damage was observed with chlorantriniliprole @ 0.006% (10.15%) and it was at par with all other insecticides, except difenthuron @ 0.05%.. The next effective ones include indoxacarb @ 0.01% (11.23%), spinosad @ 0.009% (11.23%), flubendiamide @ 0.0096%, emamectin benzoate @ 0.002% and triazophos+ deltamethrin @ 0.036%. These results derive support from Tamboli and Lolage (2008), Nishantha et al. (2009) and Anonymous (2012).

The yield data reveal that all the insecticides gave significantly higher seed yield, but the highest seed yield (3745 kg/ha) was obtained with chlorantraniliprole @ 0.006%; it was at par with indoxacarb @ 0.01% (3672 kg/ha) and spinosad @ 0.009% (3363 kg/ha). Similar results had been reported earlier (Sreekanth et al.,2013) with chlorantraniliprole followed by flubendiamide and spinosad.

Incremental Cost Benefit Ratio (ICBR) worked out with grain yield, prevailing market price and cost of respective treatment given in Table 3 reveal that maximum net realization (217828 Rs/ha) was obtained with chlorantraniliprole @ 0.006%. Perusal of data indicate that highest ICBR was obtained with indoxacarb 0.01% (1:22.51) followed by trizophos 35% + deltamethrin 1% @ 0.036% (1:16.07), chlorantraniliprole @ 0.006% (1:14.75) and spinosad 45 SC @ 0.009% (1:14.37). Thus looking to ICBR indoxacarb 0.01%, trizophos 35% + deltamethrin 1% @ 0.036%, chlorantraniliprole @ 0.006% (1:14.75) and spinosad 45 SC @ 0.009% were the most effective and economical against pigeonpea pod borer and pod fly.

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Department of Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari 396450
**Email: Patel.devendra2829@yahoo.com*

R. M. JALONDHARA AND D.R. PATEL*

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NEW RECORDS OF COLEOPTERANS ON APPLE IN HIMACHAL PRADESH

Apple is the main cash crop of Himachal Pradesh, grown in 94,438 ha contributing 82% of total fruit production. Pome fruits are attacked by over 300 insect pests in India (Pruthi and Batra, 1960; Bhalla and Pawar, 1977; Bhardwaj and Bhardwaj, 1983). Of these about a dozen are serious causing economics loss to the apple growers, which include woolly apple aphid, San Jose scale, root borer, stem borer, apple blossom thrips, leaf roller, defoliating beetles and European red mite. Two coleopterans-flea beetle *Scelodonta ?strigicollis* Motschulsky (Chrysomelidae: Coleoptera) and a weevil *Xylinophorus strigifrons*

Faust (Curculionidae: Coleoptera) were observed on the new sprouting buds of apple from silver tip to pink bud stage in apple orchards of Himachal Pradesh in 2012 and 2013. Preliminary observations on the damage by these were made and these discussed herein.

***Scelodonta ? strigicollis* Motschulsky:** Flea beetle *Scelodonta ?strigicollis* was found on apple from green tip stage to tight cluster stage. Adult is small, greyish black, shiny beetle measuring about 0.8 mm in length. It appears in groups near green tips of apple during dusk time and feeds voraciously on the sprouting buds. Voracious feeding damaged the sprouting vegetative as well as floral buds substantially, which ultimately resulted into poor flowering and fruit setting. As much as 15-20% crop loss was recorded in apple orchards of Sarhan and Kotkhai areas of district Shimla during 2013.

Trehan *et al*. (1947) found that flea beetle *Scelodonta strigicollis* fed on tender shoots and leaves, and tendrils of grapes causing substantial damage. The tender shoots may wither and drop down whereas feeding on mature leaves created elongated holes. Reddy and Rao (2006) studied the avoidable losses due to this flea beetle on Thompson seedless grapes damaging buds and tendrils in Hyderabad. Kulkarni and Patil (2012) studied the efficacy of thiamethoxam 25 WG (Actara 25 WG) against flea beetle, jassids and thrips in grapes.

***Xylinophorus strigifrons* Faust:** A curculionid, *Xylinophorus strigifrons* Faust was observed in apple orchards at early green tip stage. The observations reveal its behavior, morphology and feeding habits. It is nocturnal in habit and appeared in clusters and fed on the emerging buds of apple during March and April. Adult is pale brown measuring about 4-5mm in length with irregular black spots on the elytra, thorax and head, and on the lower margin of thorax a black border was observed. Head is protruded into broad beak instead of long snout. Most of the time these stay in mating position on emerging buds and eat away the buds in the same position. Their presence was observed near silver tip stage, and initially these make holes in buds and slowly destroy the whole cluster of buds which appears like burning of sprouting buds. This later resulted in withering and dropping down of flowering buds. Severe attack was observed on the tight cluster stage. After destroying buds, these start scrapping the bark of thin branches. After fruit set these have also been found damaging peduncles of the fruits. During day time these remain hidden under bark or cracks and crevices of the tree. The body colour resembles very much the colour of bark of apple tree which makes it difficult for the orchardists to locate them on the tree. At initial stages 10-15% damage was recorded in Ratnari and Baghi area of district Shimla.

No studies have so far been done on these coleopterans in apple, and therefore, systematic studies are required to be carried out on their biology and management.

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Dr Y S Parmar University of Horticulture and Forestry
Regional Horticultural Research and Training Station
Mashobra Shimla 171107
**Email: bhardwajsdr@gmail.com*

Sushma Bhardwaj and
Joginder Singh

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EVALUATION OF ARTIFICIAL DIETS FOR LABORATORY REARING OF *COCCINELLA SEPTEMPUNCTATA* L. (COLEOPTERA: COCCINELLIDAE)

There are two types of hosts (natural host and alternate host) and artificial diet used in rearing of entomophagous insects. An artificial substrate is one that is prepared or formulated by man, such as artificial diets. Several insects can now be conveniently reared and entomophagous insects can now be directly reared on such artificial diets (Singh, 1982). Two predatory groups (*Chrysopa* spp. and coccinellids) had been mass reared on synthetic diets and some success had been achieved with dipterous parasitoids (Singh, 1982). The ever increasing demand for large number of laboratory reared insects has necessitated the development of more efficient and economical methods of their mass production. Utilizing biological entities, such as predatory insects had also created a demand for constantly reliable sources of supply for such insects. Given the importance of *C. septempunctata* as an efficient predator of aphids, the present investigation aims to evaluate the suitability of artificial diets for its mass rearing. Also the biology of *C. septempunctata* on suitable or preferred diet under local set conditions was studied.

The study was conducted at Division of Entomology, ICAR Research Complex for NEH Region, Umiam, Meghalaya,during 2012-2014. In order to have consistent supply of mustard aphid (*Lipaphis erysimi*) as a source of food for rearing, the seedlings of mustard were raised and grown in pots housed in net house without any application of pesticides. *C. septempunctata* was collected from the field as egg mass and reared on natural host (mustard aphid) at 22 ± 4^{0}C with relative humidity of 60-70%. Artificial diets with honey and water were used to make diet in semisolid form and the other ingredients were adjusted to obtain a pasty texture due to the hygroscopic potential of the honey combined with water and all other ingredients were used. The details of diets are given in Table 1.

Table 1. Composition of artificial diets evaluated for mass rearing of *C. septempunctata*

Compound	Artificial diet (D) Number (weight of compounds in grams (g))										
	D-1	D-2	D-3	D-4	D-5	D-6	D-7	D-8	D-9	D-10	D- 11
Ascorbic acid	0.125	0.125	0.125	-	0.125	-	0.125	-	-	-	-
Scorbic acid	0.063	0.063	0.063	-	0.063	-	0.063	-	-	-	-
Catfood[a]	5.0	-	-	-	-	-	-	-	5.0	5.0	5.0
Honey	3.0	3.0	3.0	0.4	3.0	6.0	3.0	3.0	-	-	-
Water	25	-	-	-	-	-	-	-	25	25	25
Nipagin	-	0.063	0.063	-	0.063	-	0.063	-	-	-	-
$FeSo_4$	-	0.125	-	-	0.125	-	-	-	-	-	-
Egg Yolk	-	-	-	2.5	-	-	-	-	-	-	-
Casein	-	-	-	0.2	-	-	0.2	-	-	-	-
Sucrose	-	-	-	0.2	-	-	-	-	-	-	-
Pulverised dried aphids	-	-	-	0.4	-	0.2	-	-	-	0.5	-
Freezing for 1 week Aphids	-	-	-	-	2.0	-	-	-	-	-	2.0
Agar	-	-	-	-	-	0.13	-	-	-	-	-
Yeast	-	-	-	-	-	0.05	9.0	-	-	-	-
Bread crumb	-	-	-	-	-	0.5	0.5	0.5	-	-	-
Protein hydrolysate	-	-	-	-	-	0.1	-	-	-	-	-

[a]Ground wheat, ground yellow corn, soybean meal, corngluten, natural chicken flavour, animal fat, powdered cellulose, calcium carbonate, potassium chloride, vitamins, vitamin B1, vitamin B6, vitamin B12, vitamin D3, zinc sulphate, copper sulphate, magnesium sulphate, potassium iodide, yucca schidigera extract.

Treatments (T1 to T11- Diet 1 to 11; T12 to T21- from Diet 2 to 11, each with combination of lepidopteran pupae

Diet 1 was based on cat food which was originally in cube form. The fine powder of cat food was prepared and other ingredients were mixed by adding honey firstly and then finally 25ml of distilled sterile water was added into the beaker. As the diet was in a semisolid state, it was not suitable to pour them directly into the petri dishes. Therefore, the paper stripes were prepared. The Whatman filter papers/ blotter papers were sterilized at 120^{0}C in autoclave and subsequently dried (in plastic container) in a hot air oven for 24 hr and the paper was cut into rectangular pieces (1 x 3 cm). The diets were painted or smeared on one side of the strip of Whatman Filter/ blotter paper and one strip was placed in each petri dish. The other stripes with diets smeared/ painted on them were stored in airtight plastic container at 4-6^{0}C for future use. The diet preparation and application procedure of Diet 2, Diet 3, Diet 7, Diet 8, and Diet 9 was similar to that of Diet 1.

For the preparation of Diet 4, Diet 6 and Diet 10, pulverised dried aphids were used. The petri dish containing aphids were dried under hot air oven at 55^{0}C for 24 hr (Rahim and Rafique, 2001). These dried aphids along with the other ingredients were used in their respective diets (Table 1).

In the preparation of Diet 5 and Diet 11, frozen aphids were used. The aphids were frozen at low temperature (-20ºC) in air tight plastic containers (18 x 6 cm). These containers were kept in the freezer (-20ºC) for 24hr. The frozen aphids were divided into small portions into small containers (9 x 3 cm) and kept at the same temperature and for further use (Rahim and Rafique, 2001).

For the preparation of artificial diets, Diet 12 to Diet 21, a total of 1 gm of pupal crush was added within the existing recipes of these diets. For this purpose, the freshly formed pupae of cabbage butterfly *Pieris brassicae* (Linnaeus) were used. The pupae were taken from the laboratory culture of *P. brassicae* maintained at Division of Entomology, ICAR Research Complex for NEH Region, Umiam. The outer cuticle (haemolymph) was removed (Carpenter et al., 2007) and the required quantity of this was weighed out and the same was crushed and mixed in respective diets. Other ingredients and diet preparation and application procedure was exactly similar as explained above.

Among the 21 artificial diets evaluated, 11 were artificial diets and when these diets (artificial diet 2 to 11) were supplemented with lepidopteran pupae. For rearing of *C. septempunctata* on these artificial diets, the eggs laid were transferred individually on a petri dish (4 cm dia) containing artificial diet on paper stripes. A total of 6 individuals (egg/grub/adult) were tested for each replication and there were a total of five replications for each diet, with a total of 30 grubs were tested for each diet. The eggs were transferred with a wet camel brush. To avoid the escape of larvae, each plate was sealed with parafilm wrap. The observations were taken on daily basis and the diets replaced every alternate day; at the time of replacing of diets, the plates were cleaned with tissue paper. Except the different artificial diet treatment, the other rearing procedure/steps were same.

The observations on different biological/ developmental parameters of *C. septempunctata* (pre-oviposition period, oviposition period, fecundity, incubation period, larval period, pre-pupal period, pupal period, pupal weight, male longevity, female longevity and total life span) were recorded separately on daily basis for each artificial diet. The data obtained from the experiment was subjected to statistical analysis in Statistical Analysis Software SPSS, ver 2.1

Among 21 artificial diets evaluated, only Diet 1 supported all the growth parameters (from egg to adult) of *C. septempunctata* (Fig. 1 and 2); with 20 diets (Diet-2 to Diet-21), the mortality of grubs occurred at first instar and in some cases at third instar itself. The artificial diet used alone did not allow the grub development, but it affected the pre-imaginal parameters. This inability of the larvae of *C. septempunctata* to develop on artificial diet could be attributed to the fact that beetles belonging to the family Coccinellidae rarely complete the first instar when supplied with inadequate food (Michaud, 2005).

Fig. 1. Grub feeding on Diet 1

Fig. 2. Third instar grub feeding on Diet 1

Fig. 4. Grubs stuck to Diet-7

Besides, poor food quality can be associated with a specific nutrient that limits the development of the predator (Michaud, 2005).

In the present study, honey was added as a major ingredient in most of the artificial diets, with its quantity varying from 0.4 gm (Diet-4) to a maximum of 6.0 gm (Diet-6); in all these diets it was the grubs got stuck on the diet (Fig. 3), unable to move due to stickiness of honey and subsequently died due to starvation in the first instar. Similar trend was also noticed in case of Diet-6 and Diet-7 which had 6 gm and 3 gm honey, respectively (Fig. 4). However, the adults fed freely on these diets. The problem of stickiness also occurred when agar was an ingredient in artificial Diet-6. Agar was mainly used as a solidifying agent in artificial diets. The present observations agree with those of Sattar (2007) and Cohen (2000) for adults of green lace wing *Chryosoperla carnea* (Stephens). Furthermore, it has been reported that even a low quantity of agar in artificial diet increases the larval mortality in bean pod borer *Maruca vitrata* (Lingappa, 1987). The present results could also be attributed to the incorrect quantity of honey and agar.

Fig. 3. Grubs stuck to Diet-6

To further improve the performance of the diets (Diet-2 to Diet 11), the haemolymph of lepidopteran pupae were added; but the grubs were found to be reluctant towards these diets and did not even try to eat the diet, and moved away from the diet and died due to starvation within 3-4 days. This observation corroborates with those of Shirazi (2006) and Consoli and Parra (1996), and this further confirmed that addition of haemolymph from lepidopteran pupae did not show any improvement. Silva et al. (2009) reported that the artificial diet used alone did not allow the development of larvae of lady bug *Eriophis connexa* (Germar) but it affected the pre-imaginal parameters. This suggests the need for additional nutrients to artificial diets such as essential amino acids and mineral salts due to the generalist feeding behaviour of Coccinellidae.

Cat food based artificial diet (Diet-1) supported *C. septempunctata* in both Generation-1 (G1) and Generation-2 (G2). The fecundity was found to be 15.50±1.05 and 15.33±0.54 eggs in G1 and G2, respectively. Females laid the eggs in batches of 10-15 eggs (Table 2). Katsoyannos et al. (1997) observed that, generally on suitable diet, *C. septempunctata* female could lay up to 1780 eggs in one generation.

There was significant variation in larval developmental period in Generation-1 and Generation-2 on Diet-1 ($p = 0.019$). Total larval developmental period was longer in Generation-2 (25.66±1.00 days) and slightly shorter in Generation-1 (22.5±0.74). It was found that the mean larval developmental period

Table 2. Comparison of Generation-1 and Generation-2 performance on Diet-1 (n=30)

S.No	Parameters	Generation-1	Generation-2	t value	P value	S/NS
1	Pre oviposition period (days)	11.86±0.39	9.96±0.47	2.620	0.59	NS
2	Oviposition period (days)	9.30±0.47	8.66±0.59	1.443	0.222	NS
3	Fecundity (Total eggs laid/female)	15.50±1.05	15.33±0.54	0.129	0.904	NS
4	Incubation period (days)	5.06±0.31	4.20±0.39	1.781	0.149	NS
5	Larval period (days)	22.5±0.74	25.66±1.00	-3.833	0.019	S
6	Pre pupal period (days)	2.49±0.34	2.06±0.28	0.824	0.456	NS
7	Pupal period (days)	8.26±0.48	8.30±0.53	-0.071	0.946	NS
8	Pupal weight (mg)	12.76±0.53	13.13±1.54	-0.212	0.843	NS
9	Male weight (mg)	6.60±0.47	7.63±0.40	-3.092	0.037	S
10	Female weight (mg)	9.13±0.62	8.33±0.82	-0.718	0.512	NS
11	Male Longevity (days)	3.29±0.38	3.46±0.31	0.252	0.813	NS
12	Female Longevity (days)	8.63±0.27	8.53±0.38	0.601	0.580	NS
13	Total development period (days)	35.66±0.96	38.20±1.04	-1.779	0.150	NS
14	Mortality (%)	73.2±4.0	73.2±4.0	0.00	1.000	NS

* S: Significant, NS; Non Significant

on Diet-1 appeared to be significantly longer. However, the larval developmental period had been reported to be only 14.2 days by Omkar and Srivastava (2003) and 10.76± 1.35 days in lady beetle *Micrapis discolour* (Fabricius) (Chowdary et al., 2008). The differences observed now could be attributed mainly due to composition of diets, species and different rearing conditions in laboratories.

The present study showed that there was no significant variation in weight of pupa (P = 0.843) and adult female (p = 0.512) between the generations, G1 and G2 on artificial diet. However, the weight of adult male was significantly different (P = 0.037) between the two generations and it was found to be 6.60± 0.47 in G1 and 7.63±0.40 in G2 (Table 2). Kawauchi (1979) demonstrated that temperature influenced the rate of development and adult weight in coccinellids.

No significant differences were observed in terms of longevity of *C. septempunctata* in G1 and G2 on Diet-1; with males in G1 and G2, it was 3.29± 0.38 and 3.46± 0.31 days, respectively (Table 2). However, with females in G1 and G2, it was 8.63± 0.27 and 8.53± 0.38 days, respectively; and longevity of both male and female appeared to be very short on Diet-1. Ali and Rizvi (2007) reported that longevity of males and females was 62.75± 1.43 and 31.78± 0.68 days, respectively. The present findings derive support from Cabral et al. (2006) who reported that diet plays an important role in longevity of adults.

Total developmental period on Diet-1 was found to be 35.66± 0.96 and 38.20± 1.04 days in G1 and G2, respectively; and no significant variation was observed between G1 and G2; also, there was no significant variation with mortality in G1 and G2. But in general, the mortality on Diet-1 was up to 72.2%. However, in comparison with other 20 artificial diets evaluated now, Diet-1 was found to be better as it supported all the growth parameters and *C. septempunctata* was able to complete its life cycle consecutively for two generations. High mortality of *C. septempunctata* larvae observed herein derive support from Rahim and Rafique (2001) who recorded that occurrence of higher mortality on artificial diets is a common phenomenon. Moreover, the present findings was further supported by Silva et al. (2009) who observed that no adults of *E. connexa* were obtained with artificial diet as a standalone food source.

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Division of Crop Protection
ICAR Research Complex for NEH Region
Umiam 793103, Meghalaya
**Email: vinayakb785@gmail.com (corresponding author)*

V. B. Doddamani*,
G.T. Behere,
D.M. Firake and
B. Nongkynrih

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EFFECT OF NON-EDIBLE OILS ON WHITEFLY AND INCIDENCE OF PALCV IN EARLY POTATO CROP

Potato is grown in many parts of north-central and north-western parts of India as an early cash crop and more than 100 insects are associated with this crop damaging its leaf, stem, roots and tubers (Saxena and Misra, 1983). Among these, aphid (*Myzus persicae* Sulzer), leafhopper (*Empoasca fabae* Harris) and whitefly, *Bemisia tabaci* (Gennadius) are important as these cause direct damage as well as transmitting viruses. The most important among them is whitefly causing 20-60% yield losses (Malik et al., 2005). Several conventional and synthetic insecticides had been evaluated against this whitefly. Despite these yield losses due to whitefly and apical leaf curl disease in potato are increasing. The problem has been aggravated due to development of resistance against conventional pesticides. There is an urgent need to develop and evaluate bioactive products which are locally available. Many plant oils contain active chemical compounds which are useful as pesticides. Among these are: neem (*Azadirachta indica* A.Juss); China berry (*Melia azedarach* L.); custard apple (*Annona squamosa*); mahua (*Madhua longifolia* Koen); karanj (*Pongamia pinnata* Pierre) and castor (*Ricinus communis* L.). Many researchers had reported on the antifeedant,

Table 1. Incidence of whitefly and PALCV on early potato (pooled data, 2013-14 & 2014-15)

Treatment	Average weekly whitefly population/10 plants									
	Before spray	17.10	18.10	21.10	29.10	07.11	19.11	25.11	03.12	%PALCV incidence
T1 –Neem oil (2ml/l)	5.54	4.00	4.50	1.71	2.28	2.48	3.55	2.16	2.02	26.88
T2- Caster oil (2ml/l)	6.98	4.67	6.83	3.24	5.25	3.87	5.49	4.73	2.90	33.30
T3- Eucalyptus oil (2ml/l)	5.21	5.00	5.66	2.29	4.83	4.24	5.91	5.58	3.46	29.01
T4- Karanj oil (2ml/l)	6.88	6.33	6.83	2.48	4.63	3.97	4.76	5.01	2.69	28.70
T5- Mahua oil (2ml/l)	5.90	5.50	5.83	3.46	6.74	5.05	6.56	4.39	4.64	30.55
T6- Imidacloprid- 17.5 SL, (4ml/10l)	5.62	3.33	1.83	1.00	2.55	1.86	2.51	1.46	1.95	22.48
T7-Control-(water spray)	7.88	7.50	9.98	6.47	7.82	7.59	7.97	8.30	5.73	35.00
SEM±	-	0.61	0.69	0.64	0.68	0.79	0.82	0.79	0.90	2.21
CD (p=0.05)	-	1.63	2.16	1.99	2.13	1.78	2.00	1.10	1.87	NS

*Square root transformation $x = \sqrt{(x + 0.50)}$

repellent and insecticidal activity of such plants. The present study evaluates few such products against whitefly on potato.

A field trial was conducted at the Central Potato Research Institute Campus, Modipurum, Meerut during 2013 and 2014. Trial was laid out in a randomized block design with plot size of 3 x 2 m. Potato cultivar Kufri Pukhraj was planted in the 2nd week of September as an early crop with seven treatments, replicated thrice. The treatments included oils of neem, castor, eucalyptus, karanj and mahua, compared with imidacloprid 17.5 SL as a check along with untreated control. Oils at 100% concentration were used @2ml/ l of water as spray solution. Teepol (1%) was mixed in spray solution to increase the solubility of oils in water. Imidacloprid 17.5 SL was used @ 5ml/10 l. of water as spray solution. Knapsack sprayer was used with a total of seven sprays of oils- three each in October and November, with the last one in December, while imidachloprid was given as three sprays from 35 days old crop at 15 days interval. All the agronomical package and practices recommended for the region were followed.

The observations on the population buildup of whitefly were recorded on upper, middle and lower leaves of 10 randomly selected plants at 24, 48, 72 hr and further 7 days interval regularly from 35 days after planting till the physiological maturity. The yield data were recorded from net plot after removing halum in the last week of December. The yield and other characters like marketable tuber yield along with % over size, seed size and small size tubers were recorded at the time of harvest. The % emergence and disease of PALCV were also recorded, and benefit cost analysis maintained. The mean incidence of whitefly was converted using square root transformation before statistical analysis using RBD.

Observations on the incidence of whitefly as given in the pooled data in Table 1 reveal that among the oils as treatments, the minimum incidence was in the neem oil treated plots (0.71-4.5 / 10 plants from second week of October to first week of December). It was followed by eucalyptus oil (2.29-5.91/ 10 plant), karanj oil (2.48-6.83/ 10 plant), castor oil (3.24-6.83 / 10 plant) and mahua oil (3.46-6.74 / 10 plant), and these differences were significant. As regards incidence of PALCV, it was observed that among the oils, minimum incidence (26.88%) was observed with neem oil followed by karanj (28.7%) and eucalyptus oils (29.01%). However, the least disease incidence (22.48%) was with imidacloprid.

The incidence of whitefly starts with the residue population from early potato crop, natural host and weeds in the vicinity of the crop. However, the populations remained low under protected condition i.e. crop was protected by seven sprays schedule of neem oil. It was observed that high temperature boosted growth and development of whitefly which confirmed the present finding i.e. decrease in temperature and increased relative humidity from 1st

Table 2. Potato tuber yield and economic of non-edible oils treatments (pooled data, 2013-14 & 2014-15)

Treatments	Emergence (%)	Over size Tubers	Seed Size Tubers (%)	Total Tuber yield (%)	% Increase in marketable yield over (t/ha)	Increase in marketable yield over control	Cost* of potato (Rs.) control (t)	Cost of treatment** (Rs.)	Net profit (Rs.)	Cost: Benefit ratio
T1 –Neem oil (2ml/l)	84.02	8.31	45.06	27.53	24.86	5.24	39522	11740	27482	1:3.75
T2- Caster oil (2ml/l)	81.48	8.76	35.63	22.54	8.62	1.71	12704	8950	3754	1:1.41
T3- Eucalyptus oil (2ml/l)	80.80	10.20	40.33	22.44	8.44	1.61	11770	11272	3847	1:1.02
T4- Karanj oil (2ml/l)	88.21	6.02	35.93	21.39	4.68	0.91	6692	7371	-1537	1:0.90
T5- Mahua oil (2ml/l)	91.37	8.13	38.83	22.21	6.91	1.38	10292	8580	1712	1:1.19
T6- Imidacloprid- 17.5 SL,(4ml/10l)	88.76	8.53	44.67	30.45	45.43	9.62	73372	12417	60954	1:6.94
T7-Control-(water spray)	57.45	9.67	24.98	20.82	-	-	-	-	-	-
SEM±	3.38	1.73	5.64	1.62	-	-	-	-	-	-
CD (p=0.05)	4.24	NS	NS	2.27	-	-	-	-	-	-

*Mean tuber rate-800/q, ** Cost of plant product +spraying cost + labour; Seven sprays on 14.10., 20.10., 28.10., 06.11, 18.11, 24.11 and 02.12; three sprays of insecticide in T6.

week of November did not favor the buildup of whitefly.

Mean emergence (80.8-91.57%) statistically differed among the treatments in both the years. Numbers of tubers i.e. oversize and seed size did not differ statistically among the treatments (Table 2). Maximum tuber yield (27.53 t/ ha) was obtained with neem oil and also with imidachloprid. The higher disease incidence and whitefly buildup on potato crop is mainly responsible for low yield and increase in tuber yield during 2013-14 as compared to 2014-15.

The cost-benefit ratios worked out given in Table 2 reveal that neem oil ranked first indicating the maximum return Rs. 3.75 per rupee invested; this was followed by castor oil with 1:1.41, mahua oil 1:1.19, C: B ratio, respectively. Frequent spraying of neem formulation from emergence of crop up to 50 days effectively reduced the thrips, disease and significantly increased tuber yield (Bhatnagar, 2012).

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Central Potato Research Institute Campus, Modipuram, Meerut 250110 — **Anuj Bhatnagar***
***Department of Entomology, S. V. P. University of Agri. and Tech., Meerut 250110* — **R.P. Pant**
****Department of Plant Protection, CCS University, Meerut 250001* — **D.V. Singh** and**
Email: dr.anujbhatnagar@gmail.com* — **Ajay Kumar***

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EFFICACY OF INSECTICIDES AGAINST APHIDS INFESTING VEGETABLE DOLICHOS BEAN

Most of the vegetable crops, though have large yield potential, are giving lower yields. Amongst many factors, infestation by pests is a major one and cause for this reduction in yield. Dolichos bean, *Lablab purpureus* (L.) is one such important vegetable crop, and it suffers from yield losses due to pests like aphids. *Aphis craccivora* (Koch.), occurs in large colonies on this, and both nymphs and adults suck the sap from leaves, petioles, tender stems, inflorescences and tender pods. These aphids are effectively managed with chemical pesticides, and the present study evaluates some of these and the results presented herein.

MATERIALS AND METHODS

The field trial was carried out at the College of Agriculture, Dapoli using Randomized Block Design with three replications and ten treatments in the Botany farm during *rabi* 2013-14, with dolichos bean variety Konkan Bhushan. Treatment details are as follows: T1- Emamectin benzoate 5 SG 0.0033%; T2- Spinosad 45 SL 0.0035%; T3- Cartap hydrochloride 50 SP 0.1%; T4- Lambda cyhalothrin 5 EC 0.005%; T5- Acephate 75 SP 0.01; T6- Flubendiamide 5 WG 0.004%; T7- Thiamethoxam 25 WDG 0.0025%; T8- Buprofezin 25 EC 0.0025%; T9-Acetamiprid 20 SP 0.004%; T10- Novaluron 10 EC 0.075%; T11- Imidacloprid 17.8 SL 0.05%; and T12- Control (water application). The plot size was 2.70 x 3.00 m (gross) and 1.80 x 2.40 m (net) with spacing of 45 x 30cm, and the date of sowing was 8th November. Three sprays were given with ASPEE knapsack sprayer, the first when incidence was noticed and subsequent ones 15 days after previous. Observations on the incidence of aphids (no. of nymphs and adults) were recorded on three randomly selected leaves comprising top, middle and bottom canopy, with pretreatment observations a day before spraying and the post treatment ones at 1st, 3rd, 5th, 7th and 10th day after each spraying on five randomly

selected plants in each plot. The data obtained were analyzed statistically.

RESULTS AND DISCUSSION

The results given in Table 1 reveal that the pretreatment count showed non-significant variations signifying uniformity in population count of aphids.

After first spray-the treatment (T5) acephate (0.01%) recorded significantly lowest count (95.08) however, it was at par with (T8) buprofezin (0.0025%), (T6) flubendiamide (0.004%) and (T11) imidacloprid (0.05%). The treatments (T8) buprofezin (0.0025%) and (T6) flubendiamide (0.004%) were also at par with (T10) novaluron (0.075%); whereas, (T11) imidacloprid (0.05%) was comparable with (T10) novaluron (0.075%), (T9) acetamiprid (0.004%) and (T4) λ-cyhalothrin (0.005%).

Table 1. Efficacy of insecticides against aphids infesting vegetable dolichos bean (after first spray)

Sr.No.	Treatment	Conc. (%)	Average number of aphids 3 leaves/plant					
			First spray					
			Pre-treatment	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS
1.	Emamectin benzoate 5SG	0.0033	112.54 (10.66)*	112.00 (10.63)	102.48 (10.17)	89.34 (9.50)	76.08 (8.78)	49.28 (7.09)
2.	Spinosad 45SL	0.0035	111.28 (10.60)	111.20 (10.59)	100.88 (10.09)	86.80 (9.37)	73.68 (8.64)	45.40 (6.81)
3.	Cartap hydrochloride 50 SP	0.1	105.54 (10.32)	109.40 (10.51)	94.54 (9.77)	84.94 (9.27)	69.14 (8.37)	32.28 (5.77)
4.	λ-cyhalothrin 5 EC	0.005	113.68 (10.71)	108.60 (10.47)	97.02 (9.90)	82.60 (9.14)	68.68 (8.35)	36.80 (6.15)
5.	Acephate 75SP	0.01	115.68 (10.80)	95.08 (9.80)	72.74 (8.59)	52.34 (7.30)	33.68 (5.89)	3.88 (2.21)
6.	Flubendiamide 5 WG	0.004	114.94 (10.77)	99.40 (10.02)	83.14 (9.17)	67.08 (8.25)	48.48 (7.05)	10.20 (3.35)
7.	Thiomethoxam 25WDG	0.0025	109.68 (10.52)	110.60 (10.56)	100.68 (10.08)	86.28 (9.34)	71.74 (8.53)	42.40 (6.59)
8.	Buprofezin 25EC	0.0025	113.94 (10.72)	97.74 (9.94)	75.74 (8.76)	53.08 (7.35)	34.34 (5.94)	5.02 (2.45)
9.	Acetamaprid 20SP	0.004	110.54 (10.56)	107.20 (10.40)	98.74 (9.99)	76.68 (8.81)	68.34 (8.33)	27.88 (5.37)
10.	Novaluron 10 EC	0.075	109.40 (10.51)	105.28 (10.31)	91.14 (9.60)	82.34 (9.13)	62.60 (7.97)	16.74 (4.21)
11.	Imidacloprid 17.8 SL	0.05	115.02 (10.77)	100.08 (10.05)	85.20 (9.28)	69.48 (8.40)	48.74 (7.05)	13.60 (3.82)
12.	Control		108.34 (10.46)	117.68 (10.89)	130.14 (11.45)	143.02 (12.00)	155.20 (12.50)	173.20 (13.20)
	S.Em. ±		0.10	0.14	0.19	0.25	0.29	0.33
	CD at (5%)		NS	0.41	0.57	0.73	0.85	0.97

* Figures in parentheses are "n +1 square root transformed values DAS – Days after spraying
* Figures in parentheses are "n +1 square root transformed values DAS – Days after spraying
* Figures in parentheses are "n +1 square root transformed values DAS – Days after spraying

Observations recorded on third day revealed that treatment (T5) acephate (0.01%) resulted in significantly lowest aphid count (72.74) however, it was comparable with (T8) buprofezin (0.0025%) (75.74). On the other hand (T8) buprofezin (0.0025%) was also at par with (T6) flubendiamide (0.004%) and (T11) imidacloprid (0.05%) and recorded significantly less aphids than remaining treatments. On fifth day after the first spray again (T5) acephate (0.01%) and (T8) buprofezin (0.0025%) were the best and equally effective. Next in the order of effectiveness were treatments (T6) flubendiamide (0.004%) and (T11) imidacloprid (0.05%), found equally effective as that of (T9) acetamiprid (0.004%) and significantly superior over remaining treatments.

After seven days after the first spray also treatments (T5) acephate (0.01%) and (T8) buprofezin (0.0025%) proved superior, followed by (T6) flubendiamide (0.004%) and (T11) imidacloprid (0.05%), which were observed equally effective. Ten days after the first spray also treatments (T5) acephate (0.01%) and (T8) buprofezin (0.0025%) maintained their superiority.

After second spray- Table 2 provides the observations after second spray, and these indicate that

Table 2. Efficacy of insecticides against aphids infesting vegetable dolichos bean (after second spray)

Sr. No.	Treatment	Conc. (%)	Average number of aphids 3 leaves/plant				
			Second spray				
			1 DAS	3 DAS	5 DAS	7 DAS	10 DAS
1.	Emamectin benzoate 5SG	0.0033	96.88 (9.89)*	85.80 (9.32)	75.40 (8.74)	64.34 (8.08)	41.88 (6.55)
2.	Spinosad 45SL	0.0035	95.02 (9.80)	83.88 (9.21)	73.68 (8.64)	64.00 (8.06)	40.74 (6.46)
3.	Cartap hydrochloride 50 SP	0.1	92.60 (9.67)	80.34 (9.02)	67.68 (8.29)	56.74 (7.60)	29.88 (5.56)
4.	λ-cyhalothrin 5 EC	0.005	90.68 (9.57)	80.08 (9.00)	69.80 (8.41)	53.74 (7.40)	29.40 (5.51)
5.	Acephate 75SP	0.01	57.88 (7.67)	47.48 (6.96)	34.74 (5.98)	19.60 (4.54)	2.14 (1.77)
6.	Flubendiamide 5 WG	0.004	89.94 (9.54)	65.68 (8.17)	54.14 (7.43)	47.20 (6.94)	10.80 (3.44)
7.	Thiomethoxam 25WDG	0.0025	93.68 (9.73)	81.88 (9.10)	70.60 (8.46)	59.40 (7.77)	32.54 (5.79)
8.	Buprofezin 25EC	0.0025	59.68 (7.79)	50.48 (7.17)	40.93 (6.48)	29.94 (5.56)	3.80 (2.19)
9.	Acetamaprid 20SP	0.004	90.00 (9.54)	79.34 (8.96)	67.54 (8.28)	56.08 (7.56)	20.88 (4.68)
10.	Novaluron 10 EC	0.075	88.14 (9.44)	77.54 (8.86)	66.28 (8.20)	52.48 (7.31)	14.28 (3.91)
11.	Imidacloprid 17.8 SL	0.05	75.02 (8.72)	77.02 (8.83)	62.48 (7.97)	40.88 (6.47)	11.74 (3.57)
12.	Control		181.68 (13.52)	192.00 (13.89)	202.40 (14.26)	211.74 (14.59)	232.54 (15.28)
	S.Em. ±		0.33	0.31	0.33	0.54	0.38
	CD at (5%)		0.97	0.91	0.99	1.60	1.12

treatment (T5) acephate (0.01%) resulted in significantly the least aphid count (57.88), and comparable with (T8) buprofezin (0.0025%) showing 59.68 aphids; (T8) buprofezin (0.0025%) on other hand was also observed equally effective. Next in the order of effectiveness include: (T11) imidacloprid (0.05%), (T10), novaluron (0.075%), (T6) flubendiamide (0.004%), (T9) acetamiprid (0.004%), (T4) λ-cyhalothrin (0.005%) and (T3) cartap hydrochloride (0.1%).

Third day after the second spray treatment (T5) acephate (0.01%) and (T8) buprofezin (0.0025%) were found significantly superior; and (T7) thiamethoxam (0.075%), (T2) spinosad (0.0035%) and (T1) emamectin benzoate (0.0033%) were observed to be the least effective. On fifth day after the second spray again (T5) acephate (0.01%) was observed with the least aphid count (34.74); however, it was at par with (T8) buprofezin (0.0025%). Seven days after the second spray, again (T5) acephate (0.01%) was the significantly effective. After ten days after the second spray also (T5) acephate (0.01%) and (T8) buprofezin (0.0025%) were superior and equally effective. Next in order of effectiveness were (T6) flubendiamide (0.004%), (T11) imidacloprid (0.05%) and (T10) novaluron (0.075%) which were at par with (T9) Acetamiprid (0.004%).

After third spray (Table 3) - The treatment (T5)

Table 3. Efficacy of insecticides against aphids infesting vegetable dolichos bean (after third spray)

Sr. No.	Treatment	Conc. (%)	Average number of aphids 3 leaves/plant				
			Third spray				
			1 DAS	3 DAS	5 DAS	7 DAS	10 DAS
1.	Emamectin benzoate 5SG	0.0033	51.28 (7.23)*	34.68 (5.97)	21.40 (4.73)	9.68 (3.27)	0.00 (1.00)
2.	Spinosad 45SL	0.0035	46.60 (6.90)	30.74 (5.63)	19.54 (4.53)	8.60 (3.10)	0.00 (1.00)
3.	Cartap hydrochloride 50 SP	0.1	44.20 (6.72)	29.60 (5.53)	16.68 (4.20)	4.14 (2.27)	0.00 (1.00)
4.	λ-cyhalothrin 5 EC	0.005	33.14 (5.84)	20.14 (4.60)	10.94 (3.46)	4.08 (2.25)	0.00 (1.00)
5.	Acephate 75SP	0.01	10.68 (3.42)	0.28 (1.13)	0.08 (1.04)	0.00 (1.00)	0.00 (1.00)
6.	Flubendiamide 5 WG	0.004	14.60 (3.95)	4.94 (2.44)	0.08 (1.04)	0.00 (1.00)	0.00 (1.00)
7.	Thiomethoxam 25WDG	0.0025	46.48 (6.89)	28.28 (5.41)	16.48 (4.18)	5.08 (2.47)	0.00 (1.00)
8.	Buprofezin 25EC	0.0025	16.20 (4.15)	2.00 (1.73)	0.08 (1.04)	0.00 (1.00)	0.00 (1.00)
9.	Acetamaprid 20SP	0.004	24.40 (5.04)	12.14 (3.62)	4.20 (2.28)	0.00 (1.00)	0.00 (1.00)
10.	Novaluron 10 EC	0.075	21.40 (4.73)	10.28 (3.36)	3.88 (2.21)	0.00 (1.00)	0.00 (1.00)
11.	Imidacloprid 17.8 SL	0.05	18.08 (4.37)	5.80 (2.61)	0.20 (1.10)	0.00 (1.00)	0.00 (1.00)
12.	Control		274.68 (16.60)	290.74 (17.08)	306.94 (17.55)	324.68 (18.05)	347.68 (18.67)
	S.Em. ±		0.37	0.48	0.43	0.30	0.21
	CD at (5%)		1.08	1.45	1.28	0.88	0.61

Table 4. Efficacy of insecticides against aphids infesting vegetable dolichos bean and yield (pooled mean of 2013-2014)

Sr. No.	Treatment	Conc. (%)	No. of aphids 3 leaves/plant	Yield of q/ha 2013-2014
1.	Emamectin benzoate 5SG	0.0033	60.70 (7.85)	74.70
2.	Spinosad 45SL	0.0035	58.70 (7.73)	76.70
3.	Cartap hydrochloride 50 SP	0.1	54.10 (7.42)	93.29
4.	λ-cyhalothrin 5 EC	0.005	52.38 (7.31)	92.92
5.	Acephate 75SP	0.01	28.70 (5.45)	196.24
6.	Flubendiamide 5WG	0.004	39.72 (6.38)	149.20
7.	Thiomethoxam 25WDG	0.0025	56.40 (7.58)	81.74
8.	Buprofezin 25EC	0.0025	31.26 (5.68)	130.35
9.	Acetamaprid 20SP	0.004	48.90 (7.06)	105.79
10.	Novaluron 10 EC	0.075	46.15 (6.87)	155.84
11.	Imidacloprid 17.8 SL	0.05	40.55 (6.45)	137.35
12.	Control		218.95 (14.80)	42.58
	S.Em. ±		0.21	1.24
	CD at (5 %)		0.62	3.65

*****Mean of three sprays ******Figures in parentheses √n +1 transformed values

acephate (0.01%) resulted in the least aphid count (10.68), however it was at par with (T6) flubendiamide (0.004%), (T8) buprofezin (0.0025%) and (T11) imidacloprid (0.05%); (T6) flubendiamide (0.004%) in addition to (T8) buprofezin (0.0025%) and (T11) imidacloprid (0.05%) were also at par with (T10) novaluron (0.075%) whereas, (T8) buprofezin (0.0025%) (T11) imidacloprid (0.05%), (T10) novaluron (0.075%) and (T9) acetamiprid (0.004%) were similar in their efficacy.

Third day after the spray, again (T5) acephate (0.01%) was observed equally effective as that of (T8) buprofezin (0.0025%) and (T6) flubendiamide (0.004%) and significantly superior. Fifth day after the third spray, (T5) acephate (0.01%), (T6) flubendiamide (0.004%), (T8) buprofezin (0.0025%), (T11) imidacloprid (0.05%), (T10) novaluron (0.075%) and (T9) acetamiprid (0.004%) were observed equally effective. which recorded 0.08, 0.08, 0.20, 3.88 and 4.20 aphid count; remaining treatments namely (T4) »-cyhalothrin (0.005%), (T7) thiamethoxam (0.075%), (T3) cartap hydrochloride (0.1%), (T2) spinosad (0.0035%) and (T1) emamectin benzoate (0.0033%) were observed to be the least effective. Seventh day after the third spray it was shown that the treatments (T5) acephate (0.01%), (T6) flubendiamide (0.004%), (T10) novaluron (0.075%), (T9) acetamiprid (0.004%), (T8) buprofezin (0.0025%)and (T11) imidacloprid (0.05%) were aphid free and significantly superior.

The pooled data over thee sprays given in Table 4 reveal the superiority of (T5) acephate (0.01%) and (T8) buprofezin (0.0025%) with the least aphid population (28.70) and (31.26) and at par with each other; and (T6) flubendiamide (0.004%), (T11) imidacloprid (0.05%) and (T10) novaluron (0.075%) were observed at par with each other. On other hand treatment (T11) imidacloprid (0.05%) was also at par with (T10) novaluron (0.075%) and (T9) acetamiprid (0.004%). The treatments (T7) thiamethoxam (0.075%), (T1) emamectin benzoate (0.0033%) and (T2) spinosad (0.0035%) observed at par with each other were the least effective.

Thus 0.01% acephate was the most effective as reported earlier by Goncavles and Bleicher (2006), and Gour and Pareek (2003). Also, Sharma and Kumar (2013) in respect of imidacloprid Rawat et al. (2013) in respect of acetamiprid, imidacloprid and thiamethoxam corroborate the present observations. The effectiveness of acetamiprid and thiamethoxam had been reported by Jemimah et al. (2013);

thiamethoxam 25 WG @ 0.2 g/1 and imidacloprid 70 WG @ 0.3 g/1 by Kambrekar et al. (2013); and on imidacloprid by Shinde et al. (2011), Liu et al. (2010), Saad et al.(2004), Rohilla et al. (2004), Misra (2002), Gawade (2003) agree with the present observations. Cartap hydrochloride 4G had been reported earlier as effective (Ariudainambi and Prasad, 2003; Kendappa et al., 2005; Gour and Pareek, 2003) but it was found comparatively less effective.

The data on green pods yield recorded in the insecticidal treatments are presented in Table 4. These reveal that the highest total yield of 196.24 q/ha was obtained with 0.01% acephate which was significantly superior than all the remaining treatments; all the treatments were significantly superior in increasing the yield.

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P.S. Shinde* and A.L. Narangalkar

Department of Entomology
Dr. Balasaheb Sawant Kongan Krishi Vidyapeeth
Dapoli, Ratnagiri 415712
**Regional Fruit Research Station*
Vengurle, Dr.B.S.K.K.V., Dapoli
**Email: pooonamshinde@gmail.com (corresponding author)*

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BIOLOGY OF *SERRODES* SP.NR. *PARTATA* HAMPSON ON *SAPINDUS LAURIFOLIUS* VAHL.

Soap berries *Sapindus laurifolius* Vahl. [Family: Sapindaceae (common name- soap nut tree of south India (English), Ritha, Pasakotta (India), Arishthaka (Sanskrit)] is an ancient fruit, and some claim its origin to China, while others state this as India. The generic name is derived from the Latin words *sapo*, meaning "soap", and *indicus*, meaning "of India" (Quattrocchi and Umberto**,** 2000). Soapberries grow from the far

southern state of Kerala, to the northern regions of Rajasthan, and the eastern plains of the Himalaya. Soapberries have many uses, of which its pharmacological effects (*Sapindus mukorossi*) like anti-bacterial (Ibrahim *et al.*, 2006), insecticidal (Geyter *et al.*, 2007; Rahman *et al.*, 2007; Porras and Aristóbulo, 2009; Macedo *et al.,* 2011) are known.

Despite its insecticidal properties, soapnut in the Indian subcontinent is known to be infested by insect pests such as blossom webber (*Cydia* spp.) that attacks and causes damage to flowers, young fruits and twigs during October- April (Rao,1992). *Serinatha auger* and *Antilochus cogueberti* cause damage to fruits from January to April. The larvae of *Deudorix epijarbas* and *Rapala varuna* defoliate the leaves. *Fiorinia sapindi* feeds on the sap of shoots. *Phyllosticta* spp. and *Alternaria sapindi* causes leaf spot disease. The nymphs and adults of red cotton bug *Dysdercus cingulatus* damages the fruits (Kundu and Schmidt, 2015).

In August 2013, mature soapnut trees in the campus of Dr. Panjabrao Deshmukh Krishi Vidyapeeth (Dr. PDKV), Akola were observed defoliated by a semiloooper *Serrodes* sp.nr. *partata* Hampson. the larvae of *Serrodes partita* had been reported to feed on *Deinbollia pinnata* and larvae of *Serrodes trispila* on *Lecaniodiscus cupanioides* in Sierra Leone (West Africa.) (Hargreaves, 1936). The larvae feed on the leaves and defoliate the tree attributed to the total loss up to 25-30% in foliage. No information is available on the life history traits of this pest, and hence the present study.

The larvae of *Serrodes* sp.nr. *partata* were collected from the soapnut trees of University campus and reared on the fresh leaves of the soapnut in the laboratory of Department of Entomology, Dr. PDKV, Akola at ambient temperature during August to October, 2013. All the trees in the campus were found to be heavily damaged with around 45-50% foliage damage. Biology was studied and morphometrics of life stages were worked out with a digital microscope.

The various life stages and damaging symptoms are as given Fig. 1a; eggs were oval and pale green with incubation period being 5.8 ± 0.04 days (Table 1). A tiny semilooper hatched out and underwent five larval instars. Fifth instar when full grown entered into pupa. Semilooper feeds on leaves cause defoliation from last week of July to September. These were brown with three pair of true legs and five pairs of prologs; first and second instar were pale greenish yellow (Fig. 1a,b); with fifth instar having two small horns like processes on their 8th abdominal segment on dorsallye and metathoracic tergite was elevated hump like (Fig. 1e). The duration of first instar was 3.12 ± 0.67 days, second (Fig. 1b)- 4.47 ± 0.43 days, third (Fig. 1c)- 5.26 ± 0.17 days, fourth (Fig. 1d)- 5.76 ± 1.14 days, and fifth- 3.84 ± 1.23 days with total larval period being 22.15 ± 3.64 days. The pupation took place on leaves itself in silken webbings; pupa reddish brown, and obtect (Fig.1f), with mean duration being 15.93± 0.06 days (Table 1).

The length of the egg, first, second, third, fourth, fifth instar larvae, pupa and adult were observed to be: 0.58 ±0.23, 6.23 ±0.53, 14.73 ± 0.03, 32.05 ± 0.42, 40.37 ± 0.03, 50.59 ± 0.24, 25 ± 0.07 and 24.71 ± 0.87 mm, respectively; breadth of these being 0.46 ±0.67, 0.8 ±0.32, 2.35 ± 1.04, 3.18 ± 1.45, 6.17 ± 0.95, 6.96 ± 0.23, 9.5 ± 0.04 and 55.28 ± 1.62 mm, respectively (Table 1).

Adult with antennae setaceous, and femur and tibia clothed with dense and long hairs, with abdomen covered by hairs and tip of the abdomen with tuft of hairs; male was slender and small compared to the female. Forewing was pale yellowish at middle with wavy markings and triangular black mottled with yellowish patch at the base of the wing, half portion of the distal end of the fore wing dark. Hind wing was pale yellow with black dark shedding at apical margin. In female abdomen was broader than male, wing span larger than male. Forewing was pale yellow with a

Table 1. Lifecycle of *Serrodes* sp.nr. *partata* Hampson- duration and morphometrics

Stages	Duration (Days)	Length (mm)	Breadth (mm)
Egg	5.8±0.04	0.58±0.23	0.46±0.67
Larva			
1st Instar	3.12±0.67	6.23±0.53	0.8±0.32
2nd Instar	4.47±0.43	14.73±0.03	2.35±1.04
3rd Instar	5.26±0.17	32.05±0.42	3.18±1.45
4th Instar	5.76±1.14	40.37±0.03	6.17±0.95
5th Instar	3.84±1.23	50.59±0.24	6.96±0.23
Pupa	15.93±0.06	25±0.07	9.5±0.04
Adult	11±1.67	24.71±0.87	55.28±1.62

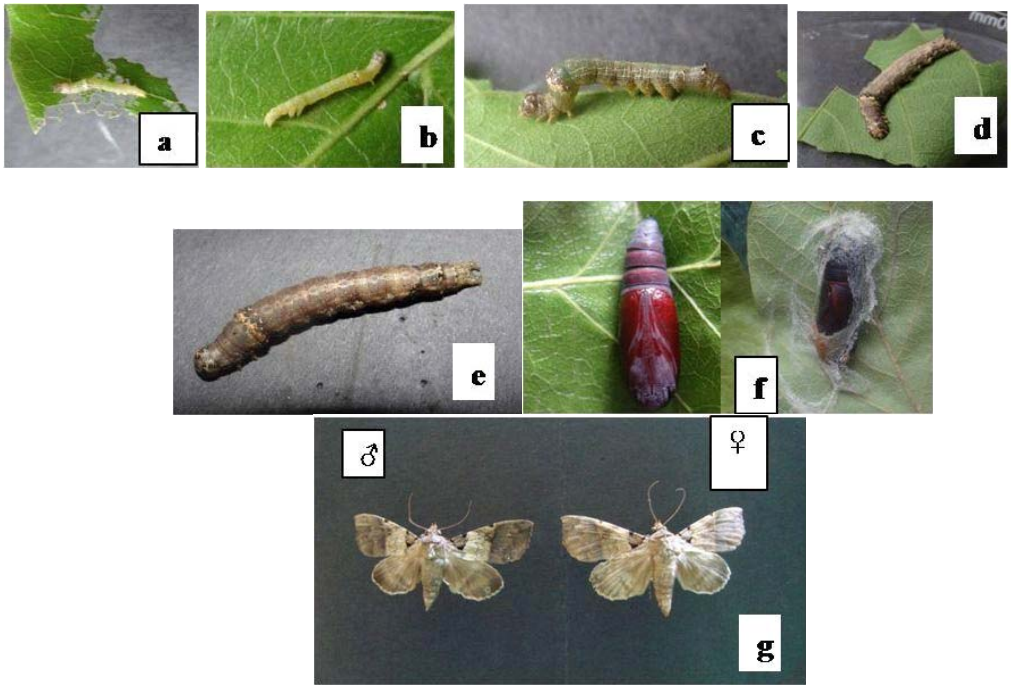

Fig. 1. Life stages of *Serrodes* sp. nr. *partata* a-1st instar , b-2nd instar, c-3rd instar, d-4th instar, e- 5th instar larva, f- pupa and g- adult

triangular dark patch at base of the wing and pale at the apical end (Fig. 1g); in hind wing margin was covered with hairs. The mean adult longevity was 11±1.67 days. The total life cycle was completed in 49.08 ± 5.67 days (Table 1).

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Department of Entomology
Dr. PDKV, Akola 444104
**Email: drsmdadmal@rediffmail.com*

D.M. Bawaskar, S.M. Dadmal*
D.B. Undirwade and
Suvarna Khadkkar

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SEASONAL INCIDENCE OF PESTS OF SAPOTA IN SOUTH GUJARAT

Sapota (*Manilkara achras* Mill), known as 'Chiku' is an important subtropical fruit, and it is largely grown in Gujarat, Maharashtra, Karnataka, Tamil Nadu, Kerala, Uttar Pradesh, Haryana, Punjab and West Bengal (Bose, 1985). It is attacked by more than 25 insect pests (Butani, 1979), with 16 insect pests found in Gujarat (Patel, 2001). These include bud borer, chiku moth, midrib folder, leaf miner, fruit flies and sucking pests. For the effective IPM it is essential to know seasonal incidence of these, and the present study explores this aspect on the bud borer, chiku moth, midrib folder, leaf miner and fruit flies on sapota in south Gujarat.

The field experiment was carried out at the College farm, College of Agriculture, N. A. U., Bharuch during 2012-13, 2013-14 and 2014-15. Orchard located at Bharuch was surveyed fortnightly and observations on the population dynamics of various pests viz., chiku bud borer, chiku moth, leaf miner, midrib folder and fruit fly made. Randomly 10 trees and 10 twigs/tree having flower buds were observed fortnightly and the bud damage by chiku moth and bud borer recorded. The % infestation was worked out based on total number of flower buds and damaged buds on 100 twigs. Similarly, 100 twigs having new flush of leaves were observed fortnightly and the leaves damaged by leaf miner and midrib folders recorded, and % infestation worked out. For monitoring of fruit fly, a Nauroji- Stone house fruit fly trap @ 10/ha was installed in the orchard and trapped flies were counted at fortnightly interval. The data obtained were correlated with weather parameters *viz.*, maximum and minimum temperature, morning and evening relative humidity (%), wind speed (km/hr), sunshine hours, rainfall (mm) and evaporation.

The three year pooled data presented in Fig. 1 reveal that the chiku moth, *Nephopteryx eugraphella* Ragonot was active throughout the year. The chiku moth damage fluctuates with six peaks, with bud damage being 2.23 to 11.52%; maximum bud damage was observed during first fortnight of September (11.52%), then it gradually decreased to 2.23%, in second fortnight of March. Almost similar observation had been reported by Nelson and Logiswaram (1998), that maximum bud damage was in June followed by September and the least in May.

As regards chiku bud borer, *Anarsia achrasella* Bradley, it was observed active throughout the year with four peaks. The bud damage ranged between 5.76 to 13.85% with maximum being during second fortnight of September (13.85%) and the least during first fortnight of April (5.76%). The data on leaf miner *Acrocercops gemoniella* Stainton reveal that its infestation is from 2.74 to 7.09%, highest being at first fortnight of December (7.09%). The midrib folder *Banisia myrsusalis elaralis* Walker was again observed throughout the year with infestation being between 4.31 to 11.69%, maximum at first fortnight of November (11.69%). These findings

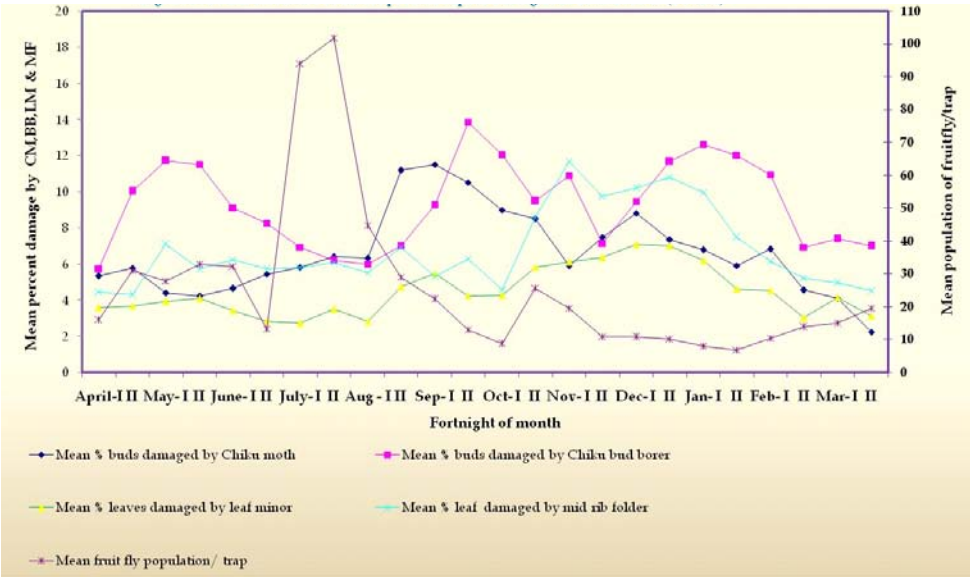

Fig. 1. Seasonal incidence of insect pests of sapola during 2012-13 to 2014-15 (Pooled)

Table 1. Correlation coefficients of sapota pest complex vs. weather parameters (pooled data, 2012-13,2013-14,2014-15)

S.No.	Weather parameter	Chiku moth	Chiku bud borer	Leaf miner	Midrib folder	Fruit fly
1	Maximum Temp.	-0.266*	-0.173	-0.263*	-0.172	0.060
2	Minimum Temp.	0.042	-0.125	-0.375*	-0.322*	0.374*
3	Morning relative humidity (MRH)	0.288*	-0.073	-0.139	-0.141	0.324*
4	Evening relative humidity (ERH)	0.271*	-0.127	-0.128	-0.134	0.399*
5	Wind velocity (WV)	-0.185	0.028	-0.386*	-0.184	0.276*
6	Bright Sunshine hour (BSS)	-0.237*	0.108	0.214	0.066	-0.435*
7	Rain fall(RF	0.066	-0.006	-0.118	-0.121	0.256*
8	Evaporation	-0.419*	-0.037	-0.168	-0.159	0.063

*Significant p=0.05

are in agreement with those of Satish et al. (2014) who observed a peak of midrib folder incidence in November and December. The activity of fruit fly was again throughout the year, with maximum catches during the second fortnight of July (101.9 fruit fly/trap) while the least catches were in the second fortnight of January (6.97 fruit fly /trap). These results corroborate those of Nandre and Shukla (2014) who observed maximum activity of fruit fly during March to August and minimum during December and January.

The correlation between pest incidence and weather factors given in Table 1 reveal the following: maximum temperature (r=-0.266), sunshine hours (r= -0.237) and evaporation (r= -0.419) had significant negative correlation with chiku moth, and morning (r=0.288) and evening relative humidity (r=0.271) had significant positive correlation. These findings are in contrast to Ghirtlahre et al. (2015), where only minimum temperature, average temperature and sunshine hours have a significant correlation with leaf infestation by leaf webber, *N. eugraphella.*

The chiku bud borer damage had no correlation with any factors, and these observations more or less corroborate with Sathis et al. (2014). As regards leaf miner, there was significant negative correlation with maximum (r= -0.263) and minimum temperature (r= -0.375), and wind velocity (r= -0.386). The midrib folder infestation was observed significantly negatively correlated with minimum temperature (r= -0.322). The results revealed that minimum temperature (r=0.374), morning relative humidity (r=0.324), evening relative humidity (r=0.399), wind velocity (r=0.276) and rainfall (r=0.256) had significant positive correlation with fruit fly population, while sunshine hours (r= -0.435) had significant negative correlation. These observations agree with those of Nandre and Shukla (2014).

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Department of Entomology, College of Agriculture
Navsari Agricultural University, Bharuch 392012
**Email: patel.devendra2829@yahoo.com*

D.R. PATEL*, J.J. PATEL
D.V. MUCHHADIYA, R.B. PATEL AND
K.G. PATEL

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SEARCHING NEW SOURCES FOR APHID RESISTANCE IN POSTRAINY SORGHUM

Sorghum aphid, *Melanaphis sachhari* (Zehntner) is a serious pest of postrainy sorghum. This aphid affects grain and fodder yields and fodder quality, and in sorghum, the losses are between 12-26% and 10-31% with an overall loss of 16% and 15% for grain yield and fodder yield, respectively (Balikai, 2001). The nymphs and adults suck sap from the lower surface of leaves, leading to stunted growth. The aphids secrete honey dew which fall on the plant as well as ground and sooty moulds grow on it. A whole plant often dies in case of heavy infestation. The infestation is more severe in crops under drought stress. As the crop is grown by resource-poor farmers, chemical control is not advisable. Host plant resistance is the best approach. Sources with moderate levels of resistance to *M. sacchari* had been reported by several workers (Sharma and Dhillon, 2005; Sharma *et al.,* 2014; Bhagwat *et al,* 2014). Though studies were done on aphid resistance on a wide range of genotypes, the established varieties, parental lines and hybrids with *rabi* adaptation were not evaluated. Hence, along with the established genotypes (maintainer lines, restorer lines, varieties and hybrids), postrainy germplasm lines that are distinct to India as well as exotic germplasm that closely resemble postrainy sorghums of India obtained are being evaluated The present study aims to identify aphid tolerant lines that can be used as sources in breeding programs and also study the agronomic and yield traits that influence the intensity of aphid damage.

Diverse postrainy sorghum genotypes (270) involving 52 varieties, 17 R-lines, 16 B-lines, 68 preliminary hybrids, 50 exotic germplasm lines and 67 landraces with postrainy season adaptation were evaluated during 2012 and 2013 post rainy seasons at the ICAR- Indian Institute of Millets Research (IIMR), Rajendranagar, in a two-replicated RBD design. There was severe infestation under natural conditions at hard dough stage (105 days after sowing) during 2013 postrainy season, and population up to 27 aphids/ cm^2 of leaf observed. Apart from the agronomic traits, observations for damage rating on scale of 1-9 as suggested by Sharma *et al.* (2014) was done, where 1 = no apparent damage and 9 = >90% of leaf area damaged. The damage rating data was subjected to logarithmic transformation and the data on % seed set to arcsine transformation before conductng ANOVA using Genstat 12^{th} edn and correlation coefficients were estimated with Microsoft Excel.

The crop growth period experienced low night temperatures ranging from 6.7 to 17°C (mean: 13.6) which was much low than normal years. The average relative humidity (RH) ranged from 40 to 83%. The crop was irrigated once during seedling establishment and once during vegetative stage. As it was grown under unirrigated conditions, the crop experienced drought. The prolonged drought spell and with suitable climatic conditions, heavy incidence of aphids was observed during 2013 postrainy season, and the damage score ranged from 2 to 8 (mean: 4.6). The genotypes CRS 20, BRJ 67, RS 585, BN 195, 104B, 609A x C43, EP 14 and EC 33 recorded aphid score of 2.0 to 2.5 (Table 1). The performance of these genotypes for other agronomic traits is given in Table 1. Among the genotypes with less damage score, the genotypes other than 609 x C43 can serve as new sources for resistance in postrainy sorghum. Apart from these lines, EP 13, EP 42, EP 45, EP 92, EP 93. EP 106, EP 117, IS 23574, IS 2235, IS 21512, IS 11189, SLV 43, SLV 46, SPY 504 and M 31-2B has moderate levels of tolerance (score <3.5) and high grain yield/plant (>50g).

The association of the damage with agronomic and yield contributing traits were studied (Table 2). Early flowering genotypes were more damaged which is related to its preference for older leaves as observed earlier by Sharma et al. (2014). Genotypes having more panicle length, less seed set% under both self and open pollination, less grain yield and low panicle harvest index under self pollination were more attacked. Due to the cold temperatures that prevail in the *rabi* season, poor seed set especially in hybrid parental lines and hybrids causes the sugar accumulation in the leaves and stem due to decrease in sink demand. This is one of the factors influencing the intensity of aphids. Similarly, the damage score was also influenced by narrow panicle width, panicle weight, grain yield and panicle harvest index under open pollination. Similar results had been known (Bhagwat *et al.* 2014, Sharma *et al.* 2014).

The trait associations indicate that breeding for medium to late maturing genotypes with good seedling vigor, higher seed set potential, moderate panicle length and greater panicle width can reduce the aphid population indicating the importance of antibiosis mode of insect resistance due to unavailability of sufficient amount of nutrients.

Unlike rainy season grown hybrids, postrainy

Table 1. Performance of promising aphid tolerant genotypes (amongst 283 evaluated)-(2013-14) postrainy season, IIMR, Rajendranagar, Hyderabad)

Genotype	Aphid damage rating (1-9)	Days to 50% flowering	Plant height	Panicle length	Panicle width	Number of primaries	Seed set% under selfing	Grain yield/ plant (self)	Panicle harvest index (self)
CRS 20	2.0(1.1)	88	235	12.5	4.4	39.5	78 (62)	38	0.78
BRJ 67	2.5(1.3)	91	160	16.4	5.9	46.5	78 (62)	53.5	0.8
RS 585	2.5(1.3)	86	178	15.0	4.0	45.5	82 (67)	28.5	0.76
BN 195	2.5(1.3)	87	153	13.5	3.4	31.0	95 (78)	51.5	0.84
104B	2.5(1.3)	92	153	16.8	4.3	61.3	78 (63)	36.5	0.66
609A × C43	2.5(1.3)	78	168	24.5	4.3	35.8	98 (81)	59.5	0.74
EP 14	2.5(1.3)	89	173	29.5	6.9	44.8	99 (83)	50.5	0.74
EC 33	2.5(1.3)	89	203	13.5	3.8	51.0	95 (80)	43.5	0.91
Mean	4.6(1.7)	84	199	17.5	4.8	52	81 (67)	41.2	0.70
Range	2.0 (l.l) to 8.0 (2.2)	61 to 97	98 to 353	8. 6 to 36.8	2.4 to 7.4	18 to 101	0 (0.1) to 100 (89.9)	2 to 88	0.2 to 0.9
Lsd (P<0.05)	3.0 (0.5)	8.0	92	6.5	1.8	27	32 (26)	29.9	0.2

Table 2. Traits contributing to aphid tolerance vs. agronomic/yield traits (2013-14 postrainy season, 1IMR, Rajendranagar)

Trait	Aphid score
Aphid score	1.00
Days to emergence	-0.06
Seedling vigour	0.12**
Days to 50% flowering	-0.41**
Plant height (cm)	0.06
Panicle length (cm)	0.28**
Panicle width (cm)	-0.16**
No. of primaries	-0.07
Seed set% (Open)	-0.19**
Seed Set% (Self)	-0.25**
Single panicle weight under open pollination	-0.12**
Grain yield per panicle under open pollination	-0.16**
Panicle harvest index for open pollinated panicle	-0.30**
Single panicle weight under self pollination	-0.30**
Grain yield per panicle under self pollination	-0.35**
Panicle harvest index for self pollinated panicle	-0.34**

season adapted hybrids are not popular with the farmers. There is an immediate need for the development of hybrid parental lines and hybrids with grain yield potential and resistant to biotic and abiotic stresses. The occurrence of aphids on postrainy season sorghum is detrimental to grain and fodder yield as well as quality and its density were greater at milk stage (Balikai, 2001). In order to build up host plant resistance, it is important to identify the resistant lines in cultivars and in different breeding groups. Hence the breeding material was grouped into maintainer lines, restorer lines, hybrids, varieties and germplasm lines and assessed for the traits that showed significant correlation with aphid score (Table 3).

The hybrids were observed to be the highly susceptible, and compared to other groups, these were early flowering, had greater panicle length, poor seed set and poor panicle harvest index. Hence, it is important to increase the sink demand in hybrids for reducing the attack. Though good seed set was noticed in the germplasm lines, these were the next most vulnerable group and the lines showed early flowering. However, the germplasm lines with highest seed set and grain yield as observed now can be introgressed in hybrid parental lines to generate hybrids with good seed set and high grain yield. Varieties were the best performing among all the groups for both resistance

Table 3. Performance of various breeding groups for aphid tolerance and agronomic traits

	Aphid score flowering	Days to 50%	Panicle length	Panicle width (Open)	Seed set % (Self)	Seed set% plant	Grain yield/ index (self)	Panicle harvest plant (self)	Grain yield/ (self) (self)	Panicle harvest index (self)
B-lines (lS)	4.1 (1.6)	88	18.6	4.1	91 (75)	83 (67)	34.4	0.7	34.4	0.68
R-lines (18)	4.1 (1.6)	85	14.7	4.7	94 (77)	88 (72)	40.2	0.7	39.0	0.79
Hybrids (69)	5.0(1.8)	82	21.8	4.6	84 (69)	65 (55)	37.3	0.6	37.3	0.64
Varieties (63)	4.1 (1.6)	87	16.3	4.6	93 (77)	89 (72)	39.0	0.8	49.3	0.76
Germplasm lines (120)	4.8(1.7)	83	15.9	5.2	90 (76)	86 (71)	49.3	0.8	40.2	0.73

and yield parameters. Resistance to aphids is monogenic and controlled by a single dominant gene (Tan *et al.,* 1985) or two dominant genes (Deshpande *et al.,* 2011). In order to breed for resistant hybrids, utilizing the tolerant hybrid parental lines can bring in resistant hybrids with matching quality as that of varieties. The novel germplasm lines identified in the current study require to be further exploited for breeding aphid tolerant hybrid parental lines.

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ICAR-Indian Institute of Millets Research,
Rajendranagar, Hyderabad 500030
**Email: sanjana@sorghum.res.in*

P. Sanjana Reddy* and
V.R. Bhagwat

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DESCRIPTION OF A NEW PIPUNCULID (DIPTERA) FROM INDO-NEPAL BORDER OF CHAMPARAN DISTRICT, BIHAR

Pipunculids belongs to the family Pipunculidae under Diptera with a worldwide distribution. The earlier name of this family was Dorilaidae, since its type genus used to be *Dorilas*, erected by Meigen (1800). It is a sister group of the flower flies (Syrphidae and Platypezidae) but can easily be differentiated by their wing venation, the cell r_{4+5} being open and the vena spuria being absent (Papp et al., 2000). Pipunculids with hover flies or flower flies form a subordinate group, Syrphidea (Griffith, 1972). The relationship of the family Pipunculidae with Syrphidae was studied by Skevington and Yeates (2001). These flies have

affinities with Conopidae (Cumming et al., 1995). Individual flies vary in body length from 1.5 mm to 5 mm and can be distinguished by their large spherical or hemispherical head which is extremely mobile and composed almost entirely of compound eyes. These are therefore called ''Big-headed Flies''. These live generally in shades of herbs, shrubs, in grasses, and garden in hilly places.

Pipunculids or big headed flies are exclusively parasitoids of various homopterans i.e. leafhoppers and planthoppers including Cixiidae, Delphacidae, Flatidae, Cercopidae, Cicadellidae, Fulgoridae (Ferrar, 1987) and Membracidae. These attack nymphs and adults of all groups except the Cercopidae, in which only adults are attacked (Waloff and Jervis, 1987). Pipunculidae is the only family of Diptera that attacks Cicadellidae, preferring species of subfamilies Deltocephalinae and Typhlocybinae (Freytag, 1985). A total of 1400 species of Pipunculidae are known (Rafael and Skevington, 2010). As far as the taxonomy of these flies is concerned, it is largely neglected in India and Nepal. This study includes description of a new species.

The collection of flies was made during July 2014 to June 2016 from various places of Indo-Nepal border i.e. Valmikinagar, Ramnagar, Hetauda and Pokhara. Hand sweeping net method was used randomly over flowers, garden, grass, herbs, shrubs and rice field in sunshine and non windy day. In 3 to 4 hours sweep only 1 to 2 insects could be collected, and dissections were done under stereozoom microscope. For temporary mounting, glycerol was used while permanent preparation were made after passing the material through the alcohol series and finally mounted in Canada balsam. Diagrams were made with camera lucida. The description follows morphology by Cammerson (1974) and classification after Hardy (1972).

A. Key to the species

1. 3rd section of costa very short compared to 4th section and lacking a distinct stigma..... .....*Tomosvaryella* 3rd section of costa with brown stigma usually equal or longer than 4th section..... *Eudorylas*.....2
2. Propleural fan present.....*Pipunculus*
   Propleural fan absent.....3
3. Wings entirely hyaline... .....*Tomosvaryella*
   Wings not entirely hyaline.....4
4. 3rd antennal segment acute, Male hypopygium with an apical membranous area and with a membranous protrusion from the apex.....*Eudorylas discors* Hardy 3rd antennal segment not acute.....5
5. Third antennal segment acuminate. Male hypopygium with a prominent cleft extending longitudinally down the right side, surstyle broad, left surstyle has a narrow pointed end... ....*Eudorylas distocruciator* Hardy - Cylindrical abdomen with four pairs of spines in 1st abdominal segment. 3rd antennal segment is more acuminate. Right surstyle curved & stout, left narrow with curved apex.....*Eudorylas hemicruciator* Hardy- 3rd antennal segment is more curved but acuminate, abdomen more cylindrical, surstyle-asymmetrical, claspers boot shaped..... *Eudorylas rajaensis* Michael-2nd segment of antenna cup shaped with 4 dorsal and 2 ventral small black bristles, coxa of each foreleg bears single spiny bristles anteriorly. Abdomen curved; 7th & 8th abdominal segments visible in specific reduced manner (Fig.), male genitalia with sursyle kidney shaped.....*Eudorylas curvibellata* sp.nov.

B. Description of *Eudorylas curvibellata* sp. nov. (Figs. 1-3)

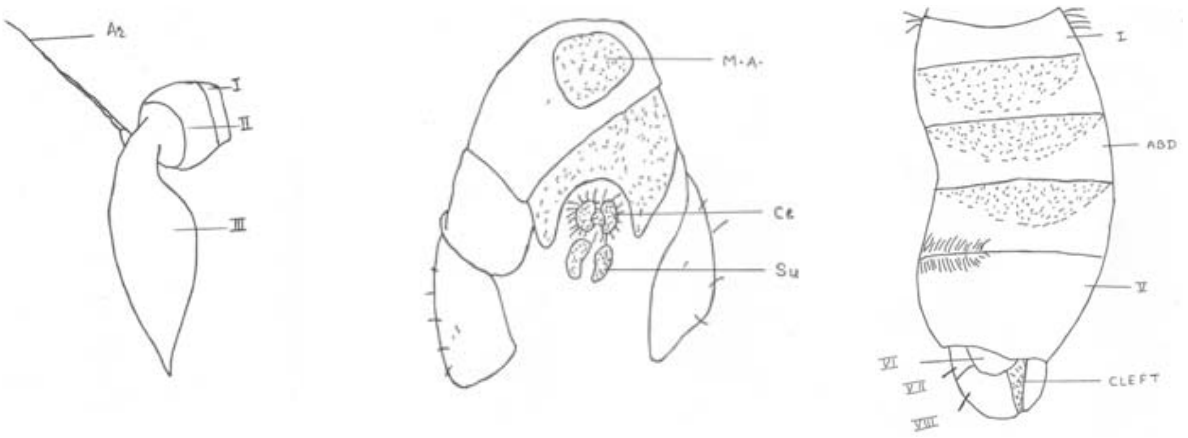
Male: Small bodied, yellowish black.

Head: Globose as longas broad,equal to the diameter of thorax, yellowish brown, dull non shiny, facets are homogenous. Separation of both eyes below the antenna, about five facets are broad, which is silvery ash black.

Antenna: 1st antennal segment is narrow brown, 2nd antennal segment is yellowish brown forming a cup shaped concavity bearing a pair of black bristles above and below. 3rd antennal segment is more curved backwardly and acuminate, colour yellowish brown up to the middle but white cream hyaline at the apex. Arista black about 2nd to 3rd antennal segment.

Thorax: Predominantly deep brown, Mesonotum shiny complete bare. It's lateral walls are rough black with minute brown hairs.Scutellum- narrow, silvery brown; Propleural fan- absent; Humeri- deep, yellowish brown; Halters- complete yellow hyaline in nature.

Wing: Hyaline with deep brown stigma filling the 3rd costal segment, 3rd coastal segment is about equal to the 4thcostal segment. 3rd and 4th combined together slightly bigger than 5th costal segment. Cross vein r-m is situated about in the middle of discal cell.



1 **2** **3**

Figs. 1-3. *Eudoryla scurvibellata,* sp.nov. 1. Antenna. 2. Male genitalia 3. Abdomen

Legs: Predominantly yellowish brown. Femora are completely bare having metallic brown shinning in the middle with yellow base and apex. It lacks ciliation on the dorsal surface except a single row of minute ciliation on the ventral surface. Tibia with four rows of brown species present dorsally, as well as ventrally. Tarsi with many rows of short yellow setae extending their full length. Last segment of the tarsi are black. Tarsal claw and pulvilli are of moderate size. Claws are little larger than pulvilli. There are entirely yellow except for the curved black apex.

Abdomen: Predominantly brownish black sub cylindrical curved. Left wall concave, Right wall convex, broadest in 3rd and 4th abdominal segment. 5th abdominal segment is largest. There is narrow slanting depression at the left junction of 4th and 5thabdominal segment from both sides.1st abdominal segment bears four large stout bristles at right side and three at left sides (perhaps one broken), 6th abdominal segment is in the form of a semi circle, Protuberance attached a little left medial base of 5th abdominal segment. 7th abdominal segment is somewhat small,square attached to left adjacent side of 6th segment. 8th abdominal segment about 0.5x as long as 5th with a large oval membranous area at it's ventroapical area and a deep vertical prominent cleft towards right side. Surstyle- a little asymmetrical, right one is little, more stout and broad at the base, left one is of same length but more cylindrical and kidney shaped. Cerci small with radiating rows of bristles on inner as well as outer side.

Body length: 3.8mm; wings: 4.5mm.

Specimen examined: *Holotype*: Male , Hatauda, Nepal, 2500 ft., 17.09.2015, Coll. Shailendra Kumar Amogh.

Etymology: The species name is based on shape of the abdomen which is curved towards left side.

Remarks: The new species is nearer to *P. Eudorylas distcruciator* Hardy, *Pip. Eud. hemicruciator* Hardy, and *Pip. Eud. rajaensis* Michael in structure of wing, antenna and thorax and presence of a prominent vertical effect in the last abdominal segment but differs: in shape of the abdomen which is curved towards left side; 7th, 8th abdominal segments also visible; surstyle a little asymmetrical, kidney shaped; and cerci small.

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Department of Biological Sciences, SHIATS, Allahabad 211007
***Department of Entomology; ***Department of Zoology,*
R.L.S.Y College, Bettiah 845438, BRABU, Muzaffarpur
**Email: shailendrakamogh@gmail.com*

Shailendra Kumar Amogh*
Ashwani Kumar and**
Prakash Michael***

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DIAGNOSTICS OF SOME INDIAN SPECIES OF *MALADERA*

White grubs are considered as pest of national importance due to their wide host range, huge economic loss and difficulty in management. *Maladera* Mulsant and Rey, 1871 is one of the important genera of white grubs causing damage to various field, horticultural and plantation crops in India. The genus is one of the largest groups consisting of more than 500 described species widely distributed in Palearctic, Oriental and Afrotropical regions (Ahrens, 2003). *Maladera castanea* (Arrow, 1913) feeds on more than 100 plant species, preferring about 30 host plants with succulent roots (Tashiro, 1987). The species may have one generation (Horion, 1958; Tashiro, 1987) to two generations/ year (David and Charles, 2009), depending on the climatic conditions with the average longevity of adults about one month (Tashiro, 1987). Annually, two generations of *Maladera* spp. were reported in Israel (Golberg *et al*., 1986; Golberg *et al*., 1989) and India (Kumawat, 1992; Yadava and Sharma, 1995). There are few studies on the genus *Maladera* from India. The phylogeny of *Maladera* been investigated with morphological data (Ahrens, 2005). The inadequate and sketchy illustrations of taxonomic characters including genitalia are not sufficient for accurate identification of the species. Hence, the present study redescribes 12 major species of the genus *Maladera viz., M. insanabilis* (Brenske, 1894), *M. iridescens* (Blanchard, 1850), *M. fumosa* (Brenske, 1898), *M. burmeisteri* (Brenske, 1898), *M. discrepens* (Moser, 1915), *M. cardoni* (Brenske, 1896), *M. simlana* (Brenske, 1898), *M. nilgirensis* (Sharp, 1903), *M. atratula* (Von Dalle Torre, 1912), *M. affinis* (Blanchard, 1850), *M. indica* (Blanchard, 1850) and *M. coxalis* (Moser, 1915).

Surveys were made in different locations of Uttar Pradesh, Himachal Pradesh, Rajasthan and Uttarakhand for the collection of sericine adults during April to July, 2013. Studies were carried out in the Insect Biosystematics Laboratory, National Pusa Collection (NPC), Division of Entomology, Indian Agricultural Research Institute, New Delhi during 2013-14. Collections were done during the night using light traps equipped with black and mercury light sources. The beetles collected in the collection bucket were transferred to bottles containing cotton swab sprinkled with ethyl acetate. Specimens were sorted out, relaxed, pinned and grouped according to external characters for preliminary studies. Later the specimens were examined under stereozoom microscope Leica EZ24HD. Drawing tube attached to a Nikon SMZ10 stereozoom microscope was used to draw the line diagrams. Photographs were taken with the help of Leica EZ24HD stereozoom microscope connected to Leica Application Suite (LAS).

For genitalia studies, the male specimens were sorted out based on pygidium and tibial spurs structure. The abdomen of the specimen was gently detached from the body and placed in 10% potassium hydroxide (KOH) solution for few hours and genitalia was

extracted out through the basal foramen. Measurements were taken for length and width of full body as well as head segment. Twelve characters were used for the redescription of the species *viz*., length and width of the body and head, length of antennal club with respect to rest of the antennae (longer / shorter / equal) punctations on clypeus (fine / coarse / rugose / shallow/ deep / thick / sparse), punctations on frons, punctation, serration and angles of pronotum, punctations and bristles on scutellum, metasternum and pygidium, angle between foretibial dentations, length of metatibial spurs with respect to first metatarsomere, presence of hairs on metatarsomeres, elytral costae (wide/ narrow) and male genitalia (phallobase and parameres).

The length and width of species studied ranged between 7.86-12.90 mm and 4.43-6.89 mm, respectively (Table 1). Characters for distinguishing species are given below:

1. Clypeal hairs and punctuations: Based on punctation patterns and presence of hairs on surface, clypeus of the species is considered as important character to distinguish the related species. Clypeus was found to be rugosely punctate only in *M. iridescens* (Fig 1.B) and *M. burmeisteri* (Fig 1.A) among studied species. The clypeal hairs on *M. burmeisteri* (Fig 1.A) are characteristic to the species, isolating it from other species.

2. Length of antennal club vs. rest of the antenna: The antennal club was longer than the rest of the antennae in *M. atratula*, *M. burmeisteri*, *M. discrepens*, *M. cardoni*, *M. indica* and *M. iridescens* (Fig 1.C-H). It was also used to distinguish between *M. indica* and *M. affinis*.

3. Scutellar, metasternal and pygidial bristles: Scutellar punctations were furnished with short bristles in *M. coxalis*, *M. iridescens*, *M. indica* and *M. fumosa* (Fig 1.I-L). Metasternal punctations were without bristles in *M. insanabilis* and *M. simlana* (Fig 1.M-N). *M. fumosa* and *M. nilgirensis* can easily be differentiated based on the pygidial bristles which were present in *M. fumosa* and absent in *M. nilgirensis* (Fig 1.O-P).

4. Metatarsal hairs: The rows of short hairs found on the inner side of metatarsomeres of *M. iridescens* and *M. discrepens* formed distinguishing character separating them from other species (Fig 1.Q-R). The length of the first metatarsomere with respect to superior metatibial spur can be used to distinguish between *M. iridescens* and *M. discrepens*.

5. Male genitalia: Male genitalia characters are considered to aid in identification of the species. The tip of the parameres was hooked in case of *M. insanabilis*, *M. affinis* and *M. nilgirensis* (Fig 1.S-U). Male genitalia of *M. insanabilis* and *M. affinis* were found to closely resemble each other, supporting the chances of sister species. Complex parameres were found in *M. iridescens*, *M. burmeisteri*, *M. discrepens*, and *M. indica*.

6. Morphometrics: The length vs. breadth ratio for the studied species are given in Table 1. Of the

Table 1. Morphometrics of *Maladera* spp., from India

Species	Body (mm)		Head (mm)		Ratio (L/B)	
	L	B	L	B	Body	Head
Maladera insanabilis (Brenske, 1894)	9.35	4.72	1.43	2.17	9:4	1:2
M. iridescens (Blanchard, 1850)	12.90	6.89	2.06	2.95	2:1	1:1
M. burmeisteri (Brenske, 1898)	9.16	5.91	1.67	2.46	9:5	1:2
M. fumosa (Brenske, 1898)	7.86	4.43	1.47	1.97	7:4	1:1
M. discrepens (Moser, 1915)	11.32	5.51	1.97	2.56	11:5	1:2
M. simlana (Brenske, 1898)	9.56	4.43	1.47	2.16	9:4	1:2
M. cardoni (Brenske, 1896)	8.56	4.53	1.57	2.16	2:1	1:2
M. affinis (Blanchard, 1850)	8.86	4.62	1.47	2.36	2:1	1:2
M. nilgirensis (Sharp, 1903)	8.46	4.62	1.50	2.16	2:1	1:2
M. indica (Blanchard, 1850)	8.66	4.33	1.47	1.97	2:1	1:1
M. coxalis (Moser, 1915)	12.01	6.40	2.16	2.75	2:1	1:1
M. atratula (Von Dalle Torre, 1912)	10.44	5.71	1.77	2.65	2:1	1:2

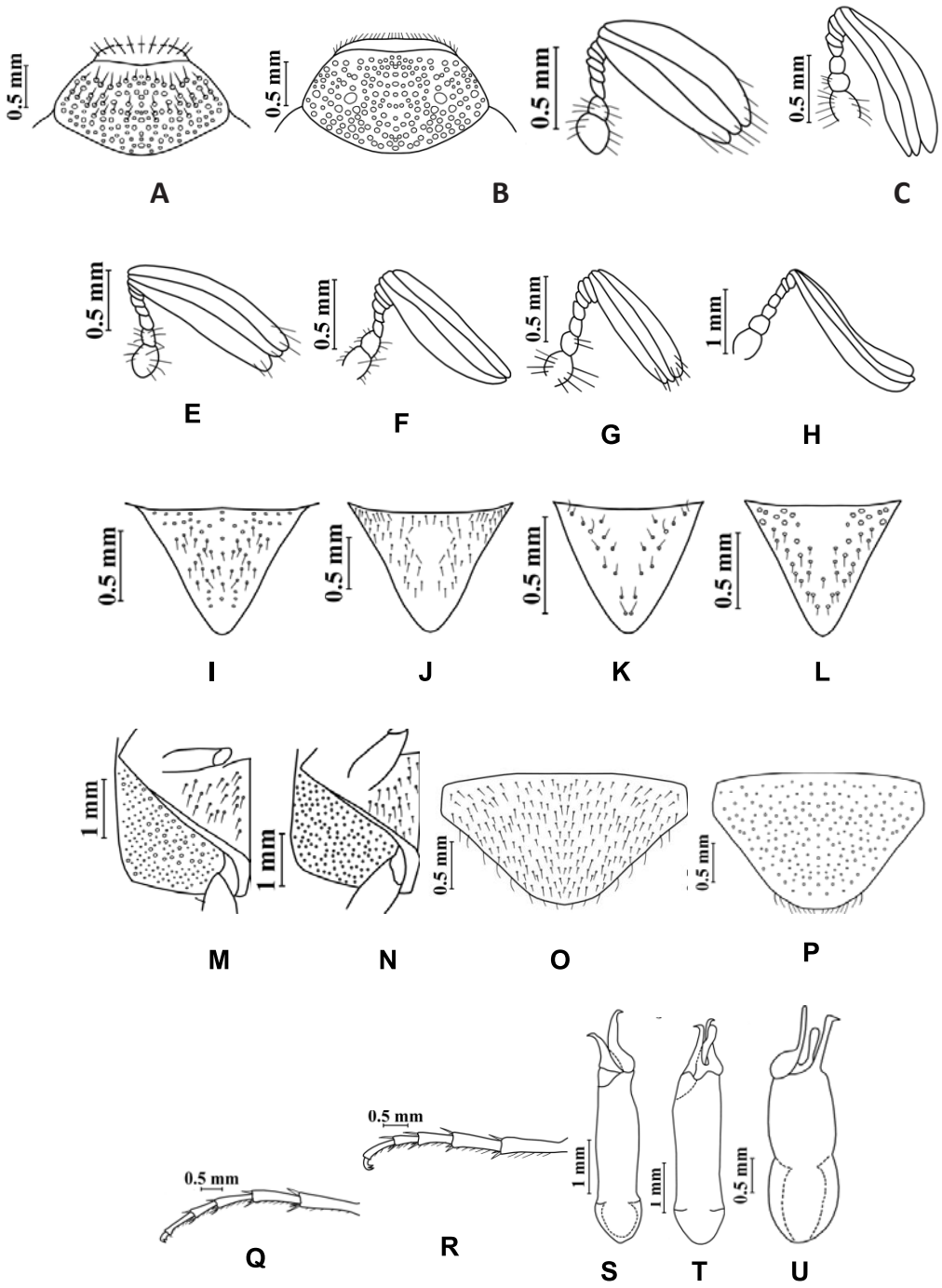

Fig 1. A. *Maladera burmeisteri* ,B. *M. iridescens*, C. *M. atratula*, D. *M. burmeisteri* E. *M. discrepens* F. *M. cardoni*, G. *M. indica*, H. *M. iridescens*, I. *M. coxalis*, J. *M. iridescens*, K. *M. indica*, L. *M. fumosa*, M. *M. simlana*, N. *M. insanabilis*, O. *M. fumosa*, P. *M. nilgirensis* Q. *M. discrepens*, R. *M. iridescens*, S. *M. insanabilis*, T. *M. affinis*, U. *M. nilgirensis*

twelve species the smallest was *M. fumosa*, while seven species were medium sized and four species *viz*., *M. iridescens*, *M. discrepens*, *M. coxalis* and *M. atratula* were comparatively larger in size measuring > 10 mm.

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Network Project on Insect Biosystematics
Division of Entomology
ICAR-Indian Agricultural Research Institute
New Delhi 110 012
**Email: sukhwinderento@gmail.com*

Sukhwinder Singh*
K. Sreedevi and
Padala Vinod Kumar

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INCIDENCE OF PIPUNCULIDS (DIPTERA) IN RICE FIELDS OF INDO- NEPAL REGION

Rice is infested by a number of insect pests, and the major ones are brown planthoppers, leafhoppers, pyrilla and gall midge. Climatic factors e.g., temperature, humidity and rainfall are the key factors for development of any rice insect pest and their natural enemies (friendly arthropods). Planthoppers and leafhoppers are important in the Indo-Nepal region especially Champaranin Bihar and Hetauda (Makawanpur) in Nepal. The populations of these are greatly infuenced by ecological and biological factors, crop physiology, climate change and farmer's control practices (Settle *et al*., 1996). Their population also significantly changes during rice development because of changes in rice plant physiology from early tillering, to milking stage (Inishi, 1968). Pipunculids (Diptera) commonly called as big headed flies are endoparasitic of these insect pests and biologically suppresses their population. Therefore, their occurrence in paddy fields is important (Yano *et al.,* 1984; Yano, 1985; Morakote and Yano, 1988; Morakote *et al.,* 1990). The present study evaluates the population dynamics of pipunculids in rice fields during July to October.

The study was carried out in paddy field located in Hetauda (27°25'N85°02'E, 1132- 3000 ft. amsl) district Makawanpur, Nepal. Makwanpur (Hetauda) belongs to Narayani zone commonly known as inner Terai includes major forest species and hills rich in floral diversity. The experimental fields were situated in a flat land on the main rice bowl of Hetauda in five different location, cultivated with mansuli, a high yielding rice variety with life span of 105 to 120 days, in plots measuring 253 m^2 (11x23).

Sampling was done at weekly intervals from July to October of 2014 and 2015 using sweep nets at vegetative, reproductive and grain maturing stage. Sweep nets with complete sweeping in zig-zag formation at the top canopy, as well as up and down between rice tiller to catch both flying as well as hiding insects were used, 10 am to 3 pm. In each session,

combination of 100 strokes were done and repeated in a week. All specimens collected were killed in killing bottle containing ethyl acetate, sorted, identified and counted. The temperature, humidity, rainfall, wind velocity and sunshine were simultaneously recorded using Hygro-thermometer and from weather station, Hetauda, and these were statistically analysed.

The incidence of pipunculids in rice during *kharif,* 2014 commenced from 2nd week of July on 09 days old plants (28th standard week) with population of 1 fl/ 100 sweeps but in 2015 it became 2 pipunculids/ 100 sweeps during 28th standard week i.e. in second week of July. Later the population increased and reached peaks with twenty and twelve during 35th standard week i.e. in 4th week of August and 36th standard week i.e. in 1st week of September during 2014 and 2015, respectively (Fig. 1,2). A declining trend was observed during 43rd standard week at the time of harvesting during both the years where the maximum temperature ranges between 23^{0}C to 30^{0}C (Table 1,2). These observations agree with those of Asai and Yano (1988)

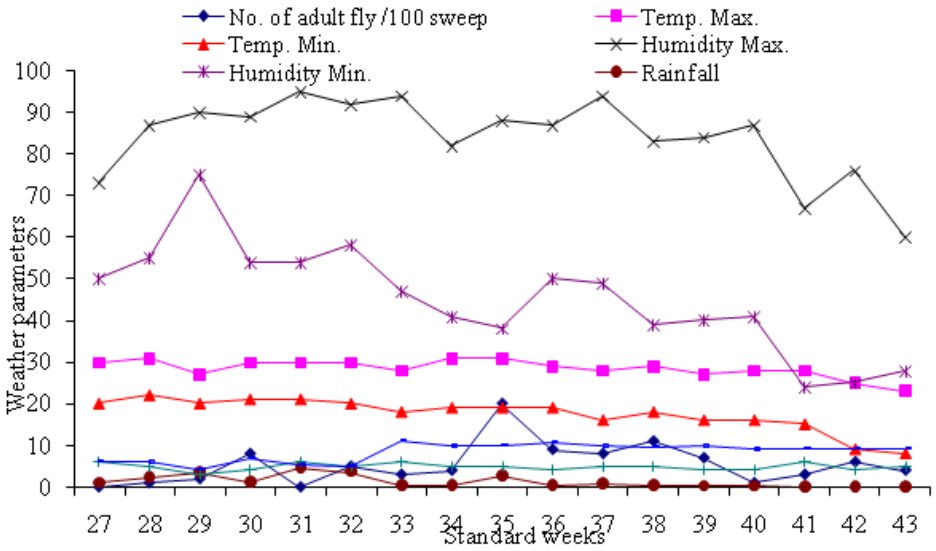

Fig. 1. Correlation of weather parameters vs. pipunculids (*kharif,* 2014)

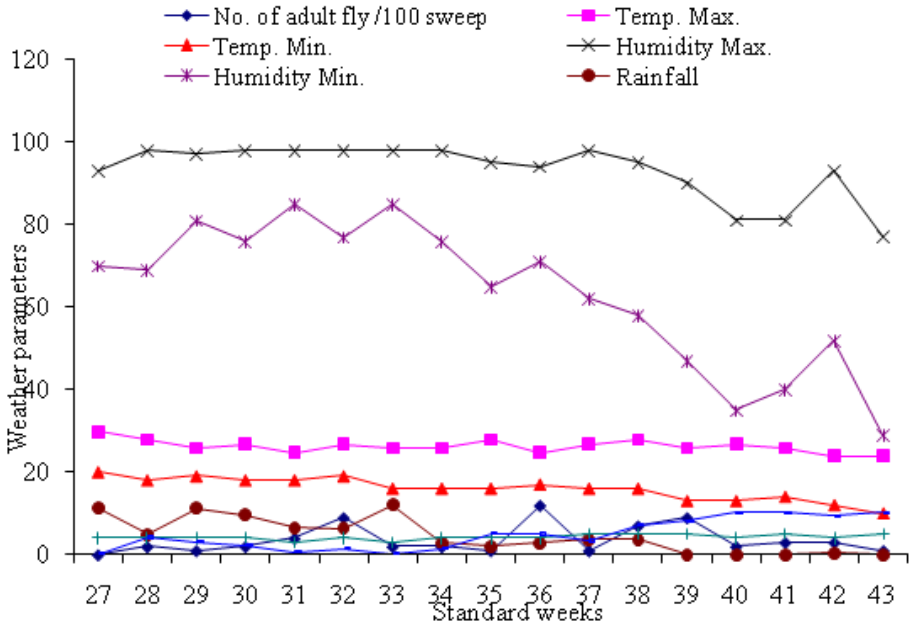

Fig. 2. Correlation of weather parameters vs. pipunculids (*kharif,* 2015)

Table 1. Seasonal incidence of pipunculids in paddy (*kharif*, 2014)

Standard week sweep	No. of adult fly/100	Temperature (^{0}C)		Humidity (%)		Rainfall (mm) (m/h)	Wind velocity	Sunshine (hr)
		Max.	Min.	Max.	Min.			
27	0	30	20	73	50	1	6	6.21
28	1	31	22	87	55	2.3	5	6.01
29	2	27	20	90	75	3.5	3	4.26
30	8	30	21	89	54	1.2	4	7.01
31	0	30	21	95	54	4.7	6	5.27
32	5	30	20	92	58	3.7	5	4.92
33	3	28	18	94	47	0.5	6	11.21
34	4	31	19	82	41	0.4	5	9.92
35	20	31	19	88	38	2.7	5	10.01
36	9	29	19	87	50	0.4	4	10.92
37	8	28	16	94	49	0.7	5	9.93
38	11	29	18	83	39	0.5	5	9.81
39	7	27	16	84	40	0.3	4	9.94
40	1	28	16	87	41	0.3	4	9.16
41	3	28	15	67	24	0	6	9.31
42	6	25	9	76	25	0	4	9.3
43	4	23	8	60	28	0	5	9.39
	r=	0.145	-0.036	0.129	-0.231	-0.072	-0.181	0.462
	t=	0.568	-0.140	0.503	-0.919	-0.279	-0.713	2.019
		NS	NS	NS	NS	NS	NS	NS

Table 2. Seasonal incidence of pipunculids in paddy fields (*kharif*, 2015)

Standard week sweep	No. of adult fly/100	Temperature (^{0}C)		Humidity (%)		Rainfall (mm) (m/h)	Wind velocity	Sunshine (hr)
		Max.	Min.	Max.	Min.			
27	0	30	20	93	70	11.2	4	0.3
28	2	28	18	98	69	4.8	4	4.26
29	1	26	19	97	81	11.3	4	3.2
30	2	27	18	98	76	9.7	4	2.2
31	4	25	18	98	85	6.5	3	0.62
32	9	27	19	98	77	6.4	4	1.56
33	2	26	16	98	85	12.1	3	0.37
34	2	26	16	98	76	3	4	1.62
35	1	28	16	95	65	2	4	5.2
36	12	25	17	94	71	3	4	5.01
37	1	27	16	98	62	3.7	5	3.36
38	7	28	16	95	58	3.6	5	7.26
39	9	26	13	90	47	0.2	5	8.31
40	2	27	13	81	35	0.1	4	10.22
41	3	26	14	81	40	0.1	5	10.19
42	3	24	12	93	52	0.6	4	9.38
43	1	24	10	77	29	0	5	10.26
	r=	-0.217	0.030	0.093	0.042	-0.236	0.120	0.104
	t=	-0.861	0.116	0.360	0.163	-0.941	0.466	0.405
	Results	NS	NS	NS	NS	NS	NS	NS

in 1979 and 1980 in the Yamaguchi area. Morakote and Yano (1990) also reported that pipunculids first population appeared in second week of July and buildup was observed up to September.

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Department of Biological Sciences, SHUATS, Allahabad 211007
***Department of Zoology, R.L.S.Y College, Bettiah 845438, BRABU, Muzaffarpur, Bihar*
****Department of Entomology, SHUATS, Allahabad 211007*
**Email: shailendrakamogh@gmail.com*

Shailendra Kumar Amogh*
Prakash Michael and**
Ashwani Kumar***

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EASY AND RESOURCE CONSERVING LARVAL REARING METHOD FOR BANANA STEM WEEVIL, *ODOIPORUS LONGICOLLIS* (OLIVIER) (COLEOPTERA: DRYOPHTHORIDAE) IN LABORATORY

Banana stem weevil, *Odoiporus longicollis* (Olivier) (Coleoptera: Dryophthoridae) (Fig. 1) is the major pest of banana in South and South East Asia, especially in India (Visalakshi et al., 1989; Padmanabhan and Sathiamoorthy, 2001 and Azam et al., 2010). Adult females lay eggs in the air chamber present in the pseudostem and emerging grubs feed on leaf sheath and sometimes reaching up to peduncle (Padmanaban et al., 2001); pupate in a cocoon made of banana fibers. All stages except adults are seen inside the stem. Damage is caused by feeding grubs which make extensive tunnels on the stem and weakens the plant. Infested plants will topple down especially at fruit emergence. In severely infested plantations, more than 20% plants do not flower, if attacked in the advanced preflowering stage. It is also estimated that the weevil causes 10-90% yield loss depending on the growth stage of the crop and management efficiency (Padmanaban and Sathiamoorthy, 2001).

Fig. 1. Adult *O. longicollis*

A well established rearing procedure is very important to enable access to its various life stages of

insects and for experiments (Koppenhofer and Reddy, 1994)- such as studying their biology, host preferences, rearing or testing of parasites or pathogens and bioassay of chemicals etc. Hence, a suitable rearing method either with the natural host or artificial diet becomes inevitable. In case of insect pests inhabiting the stems, rearing becomes very difficult (Kumar, 1969). Adding to that *O. longicollis* is a monophagous pest (Isahaque, 1978) and hence banana pseudostem becomes the only natural diet for the grubs when reared in laboratory. Even though some positive results were reported in developing artificial diet for the other close related species, banana rhizome weevil (*Cosmopolites sordidus*) by Bakaze et al. (2011), no success had been reported for *O. longicollis*. Bulk of pseudostem will be necessary daily when rearing is initiated. Previously researchers preferred whole pseudostem, cut into convenient length as rearing medium for the grubs (Kumar, 1969; Anitha and Nair, 2004; Thippaiah et al., 2011; Priyadarshini et al., 2014). But these methods require large quantity of whole pseudostem, with manpower, money and space getting wasted, necessitating devising a suitable rearing technique, and the present study attempts this.

Pseudostem of popular local cultivar, 'Nendran' (AAB) was selected as it is the most preferred or susceptible host for *O. longicollis* (Anitha, 2004; Anitha and Nair, 2004; Padmanabhan et al., 2004). Instead of whole pseudostem, leaf sheaths were evaluated in this method. Discarding outermost old and hard sheath, inner sheaths were pulled out and cut into strips of 15x6cm size; this stem piece was selected upon observations made on the feeding nature of the grub, and alos taking into account the convenience in handling and storing in containers. To facilitate the entry of grubs into the stem piece, a small hole of 1cm depth was drilled on one cut end using a sterile 1ml micropipette tip. A single grub was introduced per piece by directing their head into the hole (Fig. 2). Grubs easily crawled inside the piece and started tunneling and feeding. Sheath pieces were replaced daily and on every second day, a fresh sheath piece given for late (3^{rd} and 4^{th} instars) and early (1-2^{nd} instars) instars, respectively. When grubs attained fifth instar or prepupal, these were provided with two pieces tied with a rubber band so as to extract maximum fiber for their cocoon production. When cocoons get formed these were collected along with stem pieces and kept separately. The rearing medium was kept in reusable plastic jars (Fig. 3). Moistened tissue paper was placed at the bottom of the jars to provide sufficient humidity and

Fig. 2. Grub moving in pseudostem strip

Fig. 3. Rearing on pseudostem

top was covered using nylon mosquito net. The whole assembly was kept in ant well. Twenty such replications were maintained and biometrics of adults and grub stages recorded. Study was done under laboratory condition (28±3^{0}C, RH 70-85%), and data analysed by t-test.

As a resource conservation strategy, pseudostem sheaths were collected from pesticide free harvested or toppled plants. This was supposed to have added advantage as the pest preferred above seventh month old plants as reported by Lalitha and Ranjith (2000). In earlier methods, where whole pseudostem was used, spotting out obscured grubs was not easy and

often the grubs, especially the early stage ones could be damaged or even get killed while handling them.. In this improved method, grubs could be traced as the sheath strips were translucent, and could be easily removed by splitting open the strip. Splitting was so easy that could be done by holding the inner and outer surfaces of the piece on top or bottom side and tearing apart in opposite directions. While comparing rearing methods for *C. sordidus*, Koppenhofer and Reddy (1994) too found that pseudostem is a suitable method with less larval loss.

Some researchers even tried 2-4 grubs per whole stem piece while rearing due to the constraint in material and space. Jayanthi and Verghese (2000) reported 47.22% cannibalism among grubs when food was provided and 83.33% under starved condition. These data also support the new method of rearing in which only one grub was introduced per pseudostem sheath and it eliminates cannibalism. This new method prevented wastage of resources,in terms of insect food material, labour and space. Bioassays with grubs require recording of mortality rates at different time intervals. In methods using whole stem, movement of grubs could not be traced, but the new method enables tracing the movement of grubs, and false conclusions get avoided.

Biometrics of life stages in this new method compared with earlier method did not show any no significant deviation (Table 1). Slight increase in larval duration on whole stem observed might be due to increased food availability. The opposite sexes mated and laid eggs same as normal adults reared on whole stem pieces. Adult weevils also could be maintained using the strip method, but two to three pieces were placed in one jar as they rest in inter sheath space on pseudostem. A banana plant with 150 cm height can support around six rearing units with 12 to 24 grubs @ three to four grubs/ unit in the old method; but with modified method using sheath strips 30 to 40 grubs could be maintained. This new method of rearing *O. longicollis* can support more rearing units per plant and reduce space.

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Table 1. Details of grubs/adults reared with different methods

Parameter Mean size (mm)	New method sheath strips (length x breadth)	Old method whole stem pieces (length x breadth)	P value in t-test (length and breadth)
Male	17.03± 0.58 x 5.07±0.59	16.97± 0.61 x 5.13±0.64	0.76 and 0.77
Female	17.70± 1.05 x 5.20±0.41	17.80± 0.82 x 5.33±0.49	0.77 and 0.43
Mean duration (days)			
2nd instar			
3rd instar	2.93±0.59	3.0±0.54	0.75
4th instar	4.33±0.72	4.53±0.92	0.51
5th instar	5.27±0.71	5.4±0.63	0.59
Pupal period	8.27±0.96	8.6±0.99	0.36
	14.67±1.18	15.07±1.03	0.34

Values- Mean ± SD

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Department of Agricultural Entomology, College of Agriculture,
Kerala Agricultural University, Vellayani.P.O., Thiruvananthapuram 695522
**Email: sivanagri@yahoo.co.in*

T. Sivakumar*
T. Jiji and
N. Anitha

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HOST RANGE, NATURAL ENEMIES AND DAMAGE POTENTIAL OF COTTON MEALYBUG, *PHENACOCCUS SOLENOPSIS* TINSLEY (HEMIPTERA: PSEUDOCOCCIDAE) IN ODISHA

The cotton mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) was first recorded in Pakistan during 2005 (Abbas et al., 2005; Arif et al., 2007). Soon afterwards it was reported from Thailand and Taiwan in 2006, and became a serious and invasive pest of cotton in Pakistan and India (Hodgson et al., 2008; Dhawan et al., 2007). It had been known from all the nine cotton growing states of India *viz.,* Punjab, Haryana, Rajasthan, Gujarat, Madhya Pradesh, Maharashtra, Tamil Nadu, Andhra Pradesh and Karnataka (Dharajothi et al., 2008; Nagrare et al., 2009). Hodgson et al. (2008) reported 55 species of host plants of *P. solenopsis* belonging to 18 families from India and Pakistan. Its significant economic damage was observed on cotton, brinjal, okra, tomato, sesame, sunflower, and China rose (Sharma, 2007; Jagadish et al., 2009). It was also reported on chillies (Mohindru *et al.,* 2009), tobacco (Jat *et al.,* 2014), cashew (Maruthadurai and Singh, 2015), and pigeon pea (Khajuria *et al.,* 2015).

In India, the endoparasitoid, *Aenasius* sp., was reported to attack *P. solenopsis* (Sharma, 2007; Tanwar *et al.,* 2008); and the parasitoid was identified as *Aenasius arizonensis* (Girault) (Hymenoptera: Chalcidoidea: Encyrtidae) (Hayat, 2009). Till today, 5 species of hymenopterous parasitoids belonging to 4 families had been reported parasitising *P. solenopsis* in India. *Cryptolaemus montrouzieri* (Mulsant), *Brumoides suturalis* (F.), *Cheilomenes sexmaculatus* (F.) and *Chrysoperla zastrowi sillemi* (Espen-Petersen) are its most common predators (Tanwar et al., 2007; Radadia et al., 2008; Patel et al., 2009; Henry et al., 2010). Predators like *Scymnus coccivora* (Ayyar) and spiders were also found associated with this mealybug (Arif et al., 2012). Eight species of coccinellids and two species of chrysopids were found as important natural enemies predacious on *P. solenopsis* (Suroshe et al., 2013).

Nagrare et al. (2012) reported about infestations of *P. solenopsis*, agroecosystem wise in north zone in 17, 13, 12 and 28 host plants with G 4, G 3, G 2 and G 1 grades, respectively. Thirty, 10, 29, 60 in Central zone and 17, 11, 27 and 50 in South zone with G 4, G 3, G 2 and G 1 grades of infestations respectively. Kumar et al. (2014) reported losses in cotton due to the mealybug varied between 14.9% at Grade 1 and 53.6% at Grade 4, on a 0 to 4 severity index, with a mean reduction of 35% and 32%, during 2008 and 2009, respectively.

Currently, the mealybugs are seen in many agricultural and horticultural crops in Odisha, but, the literature available on biology, natural enemies, host range and IPM of this emerging pest is meager (Mishra, 2011), and hence the present study.

The host plants of *P. solenopsis* were surveyed at weekly intervals in Bhubaneswar (20.29° N, 85.82° E) from August 2015 to April 2016 (35th standard week of 2015 to 18th standard week of 2016). The samples of mealybugs, their natural enemies and other associated fauna were also collected in glass vials and preserved in 70% alcohol. The collected mealybugs were confirmed to be *P. solenopsis* based on the identification characters given earlier (Hodgson et al., 2008; Jhala et al., 2008; Sahito et al., 2010). The damage potential as studied on cotton, marigold, brinjal, maize and sunflower, and calculated in 0 to 4 grade (Prabhakar et al., (2013) (Table 1), and % incidence was calculated as per Abbas et al. (2010): Damage potential = Sum of total grade points (0-4 for infestation grade G-0 to G-4, respectively) of infested plants / total number of plants observed; and % incidence (PI)= Number of infested plants/total number of plants observed x 100.

In the survey conducted from 35th standard week of 2015 to 18th standard week of 2016, *P. solenopsis* was recorded from 12 host plants belonging to 10 genera of families Malvaceae, Solanaceae, Asteraceae, Poaceae, Moringaceae, Compositae and Amaranthaceae (Table 2). The cotton mealybug, *P. solenopsis* was first reported in Punjab by Dhawan et al. (2007). Survey on natural enemies revealed 4 species- one parasitoid under Hymenoptera and three predators under Coleoptera (Table 3). The natural enemy *A. arizonensis* (Girault) (Hymenoptera: Encyrtidae) found during the study was confirmed with the morphological identification characters stated by Fallahzadeh et al. (2014). Suroshe et al. (2013) reported eight species of coccinellids, two species of chrysopids and four species of parasitoids. Tanwar et al. (2011) observed two species of parasitoids i.e., *A. arizonensis* (Girault) and *Promuscidea unfasciativentris* (Girault).

The severity index was assessed in grade 0 to 4 on five host plant, highest (1.86) was on cotton followed by marigold (1.66), and lowest (0.28) on sunflower. The % incidence was highest (86.66%) in marigold followed by cotton (79.96 %), but was lowest (24.48%) in sunflower (Table 4). Hanchinal et al. (2011) observed hihest severity index of 3.42, 3.15 and 3.34 on cotton in Raichur, Gulbarga and Bellary districts of Karnataka, with infestation ranging from 2.96 to 28.22 %. Nagrare et al. (2012) gave an infestation ranging from mild (10-20%) to high (40-60%) during 2007 -08 at most of the places in the northern and central zones of India.

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Table 1. Grades of *P. solenopsis* infestation (Prabhakar et al., 2013)

S.No.	Grade	Parameters
1.	G0	No mealybug infestation.
2.	G1	Scattered appearance of few mealybugs on the plant.
3.	G2	Severe infestation of mealybug on any one branch of the plant.
4.	G3	Severe infestation of mealybug on more than one branch or half portion of the plant.
5.	G4	Severe infestation of mealybug on the whole plant.

Table 2. Host plants of *P. solenopsis* (Bhubaneswar, Odisha, 2015-16)

S.No. Host plant	Family	Season
1. *Hibiscus rosa-sinensis* L.	Malvaceae	Kharif, Rabi
2. *Abelmoschus esculentus* L.		Kharif
3. *Gossypium hirsutum* L.		Rabi
4. *Solanum melongena* L.	Solanaceae	Kharif
5. *Solanum tuberosum* L.		Rabi
6. *Solanum lycopersicum* L.		Kharif
7. *Capsicum annum* L.		Rabi
8. *Helianthus annuus* L.	Asteraceae	Rabi
9. *Zea mays* L.	Poaceae	Rabi
10. *Moringa oleifera* L.	Moringaceae	Rabi
11. *Tagetes* sp. L.	Compositae	Kharif, Rabi
12. *Achyranthes* sp. L.	Amaranthaceae	Kharif

Table 3. Natural enemies of *P. solenopsis* (Bhubaneswar, Odisha, 2015-16)

S. No.	Natural enemy	Order	Family	Host plant
1.	*Aenasius arizonensis* (Girault)	Hymenoptera	Encyrtidae	*H. rosa-sinensis* L., *G. hirsutum* L. *Tagetes* sp. L.
2.	*Cryptolaemus montrouzieri* (Mulsant)	Coleoptera	Coccinellidae	*G. hirsutum* L.
3.	*Cheilomenes sexmaculatus* (Fabricius)	Coleoptera	Coccinellidae	*G. hirsutum* L. *H. annuus* L.
4.	*Brumoides suturalis* (Fabricius)	Coleoptera	Coccinellidae	*Zea mays* L.

Table 4. Damage potential of *P. solenopsis*

S .No.	Host plant	Severity index	% infestation
1.	*Gossypium* sp. L.	1.86	79.96
2.	*Tagetes* sp. L.	1.66	86.66
3.	*Solanum melongena* L.	1.03	73.07
4.	*Zea mays* L.	0.47	47.50
5.	*Helianthus annuus* L.	0.28	24.48

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Department of Entomology, College of Agriculture
Orissa University of Agriculture and Technology
Bhubaneswar 751003
**Email: prithvi916@gmail.com*

P. Prithvi*
B. Patro and
K. Gopal

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SEASONAL INCIDENCE OF RED SPIDER MITE, *TETRANYCHUS URTICAE* KOCH INFESTING MARIGOLD IN JAMMU

Since 2000 floriculture scenario in Jammu province of Jammu and Kashmir has changed very rapidly, with more than 1094 registered progressive growers. Marigold is one of the profitable crops supporting floriculture. The two spotted red spider mite, *Tetranychus urticae* Koch is one of its most important pest, and the present study evaluates its seasonal incidence in Jammu.

The variety "Pusa Narangi Gainda" was raised with recommended agronomic practices in plots of 3 × 1 m^2 size, with row to row and plant to plant distance of 45 cm and 20 cm, respectively, at the University Research Farm, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, in 2014 and 2015. Weekly observations were recorded from five randomly selected plants, with mite population observed from the top, middle and bottom leaves of each plant, and then correlated with weather factors.

The pooled data (2014, 2015) reveal that initially the *T. urticae* population was around 7.87 mites/ leaf) in the 7th standard week, which gradually increased to its peak during 12th standard week (9.29/ leaf), when mean maximum, minimum temperature, mean relative humidity (morning and evening) and rainfall were 26.70 and 13°C, 84.5 and 58% and 6.70 mm, respectively. The least population of 3.12/ leaf was observed in 18th standard week, when mean maximum, minimum temperature, mean relative humidity (morning and evening) and rainfall were 35.8 and 18.6°C, 65.5 and 32.5% and 5.75 mm, respectively (Table 1).

	X_1	X_2	X_3	X_4	X_5
Y_1	0.602**	0.687	0.663**	-0.615	0.157*

** Correlation significant at p= 0.01, and * at p= 0.05; Regression equation obtained was: Y_1= - 40.963 + 0.645X_1 - 0.415X_2 + 0.411X_3 + 0.062X_4 – 0.048X_5 (R^2 = 0.901), where Y_1= mean mite population/leaf; X_1= maximum and X_2= Minimum temperature (°C); X_3= Mean relative humidity morning (%), and X_4 of evening; and X_5= Rainfall (mm).

Table 1. Seasonal incidence of *T. urticae* on marigold- Jammu (2014, 2015, pooled data)

Standard week	*Mean mite population/leaf	Temperature (°C)		Relative Humidity (%)		Rainfall (mm)
		Maximum	Minimum	Morning	Evening	
7	7.87	20.85	7.85	88.50	55.00	5.80
8	8.23	22.10	10.00	91.00	61.50	27.65
9	6.49	19.90	9.40	90.00	60.00	59.60
10	8.23	21.40	10.00	90.00	60.50	34.10
11	5.69	24.10	11.20	87.00	57.50	72.90
12	9.29	26.70	13.00	84.50	58.00	6.70
13	6.83	26.65	14.20	85.00	58.00	51.20
14	3.16	25.30	14.30	83.50	55.50	65.75
15	6.97	30.55	14.85	75.00	42.50	0.00
16	5.35	30.35	15.95	79.00	45.00	26.50
17	3.97	35.45	18.20	66.50	45.00	0.00
18	3.12	35.80	18.60	65.50	32.50	5.75
Range	3.12-9.29	19.90-35.80	7.85-18.60	65.50-91.00	32.50-61.50	0.00-72.90
Mean	6.27	26.60	13.13	82.13	52.58	29.66
S.Em(±)	0.59	1.57	1.01	2.56	2.63	7.78

*Mean of five leaves

These observations agree with Butani (1974) who reported that the incidence of *T. urticae* from September to January as the active period for mites on rose which later started declining till April due to excess heat. Similarly, Sudharma et al. (1995) reported severe infestation of *T. urticae* on rose with two peaks in a year, the first during October to November and the other during February to May. The population of *T. urticae* increased from February and reached its peak in March (69.65/ plant) and declined thereafter (Hole and Salunkhe, 1997).

The correlation with weather factors revealed positive but highly significant relationship with mean maximum temperature and relatively humidity (morning), r = 0.602; 0.663. Rainfall also had positive significant relationship; and the mean minimum temperature (r =0.687) with positive relationship and mean relative humidity (evening) with negative one (r = -0.615) were also observed. Regression coefficients revealed that the mite population was significantly influenced by the weather factors as follows:

In a similar study, Hole and Salunkhe (1997) too observed positively significant correlation with maximum temperature and relative humidity. The present observations are in agreement with Mandal et al. (2006) on morning relative humidity and minimum temperature in okra.

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Division of Entomology
FoA, SKUAST-J, Chatha, Jammu 180 009
**Email: suhail_jalib@yahoo.com*

Suheel Ahmad Ganai*, Hafeez Ahmad, Devinder Sharma, Sonika Sharma, Thanlass Norboo, Nadeya Khaliq And Divya Chaand

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ASSESSMENT OF AVOIDABLE YIELD LOSS DUE TO POD BORER, *HELICOVERPA ARMIGERA* IN CHICKPEA

Chickpea (*Cicer arietinum* L.) is the second most important pulse crop grown globally. The lower yields of chickpea are attributed to the regular outbreaks of pod borer, *Helicoverpa armigera* (Hubner), which is considered to be one of the major pests (Khare and Ujagir, 1977). *H. armigera* causes economic loss in chickpea by damaging tender foliage, flowers and pods. Under favourable conditions the pod damage reaches up to 90-95% (Shegal and Ujagir, 1990). Considering the economic losses caused by pod borer, protective measures need to be taken well in time to prevent the pod damage. Keeping in view the seriousness of the pest, a field trial was conducted to estimate the avoidable yield loss due to chickpea pod borer at the experimental farm of ICAR-Indian Agricultural Research Institute, New Delhi (28.08° N , 77.12 ° E , 228.61 m AMSL)

The field experiment was conducted during 2016-17 in a randomized block design (RBD) with two treatments *viz*., protected and unprotected in paired plots. Chickpea variety Pusa-1103 was sown on 15.12.2016 (50th standard meteorological week) in a plot size of 5 x 2 m with row and plant spacing of 40 x 10 cm, respectively. The recommended package of practice was followed except for the plant protection measures. The two treatments *viz*., protected and unprotected plots were replicated fourteen times. The unprotected plots had natural infestation of pod borer and were kept free from insecticides, on the other hand in protected plots, two foliar applications were given based on economic threshold level (ETL) of the pod borer. First application was done with emamectin benzoate 5SG @11 g a.i./ha at 102 days after sowing

Table 1. Mean pod damage due to pod borer and avoidable yield loss in chickpea

	Mean pod damage (%)	Grain yield (kg/ha)	Yield loss (kg/ha)	Avoidable yield loss (%)	Yield increase over control (%)
Protected	12.33 (19.92)*	552.40	-	33.74	50.93
Unprotected	54.01 (47.34)*	366.0	186.4	-	-
S.Em. ±	3.039	-	-	-	-
C.D. (p≤ 0.05)	9.28	-	-	-	-

* Figures in parentheses are arc sine transformed values

(DAS) while second application was made with chlorantraniliprole 18.5SC @ 25 g a.i./ha after 10 days of first application.

At harvest, five plants from each replication were randomly sampled for counting the total number of pods and damaged pods and per cent pod damage was computed in both treatments. Further, the % pod damage was subjected to arc sine transformation before statistical analysis. Grain yield/ plot was recorded separately from protected and unprotected plots and converted to yield/ ha. The yield increase in protected plots over unprotected (control) and avoidable yield loss was worked out according to Pradhan (1969).

The data revealed significant reduction in the pod damage (12.33%) in the protected plots when compared with unprotected plots (54.01%) (Table 1). The grain yield obtained from protected and unprotected plots were 552.40 and 366.0 kg/ha, respectively. The protected plots recorded higher grain yield than the unprotected plots accounting for 50.93% increase in yield over control due to insecticide application at the ETL. The results indicated that emamectin benzoate 5 SG @ 11 g a.i./ha and chlorantraniliprole 18.5 SC @ 25 g a.i./ha are efficient in preventing the yield loss up to 186.4 kg/ha. The total avoidable loss was estimated to be 33.74%. Earlier Shinde et al. (2014) estimated the avoidable loss in chickpea due to pod borer as 63.64%. Deshmukh et al. (2010) also reported significant reduction in larval population of *H. armigera* in protected plots as compared to unprotected plots after spraying of quinalphos (0.05%) and indoxacarb (0.0075%) alternatively, which ultimately resulted in 69.98% increase in grain yield (683 kg/ha) in protected plots. Biradar et al. (1998) found the least pod borer incidence (18.7%) and higher seed yield (11.5 q/ha) over the untreated control with 125.5% increase in yield when crop was treated with five sprays of methomyl 12.5L @ 2ml/l, thus avoiding loss up to 55.7%. Present findings thus confirms that in addition to the effective insecticides reported by earlier workers, emamectin benzoate 5 SG @ 11 g a.i./ ha and chlorantraniliprole 18.5 SC @ 25 g a.i./ ha when applied in sequence are effective in preventing the loss caused by *H. armigera* in chickpea.

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Division of Entomology
ICAR- Indian Agricultural Research Institute
New Delhi 110012
**Email: garuda344@gmail.com (corresponding author)*

D. SAGAR*
SURESH M. NEBAPURE AND
SUBHASH CHANDER

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EFFICACY OF MANAGEMENT MODULES AGAINST BRINJAL SHOOT AND FRUIT BORER *LEUCINODES ORBONALIS* IN KASHMIR

Brinjal (*Solanum melongena* L.) is affected by a number of insect pests and of these one of the major pests is the shoot and fruit borer (*Leucinodes orbonalis* Guenee). This pest inflicts losses up to 70% in Andhra Pradesh (Sasikala et al., 1999) and up to 80% in Gujarat (Jhala et al., 2003). The immediate control strategy against this had been use of insecticides, but their extensive and indiscriminate use has led to several problems like resurgence of secondary pest, health hazards and pesticide residues in edible fruits. Hence, biorational pesticides are rapidly gaining popularity, and might be the potential alternatives. The present study evaluates the efficacy and economics of some biorational pesticides along with recommended insecticides, in Kashmir.

Field experiment was laid out with some selected insecticides during *kharif* 2014 at the Experimental Farm, SKUAST (Kashmir), Shalimar, Srinagar in a Complete Randomized Block Design (CRBD). There were seven treatments and replicated thrice. Forty days old seedlings of variety *Local Long* were transplanted with row to row and plant to plant distance of 60 x 45 cm. All the recommended agronomical practices were followed as per package and practice recommended by SKUAST-Kashmir. Mechanical control comprised scouting these plots at weekly interval to locate the infested shoots, if any. The infested shoots were clipped, removed and destroyed after counting; up to five fruit pickings/harvest. All the test insecticides were applied as foliar sprays. First spray was given one and half month after transplanting, followed by four sequential sprays of each insecticide except neem for which a single spray was given as an individual treatment at fortnightly interval with the knapsack sprayer.

The field efficacy of the treatments was evaluated on the basis of observations on total number of shoots, drooped shoots, total fruits, healthy and damaged/ infested fruits. These were counted one day prior to spray as pretreatment count. Post treatment count was taken at fortnightly interval of each subsequent spray. At each harvest, observations on number and weight of healthy and damaged fruit were recorded. Effect of different treatments on the increase/decrease of yield over control was also calculated. So far as yield of net plot is concerned, weight of healthy fruits obtained in first five pickings was collectively considered for judging the treatment effect. The values of % damage were first transformed to their corresponding square root values and then statistically analyzed as a CRBD. Least significance difference (LSD) was determined at $p = 0.05$.

The harvest of only healthy fruits was considered for recording the yield from all the pickings and economics computed on the basis of current cost of chemicals/ insecticides and market price. The cost benefit ratio (CBR) was worked out for treatments, and for this cost of insecticidal formulations, labour days for clipping/destruction of drooped shoots and infested fruits; and plant protection operations were worked out. Gross income obtained from fruit was worked out on the basis of prevailing market price. Gross realization was worked out by deducting the cost incurred on different management strategies from the gross income. Net realization over control was calculated by deducting the gross realization of control from gross realization of each treatment. Net profit of a treatment was calculated by deducting total cost of treatment from net realization over control as per method described by Shah et al. (2012).

The results reveal that five sequential spray applications of emamectin benzoate at fortnightly interval resulted in the least shoot and fruit infestation (6.63 and 8.94%); treatment of spinosad was the second best; dichlorvos resulted in 14.76 and 14.71% shoot and fruit infestation. A single spray application of neem insecticide was the least effective with 19.92 and 22.25% shoot and fruit infestation, while mechanical control treatment recorded 17.02 and 20.58% shoot and fruit infestation. (Table 1).

These observations are more or less in conformity with Chiranjeevi et al. (2005) who recorded 13.97 and 25.47% shoot and fruit infestation with five sequential sprays of NSKE at fortnightly interval. Dutta et al. (2007) reported 62.8% reduction in infestation and this observation is more or less in accordance with present findings. However, Anil and Sharma (2010) reported emamectin benzoate and spinosad to be highly effective. The present findings also derive support from Shah et al. (2012) who reported that two spray

Table 1. Field efficacy of treatments against *L. orbonalis* in brinjal (Shalimar, 2014)

Treatments	Concentration (%)	Pre- count (1DBS)		% shoot and fruit infestation (15 days after each spray/ clipping/ destruction)										% Mean infestation	
				15DAT		30DAT		45DAT		60DAT		75DAT			
		Shoot	Fruit	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit	Shoot	Fruit
Mechanical control	(Clipping/ destruction of infested shoots) 5 times at 15 days interval	13.10 3.61)	14.70 (3.83)	12.13 (3.48)^{e}	13.88 (3.73)^{e}	14.00 (3.74)^{e}	19.76 (4.45)^{e}	22.00 (4.69)^{e}	27.00 (5.19)^{e}	28.00 (5.29)^{e}	31.30 (5.59)^{d}	9.00 (3.0)^{d}	11.00 (3.31)^{e}	17.02	20.58
Neem insecticide Azadirachtin 0.15% (Single spray)	0.15	13.97 3.73)	14.24 (3.77)	12.00 3.46)^{e}	13.00 (3.60)^{d}	16.66 (4.08)^{f}	20.45 (4.52)^{e}	27.0 (5.19)^{f}	30.00 (5.48)^{f}	33.3 (5.77)^{f}	33.00 (5.74)^{e}	10.66 (3.26)^{f}	14.80 (3.84)^{f}	19.92	22.25
Spinosad 2.5 SC (Five sprays)	0. 0024	11.25 (3.35)	13.40 (3.66)	8.11 2.84)^{b}	9.19 (3.10)^{b}	6.66 (2.58)^{b}	11.47 (2.99)^{b}	10.81 (3.28)^{b}	15.33 (3.91)^{c}	16.58 (4.07)^{b}	16.95 (4.11)^{b}	5.00 (2.23)^{b}	6.00 (2.55)^{b}	11.02	11.78
Emamectin benzoate 5 SG (Five sprays)	0.002	12.00 (3.46)	12.10 (3.47)	6.50 (2.54)^{a}	8.50 (2.91)^{a}	5.00 (2.23)^{a}	9.50 (2.45)^{a}	8.69 (2.94)^{a}	11.42 (3.38)^{a}	12.00 3.46)^{a}	12.10 (3.47)^{a}	3.00 (1.73)^{a}	3.20 (1.78)^{a}	6.63	8.94
Dimethoate 30 EC (Five sprays)	0.03	13.32 3.64)	14.80 (3.84)	10.19 (3.19)^{c}	10.70 (3.27)^{c}	8.66 (2.94)^{c}	11.92 (3.35)^{c}	14.60 (3.82)^{c}	14.60 (3.82)^{b}	19.69 4.43)^{c}	19.58 (4.42)^{c}	6.00 (2.44)^{c}	8.10 (2.84)^{c}	11.82	12.98
Dichlorvos 76 EC (Five sprays)	0.05	13.93 3.73)	13.90 (3.72)	11.20 (3.34)^{d}	11.20 (3.35)^{c}	12.74 (3.56)^{d}	14.97 (3.87)^{d}	18.93 (4.35)^{d}	16.70 (4.08)^{d}	20.93 (4.57)^{d}	20.30 (4.50)^{c}	10.00 (3.16)^{e}	10.40 (3.22)^{d}	14.76	14.71
Control	Water spray	12.11 3.47)	14.00 (3.74)	14.00 (3.74)^{f}	15.20 (3.89)^{f}	20.23 (4.49)^{g}	22.34 (4.72)^{f}	28.42 (5.33)^{g}	30.21 (5.49)^{f}	34.82 (5.9)^{g}	34.21 (5.84)^{e}	12.00 (3.46)^{g}	15.00 (3.87)^{g}	21.89	23.39
C.D $_{(p=0.05)}$	-	NS	NS	0.11	0.12	0.09	0.10	0.06	0.08	0.12	0.11	0.05	0.07	-	-

The values in individual columns superscripted by similar letter(s) do not differ significantly at P = 0.05; DBS - Day before spraying; DAT -Days after treatment; Figures in parentheses square root transformed values

Table 2. Efficacy of treatments in terms of % decrease in infestation by *L. orbonalis* and yield in brinjal (Shalimar, 2014)

Treatment	Shoot infestation (No. basis)	Decrease of shoot infestation over	Fruit infestation (No. basis) control	Decrease of fruit infestation over	Fruit infestation (weight basis) control	Decrease of fruit infestation over	Yield (q/ha) control
Mechanical control	17.02	22.24	20.58	12.01	20.62	31.99	146.30[e]
Neem insecticide (Azadirachtin 0.15%)	19.92	8.90	22.25	4.87	22.44	25.98	109.93[f]
Spinosad 2.5 SC	11.02	49.65	11.78	49.63	11.24	62.92	203.43[b]
Emamectin benzoate 5 SG	6.63	69.71	8.94	61.77	6.97	77.01	210.37[a]
Dimethoate 30 EC	11.82	46.00	12.98	44.50	12.62	58.37	176.86[c]
Dichlorvos 76 EC	14.76	32.57	14.71	37.10	18.12	40.23	160.83[d]
Control (Water)	21.89	-	23.39	-	30.32	-	97.32[g]
$CD_{(P = 0.05)}$							5.01

applications of emamectin benzoate recorded 7.11 and 16.07% shoot and fruit infestation, respectively; and spinosad and dichlorvos recorded 14.1 and 26.04%, and 16.34 and 28.56% shoot and fruit infestation, respectively. Shirale et al. (2012) observed similar results like the present study with spinosad, also Al-Mamun et al. (2014). The shoot infestation of 11.02% observed during present investigations is more or less in accordance with observations of Devi et al. (2014).

The highest yield of 210.37 q/ha was obtained with emamectin benzoate followed by spinosad (203.43 q/ha); however the standard check dichlorvos gave 160.83 q/ha, and the least yield was obtained with neem application (109.93 q/ha) (Table 2). The lowest fruit infestation of 6.97% on weight basis was observed with spray applications of emamectin benzoate. The spinosad treatment led to 11.24% fruit infestation, while dichlorvos led to 18.12% fruit infestation. Maximum fruit infestation of 22.44% was observed with application of neem insecticides. These results are contrary to those of Anil and Sharma (2010) with application of emamectin benzoate and spinosad. The cost benefit ratio worked out revealed that highest cost benefit ratio of 1:17.1 was obtained with dimethoate, while the second best was dichlorvos (1:13.9). Biorational insecticides emamectin benzoate and spinosad gave 1:10.0 and 1:3.1 cost benefit ratio, respectively (Table 3).

Anil and Sharma (2010) and Shah et al. (2012) obtained cost benefit ratio of 1:7.39 and 1:7.92 with spray applications of emamectin benzoate, while in the present investigation it was 1:10.0. The cost benefit

Table 3. Economics of management schedules against *L. orbonalis*

Treatment	Concentration (%)	Cost of insecticides including labour (Rs/ha)	Yield (q/ha)	Gross realization (Rs/ ha)	Net realization over control (Rs/ ha)	Net profit (Rs/ ha)	Cost benefit ratio (CBR)
Mechanical control	Clipping/destruction of infested shoots (5x)	10000	146.3	292600	97960	87960	1:8.7
Neem insecticide (Azadirachtin 0.15%)	0.15	1900	109.93	219860	25220	23320	1:12.2
Spinosad 2.5 SC	0.0024	52000	203.43	406860	212220	160220	1:3.1
Emamectin benzoate 5 SG	0.002	20600	210.37	420740	226100	205500	1:10.0
Dimethoate 30 EC	0.03	8750	176.86	353720	159080	150330	1:17.1
Dichlorvos 76 EC	0.05	8500	160.83	321660	127020	118520	1:13.9
Control (Water)	Water spray	-	97.32	194640	-	-	-

ratio of 1:3.1 with spinosad obtained now is far less than the one shown by Anil and Sharma (2010). Similarly, cost benefit ratio of 1:13.9 with dichlorvos now is lesser compared to 1:20.7 shown by Shah et al. (2012); and the same authors obtained a cost benefit ratio of 1:6.49 with spinosad.

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Division of Entomology
Sher -e- Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar, 190 025
**Email: pathaniasjs@gmail.com*

Ahmad, S.I.
Pathania, S.S.*
Nehru, R.K. and
Wani A. Rouf

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EFFECT OF EXTRACTS OF *CENTELLA ASIATICA* ON THE PULSE BEETLE *CALLOSOBRUCHUS CHINENSIS* L.

Insects have been causing tremendous losses not only to the crops growing in fields but also to post harvest commodities during storage. The pulse beetle, *Callosobruchus chinensis* L. is the most widespread and destructive major insect pest of stored legumes (Park et al., 2003). Females lay eggs on the seeds, and hatching larvae bore inside and spend their life within the seed. The grains become completely hollow and unsuitable for human consumption. Various methods are being used for controlling insects including the use of chemicals. But chemical pesticides cause toxicity to humans and warm-blooded animals (Salma Mazid and Jogen Ch. Kalita, 2011). There comes the importance of biological pesticides as they do not lead to resistance because of their degradable nature. This study is an attempt to analyze the effective toxicant properties of the plant *Centella asiatica* against *C. chinensis* using leaf extracts.

Experiment was conducted in the Entomology Research Laboratory, Department of Zoology, University College, Thiruvananthapuram. *C. chinensis* adults were obtained from naturally infested green gram grains. The adults were mass reared on clean and uninfested green gram. Preparation of aqueous, ethanol and aetone extracts of plants was done as follows: Aqueous extract was prepared as given in Talukdar and Howse (1993) and ethanol and acetone extracts were prepared by soxhlet method.

Table 1. Effect of leaf extracts of *Centella asiatica* on *Callosobruchus chinensis* (LD_{50})

Group	Dose*	Log dose			% dead			% corrected			probit		
		aqueous	ethanol	Acetone	aqueous	ethanol	Acetone	aqueous	ethanol	Acetone	Aqueous	ethanol	Acetone
1	200mg/kg	2.3	2.3	2.3	26	20	28	26	20	28	4.36	4.16	4.42
2	400mg/kg	2.6	2.6	2.6	45	40	48	45	40	48	4.87	4.75	4.95
3	600mg/kg	2.7	2.7	2.7	52	50	56	52	50	56	5.05	5.00	5.15
4	800mg/kg	2.9	2.9	2.9	60	60	64	60	60	64	5.25	5.25	5.36

*weight of plant/weight of feed

The extracts were applied at different doses (0.2%, 0.4%,0.6% and 0.8%) on Whatmann No. 1 filter paper and air dried for an hour. The controls were treated with acetone, ethyl alcohol or distilled water respectively for acetone, ethanol and aqueous treatments. The treated and control filter paper discs were placed singly at the bottom of plastic jars and 200g of green gram seeds were placed on the papers. Hundred insects *were* released in each of these, and there were three replicates for each treatment and control. Observations were recorded on the seventh day of treatment. Bioassay of digestive enzymes, protease (Birk et al.1962) and amylase (Bernfield, 1948) were done on both control and insects treated with sublethal doses.

The data obtained were computed as mean ± standard deviation, and these were subjected to statistical analysis- ANOVA (pd"0.05) with SPSS software (Daniel, 2006). LD_{50} was calculated using probit analysis (Muhammad Akram Randhawa, 1944). Probit values were plotted against log doses and the dose corresponding to probit 5 that is 50% was found out.

The number of adults surviving after the treatment was recorded for seven days consecutively. Acetone and ethanol extracts showed significant mortality compared to the aqueous extract. Table 1 provides the effect of extracts in terms of LD_{50}. Log LD 50 is 2.8 and LD 50 is 56 mg for aqueous extract, Log LD 50 is 2.75 and LD 50 is 50.5 for ethanol extract and for acetone extract Log LD 50 is 2.6 and LD 50 is 48mg. Lethal and sublethal doses were: 56mg and 54mg in the case of aqueous extract, 50.5 mg and 48.5 mg in ethanol extract and 48 mg and 46 mg in acetone extract. The Table 2 gives the effect of these doses of the three leaf extracts on the digestive enzymes. It was observed that both amylase and protease decreased as compared to control.

Table 2. Effect of sublethal doses of extracts of *C. asiatica* on digestive enzymes *C. chinensis*

Enzyme	*Centella asiatica*			
	control	aqueous	ethanol	acetone
Amylase U/L	4.2±0.02	2.3±0.03	1.8±0.04	1.3±0.01
proteaseU/L	4.9±0,01	1.7±0.03	1.3±0.01	1.1±0.02

Zia et al. (2011) studied the effect of aqueous extracts from ten plants on mortality of *C. chinensis*. *Centella asiatica* contains primary metabolites like saponins also called triterpenoids which are known to be insect deterrent and toxic to insects. Toxic and deterrent modes of action had been suggested as responsible for the activity of several triterpenoid (Ortego et al., 1999). Our results demonstrate that both solvent and aqueous extracts of *C. asiatica* are toxic to *C. chinensis*. Maximum mortality was obtained with acetone extract. Decrease in level of digestive enzymes indicate impairment of nutrition and starvation might occur leading to death. Inactivation of digestive enzymes by inhibitors results in blocking of gut amylases and other digestive enzymes such as proteinases, leading to poor nutrient utilization, development retardation, and death because of starvation (Isman, 2006)

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Department of Zoology,
University College, Thiruvananthapuram 695034
**bindhulayathil@gmail.com*

Bindhu, V. R.
Ganga, S. and
Susha Dayanandan

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PROCEEDING OF THE EXECUTIVE COMMITTEE OF THE ENTOMOLOGICAL SOCIETY OF INDIA (ESI) HELD ON 09 MAY 2018 AT 2.00 PM IN THE DIVISION OF ENTOMOLOGY, IARI, NEW DELHI

The following were present:

S. No.	Name	Designation
1.	Dr. S.N. Puri	President
2.	Dr. B.V. Patil	Vice President
3.	Dr. N.K. Krishna Kumar	Vice President
4.	Dr. V.V. Ramamurthy	Chief Editor
5.	Dr. J.P. Singh	General Secretary
6.	Dr. S.S. Suroshe	Councillor
7.	Dr. Subhash Chander	Special Invitee & Ex Joint Secretary
8.	Dr. P.R. Shashank	Special Invitee

The Executive Committee (EC) members Drs. Dr. M. Premjit Singh (Vice President), and H.K. Singh (Councillor) were given leave of absence as they could not attend the meeting due to preoccupation. The EC placed on record its appreciation and gratitude to the outgoing EC members.

The following agenda items were discussed and the proceedings are as follows:

A. Society Activities

1. Membership:
   - Discussion on modification in terms and conditions for life membership were held.
   - It was decided that membership (life) should be given immediately; and fellowship will be conferred after five years as per the existing norms. Onetime payment to become life member will be Rs. 15000/=.
   - Proposal for reducing membership fee to Rs 500/ year for students was discussed. The proposal was not approved.
   - Introduction of corporate membership was discussed and EC decided to accept corporate membership @ Rs. 1 lakh each as onetime payment.

     All the Head/Prof's of Department of Entomology in Colleges/Universities/ICAR Crop Institutes will be sent a request to inform Entomologists and Post Graduate Students to become members/life members.

     (Action: General Secretary/Treasurer)

2. Processing fee:
   - Discussion on waive off processing fee for students: If the M.Sc. student is first author and research paper is from his/her thesis only then no processing fee will be charged.

     (Action: Chief Editor/Treasurer)

3. Deliberation on strengthening regional chapters
   - Regional chapters will be strengthened across the different zones of the country. Each zone will be headed by Zonal President which must enroll at least 50 life members. Zonal President can be assisted by Chapters each held by a Councillor, and each Chapter must have at least 25 life members. The detailed work plan for strengthening the regional chapters will be drafted by Dr. B.V. Patil.

     (Action: Dr. B.V. Patil)

4. Nomination by the EC to the positions in ESI

- Nomination of Joint Secretary, and Treasurer was discussed and EC nominated Drs. Subhash Chander, Professor, Division of Entomology as Joint Secretary and NM Meshram, Scientist, Division of Entomology, IARI as Treasurer.
- It was also decided to induct Head/Professor Division of Entomology, IARI, New Delhi;, Director, NBAIR, Bengaluru, as Ex Officio Advisers; and Dr. K.S. Khokhar, Ex-VC, HAU, Hisar as Advisor. Pending bye laws changes to this effect these Advisers will be shown as Honorary Vice Presidents as is being practiced now.

(Action: General Secretary)

5. Conducting regular Seminar/Symposia

- EC decided to have national/international seminar/symposia at least once in two years.

(Action: General Secretary)

6. Theme for the upcoming National Symposium to be held in July-August, 2018 in New Delhi (tentative) was discussed.

- EC decided to have "Lessons from transgenics in IPM: The way forward" as the theme for upcoming one to be held at IARI, New Delhi in July / August, 2018 (tentative). The details about brochure, detailed programme will be jointly drafted by Dr. BVP and Dr. NKK

(Action: Drs. B.V.P./N.K.K.)

7. Introduction of Lecture series/regular guest lectures

- EC discussed and decided to have lecture series in memory of eminent Indian entomologists. Names for these lecture series will be finalized by Drs. SSS and PRS. Guest lecture series is to be organized by the Pusa Entomology Club (PEC), Division of Entomology, IARI, New Delhi to be sponsored by ESI.

(Action: Drs. S.S.S./P.R.S.)

8. India Storage Forum incorporation with ESI as approved by the earlier EC was discussed

- EC agreed to include India Storage Forum and its related activities under ESI, as a separate arm, with the terms and conditions as already finalized by the previous EC.

(Action: Chief Editor)

9. Financing of EC members for attending ESI meeting

- EC discussed and agreed to finance EC members for attending ESI EC meeting on case to case basis.

(Action: General Secretary)

B. Awards/Student Travel Grants/Fellows

- ESI Student Grant for sponsoring of attending well recognized International Conferences/Workshops with main theme in Entomology was discussed. EC agreed to sponsor registration fee of two students/ year subject to a maximum of Rs. 25,000/- each. The student must submit the abstract and other essential details including travel requirements at least two months before the conference dates and this will be vetted by the EC for grant.

(Action: General Secretary)

10. Introduction of ESI Best PhD Thesis Award in Entomology

- EC discussed and agreed to introduce one ESI Best PhD Thesis Award in Entomology/calendar year. The terms and conditions of ICAR's Jawaharlal Nehru Best PhD thesis award will be adopted for scrutiny. The award will not carry any money but TA for receiving the award restricted to 3rdAC/Rs. 5000/- whichever is less will be given.

(Action: General Secretary)

11. Introduction of ESI Young Scientist Award in Entomology

- EC discussed and agreed to introduce one ESI Young Scientist Award/calendar year. This award will be for the best Entomology contribution and restricted to young researchers up to 40 years of age, and the cutoff date will be 31st December of the previous year. Research undertaken should not be part of the dissertation (thesis) submitted.

(Action: General Secretary)

12. ESI Lifetime achievement award to be initiated.

- EC discussed and agreed to introduce one ESI Lifetime Achievement Award/ calendar year. The EC has to unanimously decide the candidate for this award based on original contributions in Entomology. This award will not carry any money but TA/DA will be provided if required to the Awardee.

(Action: General Secretary)

13. ESI Nominated/Distinguished Fellows to be initiated.

- EC discussed and agreed to introduce five ESI Nominated Fellows/calendar year. The applications will be scrutinized by EC. The guidelines and evaluation will be the one that is being currently adopted by the Indian Society of Genetics and Plant Breeding. Candidates should apply in the specific proforma as per ESI. The nomenclature will be finalized by Dr B.V.P./Dr. N.K.K.

(Action: General Secretary/Dr B.V.P., N.K.K.)

14. Quarterly ESI magazine to be published online.

- EC discussed and agreed to start online quarterly Magazine named as "Indian Entomologist". The Magazine will cover the general topics related to insect science and technology. EC decided to have Dr. P.R. Shashank as the Editor and Nodal officer for this.

(Action: Dr. P.R.S./Chief Editor).

15. Photo contest

- EC decided to introduce a photo contest to include one best photo in every issue of the Journal. Photos related to Insects/Insect Science can be submitted with a brief caption. Winner will be given certificate and photo will appear in the Journal issue.

(Action: Dr. P.R.S./Chief Editor)

C. Journal activities

16. Strengthening Editorial Board and including International Entomologists of repute in the Editorial (Advisory) Board.

- It was decided to have Sections of Entomology similar to Journal of Economic Entomology (International Journal) in the existing Editorial Board of the IJE along with Section Editors and Associate Section Editors for smooth, timely and quality review of research papers.

(Action: Drs. S.S.S./P.R.S.)

- It was decided to have an International Advisory Board consisting of eminent entomologist of repute working abroad. Action to contact the promising ones is to be taken for getting their consent.

(Action: Dr. B.V.P.)

17. Discussion on online review of the manuscripts and inclusion of platform for this.

- It was decided to solicit quotations from the prospective bidders based on our requirement. EC agreed to adopt Online Journal Management System for fast review and publication of manuscripts.

(Action: General Secretary)

18. Archiving of back volumes of IJE

- EC accepted to provide free access to all the back volumes of IJE to the ESI life members. It was also decided that same will be negotiated with prospective bidders for public use.

(Action: Chief Editor/General Secretary)

19. Sending of only PDF copy of journal to life members/members.

- EC unanimously agreed to the proposal to provide only PDF versions of the IJE issues to the ESI members having email account. EC felt that it is time to restrict hard copy usage to reduce the financial burden on the Society with the option to select only PDF copy instead of Hard copy. Correspondence will be made with members for this purpose

(Action: Chief Editor/General Secretary)

D. Society Infrastructure

20. Staff salary: EC agreed to continue paying Rs. 10000/- pm for Mr. Kushiram. Also to pay small honorarium to the other staff that is being used for computer/ website work from time to time was approved.

(Action: Chief Editor/General Secretary)

21. Office place (addition in the new location) and furnishing: EC agreed to furnish the ESI office with necessary infrastructure.

(Action: Chief Editor/General Secretary)

The meeting ended with a vote of thanks to the Chair and members of the EC.

President **General Secretary**

INSTRUCTION TO CONTRIBUTORS

(see www.entosocindia.org)

Indian Journal of Entomology, is a leading journal in entomological science published quarterly by *The Entomological Society of India*. The Society invites and accepts contributions from the members. After requisite peer reviewing, it publishes original articles on various aspects of entomology – both basic and applied, covering taxonomy, toxicology, ecology, biodiversity, pest management and pesticides, biopesticides and botanicals, biotechnological approaches in entomology, inclusive of latest trends in frontier technologies like application of remote sensing, and crop-pest modeling. Article should be original, indicate period (years) of experimentation, based on data of minimum 2 years for full research paper, must not be the work of more than 5 years old. The review papers, research papers, and short notes should not exceed 30, 20 and 7 typed pages including tables and figures respectively.

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ABSTRACT written in complete and simple sentences, should not be more than 150 words. Key words (maximum seven) must be given; and these should appear just beneath the abstract.

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Rembold, H., Forster, H. and Czoppelt, C.H. 1987. Structure and biological activity of azadirachtins A and B. In: Proceedings of third neem conference, Nairobi, 1986. pp. 149-160.

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Prakash, V. 1996. Status distribution and breeding biology of lesser spotted eagle *Aquila pomanna* hastate in Keoladeo National Park, pp. 357-375. Meyburg, B.U. and R.D. Chancellor (eds.). Eagle Studies. World Working Group on Birds of Prey (WWGBP), London. 670pp.

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