ISSN 0367-8288 (PRINT)
ISSN 0974-8172 (ONLINE)

INDIAN JOURNAL OF ENTOMOLOGY

VOLUME 84 PART 1 March 2022

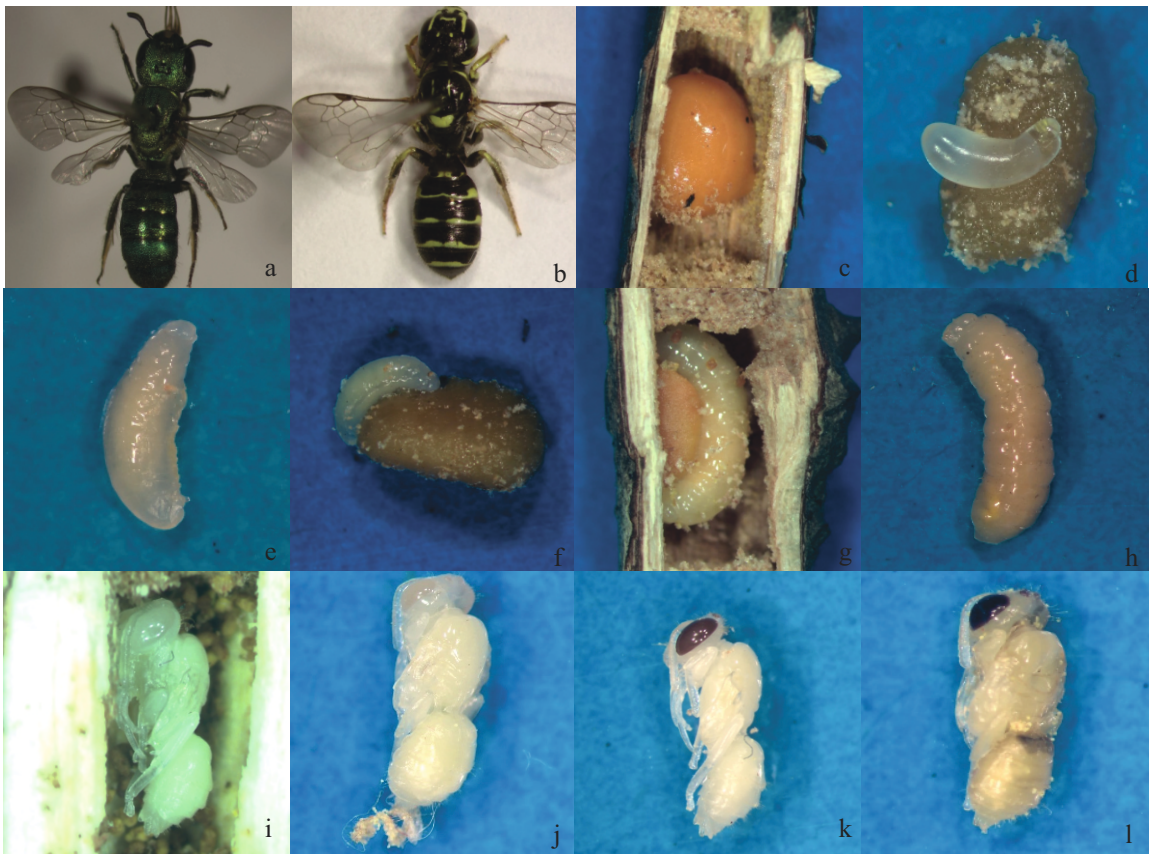


Fig. 1a-l. Carpenter bees-nest architecture and life stages; a. *C. smaragdula* adult; b. *C. hieroglyphica* adult; c. *C. smaragdula* nest with pollen provision; d. freshly laid egg by *C. hieroglyphica*; e. first instar larva of *C. smaragdula*; f. *C. hieroglyphica* larva with two third size of pollen ball; g. *C. hieroglyphica* larva with twice the size of pollen ball; h. pre-defecating larva of *C. smaragdula*; i. white eyed pupa of *C. smaragdula*; j. pink eyed pupa of *C. smaragdula*; k. brown eyed pupa of *C. smaragdula*; l. black eyed pupa of *C. hieroglyphica* with half body pigmentation.
For details see page No.38-43 of this issue.

Published by
The Entomological Society of India

THE ENTOMOLOGICAL SOCIETY OF INDIA

www.entosocindia.org
(Registration No. S 2434 of 1963-64 dt. 12.3.1964) NITI Aayog ID: VO/NGO-DL/2016/0104219

EXECUTIVE COMMITTEE*

EDITORIAL BOARD

Manuscripts to be submitted online in indianentomology.org
All communications should be addressed to : ENTOMOLOGICAL SOCIETY OF INDIA
Division of Entomology ICAR- Indian Agricultural Research Institute, New Delhi 110012, India
Email: entosocindia@gmail.com

Annual Membership Fee :	**India**			**Foreign**		
	Individual	:	India Rs. 1000/-	Individual	:	US $ 100
	Institutional	:	India Rs. 6000/-	Institutional	:	US $ 700

For more details on membership etc., please refer to the subscription details/ membership form appended in the journal before contents page
www.entosocindia.org

Subscriptions by Demand Draft/ Cheque (payable to Entomological Society of India at New Delhi). For online payment- State Bank of India, NSC Beej Bhavan, Pusa Campus, New Delhi-110012. Current A/c No. 11084230887, IFSC Code SBIN0005389. A/c Name–Entomological Society of India. Payment Gateway available in website.

Entomological Society of India (ESI)

Condoles with Grief the Sudden Demise of Shri Khushi Ram

Khushi Ram served the ESI for more than four decades with devotion and dedication. ESI remembers this with gratitude and reverence

MAY HIS SOUL REST IN PEACE

Indian Journal of Entomology

Volume 84 March 2022 Part 1

Published by:
THE ENTOMOLOGICAL SOCIETY OF INDIA
(online www.indianjournals.com)

THE ENTOMOLOGICAL SOCIETY OF INDIA

(www.entosocindia.org)

(Founded 1938)

The Entomological Society of India (ESI) was founded in 1938 as a registered society under the Societies Registration Act 1957 as extended to the Union territory of Delhi under Registration No. S. 2434 of 1963-64 dt. 12.3.1964. It is registered with NITI Aayog under unique ID of VO/NGO-DL.2016/0104219. It is one of the largest professional societies in India serving entomologists and researchers in related disciplines.

The main objective of the Society is to encourage and promote the dissemination of entomological knowledge. It arranges interactions of entomologists at the headquarters and at various places where the branches/chapters of the Society are getting initiated. The annual general body meetings are held regularly and whenever necessary. These interactions provide opportunities to the members and others interested in the subject to keep in touch with the entomological activities, both in India and abroad. The Society has chapters, each with a minimum of 25 members and these conduct events for the promotion of Entomology.

The membership of the Society is open to all persons, above 18 years of age, who are interested in Entomology. Ordinary members have to pay an admission fee of Rs. 100/- and an annual subscription (pdf only) of Rs. 1000/-. From 2019, on payment of Rs. 15100/- one can have the option of straightaway becoming Life Member. Life membership had been restricted earlier to only those who have completed five years as ordinary members, but this condition has been waived off now, for some fixed duration. These payments are required to be made by NEFT transaction or in the form of DD or multicity cheque payable at New Delhi in favour of "Entomological Society of India". NEFT details are given below. Life Members who wish to be considered as Fellows of the Society may send two copies of their biodata to the Entomological Society of India, Room No. 4A, Division of Entomology, IARI, New Delhi 110012. The biodata of the members will be screened by the competent committee of the Society before the declaration of the Fellows of the Society (FESI). The Society may occasionally elect Honorary Members, persons well known for their services to the cause of Entomology. For more details see website of ESI- www.entosocindia.org, and website of Indian Journal of Entomology OJMS at indianentomology.org.

Articles submitted for publication must adhere to the Journal's current format and style and the Instructions to authors given in the website of the Society i.e., www.entosocindia.org or in OJMS website indianentomology.org. Each article will require a processing fee of Rs. 1000, to be made by NEFT transaction or in the form of DD or multicity cheque payable at New Delhi in favour of "Entomological Society of India". NEFT details are given below. The processing fee is non-refundable. It is obligatory that each author must be a member of the Society and articles are to be submitted online at the online submission/ review platform i.e., indianentomology.org. A PAYNOW link is provided in the website under Membership for facilitating online payments which can be used. With effect from 1.4.2022 there are changes in the article processing charges etc. The Journal is migrating to APC (Article Processing charges) which has been updated in the website indianentomology.org and also at www.entosocindia.org.

The Indian Journal of Entomology: The official publication of the Society was started in 1939. Since 1956, it is being published as a quarterly Journal and the four parts are published each in March, June, September and December. It is online published from 2008 (Volume 70) onwards (through indianjournal.com). This is going to be open access w.e.f 2022 Volume 84 for which processing is on, and details can be seen in our ESI website and OJMS website.in January 2022 (See indianentomology.org).

Bionotes: This publication is privately issued by late Dr R K Varshney from Aligarh. Its online version is hosted by the Society in the website.

Memoirs: Whenever suitable material and finances are available, the Society issues special numbers in the form of Memoirs. Sixteen such Memoirs on different topics have been published so far.

The Bulletin of Entomology: This publication, which was privately issued from erstwhile Madras, had been taken over by the Society from 1967. The Bulletin is an occasional, irregular publication, containing papers on bionomics, taxonomy, morphology etc. Subscription for the Bulletin of Entomology is Rs. 1000/- annually. Any entomologist who wishes to publish lengthy manuscripts can use this.

Indian Entomologist: It is a biannual online Magazine published by the Entomological Society of India

The Journal of Grain Storage Research: Its single issue was brought out in April 2016. It was to be taken up further by the Society for Grain Storage Research, under the "indiastorageforum" which is still under formation. Any entity who/ which will like to take up this under the banner of the Entomological Society of India, may contact the Chief Editor.

Reprints: Reprints will not be supplied. The Journal is available online and PDF of the papers published can be provided on specific request. Authors can freely download the pdf of the papers from indianentomology.org.

Disclaimer: Articles published herein report the results of research done by the authors. Mention of a proprietary product/ commercial formulation/pesticide does not constitute recommendations or endorsement for its use by the Journal/Entomological Society of India. Use of registered trade names/ trademarks etc., used in the articles even without specific indications thereof, are not to be considered unprotected by law. All articles published in the Journal are signed by the authors, unless otherwise stated and solely reflect the individual views of the authors and not necessarily any official view of the Journal/Society. The Journal/Society assumes no responsibility for the contents/completeness/views/other items/accuracy of the conclusion reported therein. Submissions made by the authors are by default deemed to have satisfied the journal publication policy and the publications ethics pronounced clearly on the issues of the Journal and website.

EDITORIAL

In the Editorial last year, I wrote “CHANGE is the only constant in life” and that the Indian Journal of Entomology is continuing with this CHANGE constantly. True to this, I am proud such “CHANGES” are in this volume too. With the Journal enrolling two well acclaimed review editors- starting with this issue, we are publishing invited reviews. Also, there are new columns under “Perspective” and “Opinion” through which the Journal has opened up for the views of the industry and experts. The Journal has a new look - not in its “showing off”, but in its contents, as stated by me last year. The Journal has moved to “OPEN ACCESS” with a new OJMS system, managed by an internationally reputed, professional journal handler with effect from 2022. The journal can now boast of an up-to-date professional management system with a strong backup of peer review, plagiarism check, journal management and above all “open access”. The doi assignments, and online publishing are also migrating towards making the Journal up-to-date and state of the art, with a view to scaling up its citations. Yes, the Journal believes in the reality that the measure of intelligence is the ability to “CHANGE”, and I am hopeful that the “intelligence” making the Journal “CHANGE” will progress it and its’ contents in the upcoming issues. I am sure the authors will relish these changes and appreciate the fact that the Journal is now similar to many other well standing ones. I wish this “CHANGE” also happens with the authors and their manuscripts. The Journal will look forward to improved quality of submissions by the authors, and their changed outlook towards entomology publishing. I am sure all of us will agree that it is an imminent need.

Let me reiterate the fact that the measure of intelligence lies in our ability to “CHANGE” and we need to change constantly in our endeavours. Entomology provides multiple opportunities for researchers and scientists for this CHANGE, as insects provide useful and valuable models for deciphering life in its real meaning, and with a strong scientific backing. Many things happen in our life, and insects and their life can provide suitable explanations for these. Many intriguing aspects of human life could be explained with these. Social insects and sociobiology are such aspects that deserve a special mention here, as these relate to one of the special aspects of human life. For example, I am citing one (at the link below) which provides a glimpse of -how interesting it is, and how we can learn from insects and their behaviour.

https://science.thewire.in/the-sciences/ropalidia-marginata-primitive-eusocial-species-queen-succession.

There is “More Fun than Fun” when we happen to read such episodes and realize that there is a lot to be learnt from insects and their life. Such learning is really extraordinary, and provides essence for our life. As Editor of a Journal, I am envious about how such biological explanations using insects have been moulded by its inventor Prof. Raghavendra Gadagkar towards explaining simple things that happen in biology of insects. I sincerely urge all the readers of our Journal to atleast just peek into these episodes, and appreciate and enjoy the intriguing facts of insects and their biology. Such readings, I am sure will enhance our intelligence. These will enable us appreciating the fact that such enhancements lie in our ability to “CHANGE”, and trigger the same in our dealings with Entomology sooner than later.

Indian Journal of Entomology 84(1): 1-5 (2022) DoI.: 10.55446/IJE.2021.4

EFFICACY OF INSECTICIDES AGAINST PEA WEEVIL *BRUCHUS PISORUM* (L.) ON FIELD PEA

Garuma Nemera Roge*, Waktole Sori Gobena[1] and Wakuma Bayissa Hundessa[2]

Holetta Agricultural Research Center, P O Box 31, Holetta, Ethiopia
[1]Ethiopian Horticulture Producer Exporters Association, P O Box 22241, Addis Ababa, Ethiopia
[2]Jimma University, College of Agriculture and Veterinary Medicine, Department of Horticulture and Plant Sciences; P O Box 307, Jimma, Ethiopia
*Email: grmn2007@gmail.com (corresponding author)

ABSTRACT

Field pea *Pisum sativum* L. is an important legume crop in Ethiopia and insect pests are the major constraints in its production. Amongst these pea weevil *Bruchus pisorum* L. is important. This study evaluates the effects of lambda cyhalothrin (Karate 50EC), chlorantraniliprole (Coragen 200SC) and carbaryl (Sevin 85WP) under field conditions at the Holetta Agricultural Research Center, Ethiopia. The insecticides were applied at flowering, pod setting and both at flowering and pod setting stages, using the susceptible variety 'Burkitu' in randomized complete block design. The results revealed that there was no significant difference among the treatments. Similarly, insecticide application frequency and crop phenology had no effect on the incidence of egg and larvae in field, and on adult emergence under storage conditions.

Key words: *Pisum sativum*, *Bruchus pisorum*, lambda cyhalothrin (Karate 50EC), chlorantraniliprole (Coragen 200SC) and carbaryl (Sevin 85WP), crop phenology, flowering, pod setting, egg, larva, adult

Field pea *Pisum sativum* is the second most important legume crop in Ethiopia after faba bean (CSA, 2018), and it is grown in altitudes ranging from 1800-3000 masl, with annual rainfall of 700-1000 mm (Mussa et al., 2003). However, the productivity remains below world average (2 t/ ha) (FAOSTAT, 2017). This might be attributed to biotic and abiotic constraints. Insects such as pea weevil, pea leaf weevil, pea aphid, army worm, Lygus bugs and cut worms are the major pests (Hagedorn, 1976; Gorfu and Beshir, 1994; Daniel, 2010). Bruchids are the most important insect pests of food legumes (Bushara, 1988; Kashiwaba et al., 2003).

Pea weevil *Bruchus pisorum* L., is an economically important pest causing significant losses (Clement et al., 2000). Worku (1998) and Seyoum et al. (2012) also reported yield losses up to 85% and weight losses up to 59% at Sekota, Ethiopia. The seed damage caused by the pest resulted in low market value due to less value for human consumption and animal feed, and also poor in germination (Clement et al., 2002; Seyoum et al., 2012). Thus, it is a cosmopolitan and most destructive insect pest of the pea cultivars which is believed to be introduced in to Ethiopia during mid-1970s (Clement et al., 2009). The insect is strictly monophagous and completes its univoltine life cycle only on pea crop. Upon emergence from hibernation sites, the adults fly into the pea fields and search for mate and oviposition sites. Many factors decide its preference to oviposit (Mendesil et al., 2016). Female insects first become sexually mature by feeding pea flower (Pajni and Sood, 1975). The larvae once hatched, burrow through the pod wall into maturing seeds to consume them and complete its development resulting in yield and quality loss (Michael et al., 1993). Such cryptic nature complicates its management. Better control of the pest is usually achieved with contact insecticides against adults in fields before they lay eggs on pods (Horne and Bailey, 1991; Smith and Hepworth, 1992; Clement et al., 2000; Afonin et al., 2008). The infestation starts in the field when adults first lay their eggs, which starts from the crop's flowering stage up to pod setting stage. Thus, repeated application of insecticides is required, and generating information on the efficacy of insecticides is required. The present evaluates insecticides viz., lambda cyhalothrin (Karate 50EC), chlorantraniliprole (Coragen 200SC) and carbaryl (Sevin 85WP) and also finds the best time of application of these.

MATERIALS AND METHODS

The experiment was conducted during the main cropping season of 2017/ 2018 at the Holetta Agricultural Research Center (HARC) field experimental site, Ethiopia (9º00'N, 38º30'E, 2400 masl). Susceptible field pea variety called 'Burkitu' was used with spacing

of 20 and 5 cm between rows and plants, respectively. The insecticides evaluated include- Karate® 50EC (lambda-cyhalothrin) at 0.048 ml; Coragen®200SC (chlorantraniliprole) at 0.03 ml; and Sevin 85WP (carbaryl) at 1.8 x 10^{-4} kg/ plot. These were applied at flowering, pod setting and both at flowering and pod setting stages, with plots (1.5 x 0.8= 1.2 m^2) arranged in a completely randomized block design and replicated four times. The buffer spacing was 1 and 1.5 m between plots and adjacent replications, respectively. All other agronomic practices were done as recommended for the crop in the area.

Before the second spray at pod setting stage, pods were carefully assessed and estimates of adult *B. pisorum* incidence was made with 25 sweeps with a sweep net following the insect's threshold level (Baker, 2016). Ten plants from each middle row were selected and ten pods with eggs were tagged and the number of eggs from each pod was recorded. After applying the second spray, post-spray egg count was made to see the ovicidal effect. Number of larvae was counted by dissecting 50 dry seeds taken randomly from each tagged pod at harvest. Fifty-gram seeds from each treatment were randomly taken and allocated to determine the number of adults emerged/ experimental unit in a plastic jar of 250 ml capacity. The jars were inspected on daily basis for the emergence of adults. The temperature (^{0}C) and relative humidity (%) of the laboratory room was recorded using thermo-hygrometer on daily basis. The number of days required for adults to emerge was recorded starting from harvest until the first adult emerged off seeds.

The % grain damage was calculated by separating healthy (without holes) ones from the sieved samples following Khattak et al. (1987). After separating grains into damaged with exit holes and undamaged ones, these were weighed separately and % weight loss was computed following Gwinner et al. (1996). Clean, 1000 seeds were taken from each treatment and weighed in gram after adjusting the moisture content to 10% (Cassells and Armstrong, 1998). Yield/ plots at harvest was taken and converted into ha basis. Phytotoxicity score was made after each spray based on leaf scorch scale of 0-3; where 0 = no symptom, 1 = light, 2 = medium, 3 = heavy scorching, according to pesticide efficacy testing protocol and procedures for registration of pesticides in Ethiopia (Lavadinho, 2001; Deneer et al., 2014). Mean of pre and post spray egg counts at pod setting stage was subjected to % efficacy calculation using Abbott's formula (1985).

Germination test was done to observe the effects of the treatments on the pea's seed viability. Fifty seeds were randomly selected from each treatment and placed on moist filter paper on petridish for seven days following Gwinner et al. (1996) and % germination computed. Data on larvae count, adults emerged, % grain damage, grain weight loss and germination were square root transformed and subjected to ANOVA (Gomez and Gomez, 1984) and least significant difference (LSD, p=0.05) used for mean separation using SAS v. 9.3 (SAS, 2011) software.

RESULTS AND DISCUSSION

There was insignificant difference with pre and post treatment application egg counts; though statistically non-significant, there was a clear reduction with treatments. Seidenglanz et al. (2011) observed that pyrethroid insecticides were more effective compared to the neonicotinoids. As such the number of died eggs might be compensated by the newly oviposited eggs and, egg numbers before and after treatment application probably balanced each other. Position of eggs on the pods in relation to the direction of spraying and eggs which might be laid after the treatment application could also influence the egg numbers. The form in which the eggs of *B. pisorum* laid might also have its influence on the efficiency of the treatments as the eggs of the insect usually laid in the form of clusters than single eggs in which only the upper top eggs face treatments and the bottom eggs rarely affected by the applied insecticides (Seidenglanz et al., 2007).

With, larval and adult counts also the results are non-significant, but with larvae, carbaryl at flowering stage showing maximum efficacy (Table 1). Aznar-Fernandez et al. (2018) and Afonin et al. (2008) observed that food competition can lead to death of many larvae. As many as 45 eggs can be laid on single pod and usually about 5 larvae can get into one grain even though usually only one larvae develops and pupate while the others perish either because of physical damage during exit or due to food competition. Thus, the larvicidal effects, the number of emerged adults became minimal and there were no significant differences. Thousand seed weight and yield also did not show significant differences, as infestation of *B. pisorum* starts in the field and the feeding continues until the adults exit off the seeds in the store. As such, the effect the insect is more of on seed weight loss and quality in the store than direct yield loss at harvest, the result in line with the findings of Gagic et al. (2016). Only least grain damage and loss in

Table 1. Efficacy of insecticides on *B. pisorum* on field pea

Treatments	Egg counts (eggs/pod)		Larvae/ 50 seeds** (Mean± SE)	No. of adults/ 50 g seeds** (Mean± SE)	Grain damage (%) **	Grain weight loss (%) **	Germination (%) **	Days to adult Emergency	Efficacy of treatments on egg (%)	Thousand seed weight (g) (Mean± SE)	Yield (Qt./ ha) (Mean± SE)
	Before spray (Mean± SE)	After spray (Mean± SE)									
- Karate® 50EC (lambda-cyhalothrin) (F)	4.50± 0.17	2.03± 0.1	5.5 (2.28± 0.09)	2.25 (1.54± 0.08)	0.76 (1.09± 0.03)	0.1 (0.77± 0.02)	89 (94.26± 0.64)	50.63± 2.68	61.44	308.77± 2.08	41.45± 1.74
- Karate® 50EC (lambda-cyhalothrin) (P)	4.58± 0.14	2.10± 0.09	4.25 (1.92± 0.2)	3 (1.75± 0.17)	0.85 (1.1± 0.12)	0.21 (0.83± 0.03)	91 (95.31± 0.88)	44.18± 2.35	50.08	291.27± 7.81	37.18± 2.13
- Karate® 50EC (lambda-cyhalothrin) (F+P)	3.83± 0.22	1.58± 0.13	2.25 (1.61± 0.17)	4 (1.94± 0.09)	1.83 (1.38± 0.05)	0.47 (0.95± 0.01)	88 (93.76± 0.28)	53.2± 2.12	53.60	298.52± 6.40	42.63±1.23
Coragen®200SC (chlorantraniliprole) (F)	4.53± 0.14	1.85± 0.05	2.25 (1.61± 0.08)	1.25 (1.26± 0.18)	0.47 (0.97± 0.12)	0.16 (0.81± 0.04)	85 (92.17± 0.79)	62.28± 0.62	66.59	296.74± 0.86	36.05± 1.56
Coragen®200SC (chlorantraniliprole) (P)	3.98± 0.16	1.65± 0.07	3.5 (1.88± 0.09)	1.75 (1.41± 0.11)	0.45 (0.95± 0.06)	0.14 (0.8± 0.01)	90 (94.84± 0.43)	52.15± 2.75	52.12	268.34± 6.19	40.6± 1.53
Coragen®200SC (chlorantraniliprole) (F+P)	4.65± 0.28	2.03± 0.16	7 (2.61± 0.12)	3.25 (1.88± 0.07)	0.99 (1.18± 0.05)	0.22 (0.84± 0.01)	84 (91.64± 0.62)	47.73± 1.83	56.32	278.42± 5.42	42.96± 1.39
Sevin 85WP (carbaryl) (F)	5± 0.13	2.30± 0.05	1.5 (1.35± 0.18)	4 (1.98± 0.1)	1.24 (1.27± 0.08)	0.17 (0.82± 0.01)	81 (89.99± 0.2)	40.85± 2.03	58.22	285.74± 2.55	45.72± 1.79
Sevin 85WP (carbaryl) (P)	4.78± 0.21	2.23± 0.1	9.25 (2.98± 0.17)	2 (1.48± 0.15)	0.56 (0.95± 0.07)	0.09 (0.76± 0.02)	89 (94.3± 0.58)	62.7± 1.26	64.01	281.67± 5.37	35.96± 0.63
Sevin 85WP (carbaryl) (F+P)	4.63± 0.22	2.13± 0.09	7.5 (2.56± 0.06)	4.25 (1.96± 0.08)	1.95 (1.45± 0.04)	0.34 (0.9± 0.01)	91 (95.31± 0.43)	55.65± 3.14	53.33	271.5± 1.79	38.93± 0.57
Control (untreated)	5± 0.24	2.30± 0.09	4.75 (2.14± 0.06)	4 (2.06± 0.08)	1.18 (1.24± 0.05)	0.22 (0.85± 0.02)	85 (92.18± 0.58)	50.5± 2.66	0.00	295.07± 2.14	45.41± 1.24
LSD (0.05)	1.22ns	0.77ns	1.33ns	1.07ns	0.66ns	0.20ns	4.75ns	21.76ns	-	42.60ns	9.74ns
CV	18.42	26.34	43.76	42.83	39.11	17.03	3.5	28.85	-	10.21	16.5

**=Square root transformed; (F) = at flowering, (P) = at pod setting, (F+P) = at both flowering and pod setting stages; ns = non-significant (p-0.05), SE = standard error. means within parentheses in a column after transformation; ns= non-significant (p=0.05); SE= standard error.

grain weight were observed as the insecticides inhibited only the pupation of larvae with their larvicidal effects. These results agree with those of Smith (1990) that grain weight loss is <4% when the *B. pisorum* is managed by spraying insecticides. This study also conforms to the findings of Horne and Bailey (1991) that damage can be reduced by managing adult *B. pisorum* in the field pea.

Fumigating the stored pea also found to be associated with lower damage (Mihiretu and Wale, 2013). Results from germination test showed non-significant difference, it was >80% in all treatments agreeing with observations of Matthews and Holding (2005). There was non-significant difference with regard to days for adult emergence- the least of 40.85± 2.03 was observed in carbaryl applied at flowering stage, and maximum of 62.7± 1.26 with carbaryl sprayed at pod setting stage; while chlorantraniliprole at flowering stage and carbaryl at pod setting stage were the best in delaying the number of days to adult emergence. The efficacy of the treatments at three growth stages 50.08 to 66.59% with insignificant differences- chlorantraniliprole at flowering stage showed maximum efficacy (66.59%), followed by carbaryl at pod setting stage (64.01%). Thus, in general carbaryl and chlorantraniliprole at flowering stage performed best with terms of their larvicidal effects.

ACKNOWLEDGEMENTS

The authors thank the Holetta Agricultural Research Center for providing the planting material, experimental plots and some laboratory materials; also, the Ethiopian Institute of Agricultural Research (EIAR) for funding the project.

Conflict of interest: No potential conflict of interest reported.

REFERENCES

Abbott W S. 1925. A method of computing the effectiveness of an insecticide. Journal of Economic Entomology 18: 265-267.

Afonin A N, Greene S L, Dzyubenko N I, Frolov A N. 2008. Interactive agricultural ecological atlas of Russia and neighboring countries. Economic plants and their diseases, pests and weeds. http://www.agroatlas.ru/en/content/cultural/#MediCago_lupulina_k/index.html

Aryamanesh N, Byrne O, Hardie D C, Khan T, Siddique K H M, Yan G. 2012. Large-scale density-based screening for pea weevil resistance in advanced backcross lines derived from cultivated field pea (*Pisum sativum*) and *Pisum fulvum*. Crop and Pasture Science 63(7): 612-618.

Baker G. 2016. Pea weevil. Fact sheet. Primary Industries and Resources & South Australian Research and Development Institute, Australia. 8 pp.

Bushara A G. 1988. Insect depredation during storage. World Crops: Cool season food legumes. Summerfield R J (ed.). Kluwer: Dordrecht, the Netherlands. 367-378 pp .

Cassells J, Armstrong E. 1998. Harvest and storage, timing all important in boosting quality, NSW Agriculture.

Clement S L, Wightman J A, Hardie D C, Bailey P, Baker G, McDonald G. 2000. Opportunities for integrated management of insect pests of grain legumes. Knight R. (ed.). Linking research and marketing opportunities for pulses in the 21st century. Kluwer Academic, Dordrecht, Netherlands. 467-480 pp.

Clement S L, Hardie D C, Elberson L R. 2002. Variation among *Pisum fulvum* accessions for resistance to pea weevil. Crop Science 42(6): 2167-2173.

Clement S L, McPhee K E, Elberson L R, Evans M A. 2009. Pea weevil, *Bruchus pisorum* L. (Coleoptera: Bruchidae), resistance in *Pisum sativum*× *Pisum fulvum* inter specific crosses. Plant Breeding 128(5): 478-485.

CSA (Central Statistics Agency). 2018. Agricultural sample survey 2017/2018, Volume I: Report on Area and Production of Crops, Addis Ababa, Ethiopia.

Daniel, W. 2010. Insect pests of field peas and lentils. NC Research Extension Center, Minot.

Deneer J W, Adriaanse P I, De Boer P, Busschers M, Lahr J, Schoor C, Van Vliet P, Woldeamanual A. 2014. A scientific evaluation system for the registration of pesticides in Ethiopia (No. 2547), Alterra Wageningen U R.

Gagic V, Riggi L G, Ekbom B, Malsher G, Rusch A, Bommarco R. 2016. Interactive effects of pests increase yield. Ecology and Evolution 6(7): 2149-2157.

Gorfu D, Beshir T. 1994. Field pea diseases in Ethiopia. Proceedings. National cool-season food legumes review conference, Addis Abeba (Ethiopia), 16-20 December 1993. ICARDA/IAR.

Gwinner J, Harnisch R, Muck O. 1996. Manual on the prevention of post-harvest seed losses, post-harvest project, GTZ, D-2000, Hamburg, FRG. 294.

FAOSTAT. 2017. Crops production. http://www.fao.org/faostat/en/#data/QC

Hagedorn D J. 1976. Handbook of pea diseases. A Cooperative Extension Program. University of Wisconson.

Horne J, Bailey P. 1991. *Bruchus pisorum* L. (Bruchidae: Coleoptera,) control by a knockdown pyrethroid in field peas. Crop Protection 10(1): 53-56.

Kashiwaba K, Tomooka N, Kaga A, Han O K, Vaughan D A. 2003. Characterization of resistance to three bruchid species (*Callosobruchus* spp., Coleoptera, Bruchidae) in cultivated rice bean (*Vigna umbellata*). Journal of Economic Entomology 96: 207-213.

Khattak S U, Jan K Y, Hussain N, Khalil K. 1987. Resistance of chick-pea cultivars to Pulse beetle, *Callososbruchus maculatus*. Scientific Khybert 8: 1-8.

Lavadinho A M P. 2001. Efficacy evaluation of plant protection products, EPPO Bulletin, 31(3): 345-352.

Matthews P, Holding D. 2005. Germination testing and seed rate calculation. Pulse Pt 20: 1-4.

Mendesil E, Rämert B, Marttila S, Hillbur Y, Anderson P. 2016. Oviposition preference of pea weevil, *Bruchus pisorum* L. among host and non-host plants and its implication for pest management. Frontiers in Plant Sciences 6: 1186.

Michael P, Hardie D C, Mangano P. 1993. Insect and mite control. Pritchard I, Carpenter J, Anderson W. (eds.). Growing field peas.

Western Australian Department of Agriculture, Western Australia, Perth, Australia. 65-77 pp.

Mihiretu E, Wale M., 2013. Effect of harvesting and threshing time and grain fumigation of field peas (*Pisum sativum* L.) on pea weevil (*Bruchus pisorum* (L.) (Coleoptera: Bruchidae) development and damage. Ethiopian Journal of Science and Technology 6(1): 13-24.

Mussa J, Tezera W, Gemechu K. 2003. Review of field pea (*Pisum sativum* L.) Genetics and breeding research in Ethiopia. Food and Forage Legumes of Ethiopia. Progress and prospects. Proceedings of a Workshop on Food and Forage Legumes. pp.22-26.

Pajni H R, Sood S. 1975. Effect of pea pollen feeding on maturation & copulation in the beetle, *Bruchus pisorum* L. Indian Journal Of Experimental Biology 13(2): 202-203.

SAS Institute. 2011. Statistical Analysis System Version 9.3, SAS Institute, Inc., Cary, NC, USA.

Seidenglanz M, Rotrekl J, Cejtchaml J, Poslušná J. 2007. Možnosti ochrany hrachu proti zrnokazovi hrachovému (*Bruchus pisorum* L.; Chrysomelidae; Coleoptera). Proceedings Conference. Aktuální poznatky v pěstování, šlechtění, ochraně rostlin a zpra-cování produktů, November 8-9, 2007, VÚP Troubsko u Brna, Brno. pp.129-136.

Seidenglanz M, Rotrekl J, Poslušná J, Kolařík P. 2011. Ovicidal effects of thiacloprid, acetamiprid, lambda-cyhalothrin and alpha-cypermethrin on *Bruchus pisorum* L. (Coleoptera: Bruchidae) eggs. Plant Protection Science 47(3): 109-114.

Seyoum E, Damte T, Bejiga G, Tesfaye A. 2012. The status of pea weevil, *Bruchus pisorum* (Coleoptera: Bruchidae) in Ethiopia. Proceedings. 17th Annual Conference, 26-27 November 2010. Invasive plant pests threatening Ethiopian agriculture, Ethiopia, Addis Ababa: Plant Protection Society of Ethiopia. 52-66 pp.

Smith A M. 1990. Pea weevil (*Bruchus pisorum* L.) and crop loss-implications for management. Bruchids and legumes: economics, ecology and coevolution 46: 105-114. Springer, Dordrecht.

Smith M A, Hepworth G. 1992. Sampling statistics and a sampling plan for eggs of pea weevil (Coleoptera: Bruchidae). Journal of Economic Entomology 85(5): 1791-1796.

Worku T. 1998. New insect pest on field pea. 'Gibrinachen', Amharic Edition, Bureau of Agriculture, Bahir Dar, Ethiopia 1(1): 13-14.

(Manuscript Received: September, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20357

Indian Journal of Entomology 84(1): 6-23 (2022) DoI.: 10.55446/IJE.2021.25

TAXONOMIC STUDIES ON GRAMINACEOUS STEM BORERS FROM NORTH INDIA

Adrish Dey and P R Shashank*

Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi 110012, India
*Email: spathour@gmail.com (corresponding author)

ABSTRACT

Thirteen species of stem borers attacking graminaceous crops, belonging to five genera viz. *Chilo* Zincken, 1817; *Scirpophaga* Treitschke, 1832; *Bissetia* Kapur, 1950; *Emmalocera* Ragonot, 1888; *Sesamia* (Guenee, 1852) have been redescribed with current valid names, synonyms, authors, distribution, and host plants. The specimens were identified from characters of the genitalia such as shape of the uncus, gnathos, valva, projections of the costa or tegumen, and shape of aedeagus. The genitalia of *Emmalocera aurifusellus* (Walker, 1866) is described here for the first time. Photographic illustrations for each species which includes the male and female habitus, and the genitalia of both sexes and diagnostic keys are provided.

Key words: Lepidoptera, Noctuidae, Crambidae, Pyralidae, *Chilo, Scirpophaga, Bissetia*

Graminaceous crops are one of the most important sources of food for humans and their livestock. Rice, maize, wheat, sugarcane, pearl millet and sorghum are important graminaceous crops in India. Many biotic factors hinder the productivity of these crops of which 20–40% of crop losses occur across the world due to pests and among them lepidopteran stem borers cause the most significant damage (Vallée et al., 2016). Especially, lepidopteran stem borers belonging to family Crambidae, Pyralidae and Noctuidae are the important economic pests of these graminaceous crops worldwide, reducing crop yields up to 40% (Lee et al., 2019). Among several stem borers, genus *Chilo* Zincken, 1817; *Scirpophaga* Treitschke, 1832 and *Sesamia* (Guenee, 1852) are economically important and taxonomically complex.

In India, many historical accounts have documented lepidopteran insect pests *viz*., Cotes (1889-1896), Lefroy (1909), Fletcher (1914), Pruthi (1969), Kapur (1950) Kollar (1844-48) and Moore (1865) contributed to stem borer fauna from India. Walker (1863) published a list of specimens in the collection of British Museum (now NHM, London). Moore (1884-87) published the *Lepidoptera of Ceylon*, including pyralid and present crambids fauna. Butler (1879) dealt with the North Eastern fauna and provided illustrations of lepidopteran type specimens present in the British Museum. Ghai et al. (1979) reported lepidopterous pests associated with rice crop in India including several rice stem borers. Arora (2000) studied taxonomy of economically important pyralids and crambids from India and provided keys for identification of economically important species of crambids. However, most of the isolated publications are on stem borers with special reference to crops i.e., rice, maize, sugarcane and sorghum. Moreover, majority of the publications provide line diagrams which are difficult to be understood by many non-taxonomists. Keeping this in view, in present study we redescribe important stem borer species occur in North India along with current taxonomic status, colour illustrations, Host plants, distribution, remarks and diagnostic keys for their identification.

MATERIALS AND METHODS

The materials used were obtained from different sources. A substantial number of identified specimens were obtained from National Pusa Collection (NPC), Division of Entomology, ICAR-Indian Agricultural Research Institute, New Delhi. Some specimens were also sorted out from the unidentified collections at NPC. The specimens were also collected from different locations *viz*., New Delhi, Lucknow and Punjab. Characters like length of labial palpi with respect to the diameter of the eye, venation of forewing and hindwing giving emphasis to the origin of the veins, specific colour and markings on wings, characters of male genitalia like the shape of gnathos, uncus, the shape of the valva, presence of costal or subteguminal processes, shape of the aedeagus etc. and characters of the female genitalia like the presence or absence of signum, shape of the bursa copulatrix etc. were used in the present study.

For preparation of genitalia slides, the abdomen of the moths was separated by a small hitch at its base. The separated abdomen was then placed in a

cavity block containing 10% KOH solution and left overnight. The abdomen was then washed in a cavity block with distilled water to remove excess KOH. The abdomen was then placed in another cavity block containing 10% ethanol. Using a pair of fine forceps, the genitalia was then separated gently from the abdomen. The separated genitalia structures were then placed on a clear microscope slide in 98% pure glycerol medium, covered with a cover slip and thereafter photographed and identified. The terminologies of Klots (1965) were adopted to describe the genitalia. After examining the specimen parts, it was transferred to into a micro-vial containing 98% glycerol and pinned below the respective specimen. The adult moths were photographed using a Canon 80D with 110 mm macro lens. The slides of male and female genitalia were photographed with digital camera Leica DFC 425C on a Leica 205FA stereo zoom microscope with auto-montage at the National Pusa Collection (NPC), Division of Entomology, ICAR-IARI, New Delhi. The specimens were identified with the help of genitalia structures using appropriate literature (Kapur, 1950; Bleszynski, 1970; Lewvanich, 1981; Arora, 2000).

RESULTS AND DISCUSSION

The stem borers infesting graminaceous crops are economically important and mostly belong to different families including Crambidae, Pyralidae and Noctuidae. The species can be recognised by the shape of labial palpi, wing venation pattern and genitalia. The species dealt within this paper in the aforementioned families are *Bissetia steniellus* (Hampson, 1899); *Chilo auricilius* Dudgeon, 1905; *Chilo infuscatellus* Snellen, 1890; *Chilo partellus* (Swinhoe, 1885); *Chilo sacchariphagus* Bojer, 1856; *Scirpophaga excerptalis* (Walker, 1863); *Scirpophaga gilviberbis* Zeller, 1863; *Scirpophaga incertulas* (Walker, 1863); *Scirpophaga nivella* (Fabricius, 1794) belonging to Crambidae; *Emmalocera aurifusellus* (Walker, 1866); *Emmalocera depressella* (Swinhoe, 1885) of Pyralidae family; *Sesamia inferens* (Walker, 1856) and *Sesamia uniformis* (Dudgeon, 1905) of Noctuidae.

1. *Bissetia steniellus* (Hampson, 1899) [Figs. 1, 2, 27, 40]

Chilo steniellus Hampson, 1899: 305; *Chilo trypetes* Bisset, 1939: 47, 48; *Chilo griseoradians* de Joannis, 1930: 603

The species was first placed under *Chilo*, due to the characters of the frons and venation of the forewing. Bisset (1939) described it as *Chilo trypetes*. Kapur (1950) placed it under *Bissetia* owing to the shape of the frons, serration in antennae and characters of genitalia.

Redescription: Pale brownish head. Length of labial palpi more than three times the diameter of the compound eye. Segments of male antenna very broad and widely located and segments of female antenna are at some point flat and serrated. Forewings brownish grey. SC and R_1 cross each other forming a cross, none of these two veins reach the costal margins. R_2 takes its origin from the anterior angle of the cell. R_3 originates from the upper region in the anterior of the cell and then separates into branches R_3 and R_4. R_5 arises from the anterior angle of the cell. M_1 originates from RS after the angle of the cell; M_2 and M_3 arise from lower angle of cell; Cula and Culb arise from before angle of the cell. Hindwing whitish in colour. SC + R_1 and RS diverge out from a common stalk from which M_1 also originates. M_2 and M_3 slightly stalked at origin and diverge after the posterior angle.

Male genitalia with moderately enlarged collar shaped vinculum, curved in middle and bent on both sides. Costa has two broad teeth like projections proximally, serrations on costal arm near the projection, serrations have sparse hairs. Distal region of valval curved, narrow, elongated and covered with long hairs. Tegumen triangular in shape; apex and sides of the tegumen are sclerotised. Uncus and gnathos narrow, pointed at the apex and almost as long as the tegumen. Aedeagus tubular shaped without any cornuti. Female genitalia with ovipositor opening funnel-shaped, and seems like a single elongated plate. Ostium bursae longitudinally oval shaped and sunk in the genital chamber. Ductus bursae sclerotized at its proximal one-third portion. Pear shaped bursa copulatrix, spot like signum present on mid-ventral surface.

Material examined: India: Punjab, 6♂ and 11♀, 2.viii.1997, on sugarcane coll. Z.H. Khan

Distribution: India, Vietnam (Nuss et al., 2003-2020), China (Kapur, 1950)

Host plants: exclusively on Sugarcane (Kapur, 1950)

Remarks: *Bissetia steniellus* was initially described as *Chilo typetes*, based on the forewing venation and frons characteristics. Apart from the differences in genitalia, Kapur (1950) observed that although quite similar, the frons shape is not identical in *Chilo* and

Bissetia genera. A conspicuous corneous point and lower ridge observed in *Bissetia* but not in *Chilo*. Moreover, *Chilo* has well developed ocelli and the antenna not distinctly serrate; whereas in *Bissetia* there is no ocelli and antennal serrations are comparatively distinct.

2. *Chilo auricilius* Dudgeon, 1905 [Figs. 3, 4, 28, 41]

Chilo auricilia Dudgeon 1905: 405; *Diatraea auricilia* (Dudgeon): Fletcher 1928: 58; Gupta 1940: 799; *Chilotraea auricilia* (Dudgeon): Kapur 1950: 408; *Chilo popescugorji* Bleszynski 1963: 179; *Chilo auricilia* Dudgeon: Bleszynski and Collins 1962: 239; *Chilo auricilius* Dudgeon; Bleszynski 1965: 113; 1969: 16.

This species was first described by Dudgeon as *Chilo auricilia.* Hampson (1912) stated that *Chilo auricilia* and *Chilo suppressalis* Walker were synonyms. In 1918, Fletcher considered *auricilia* as a distinct species. But in 1928, he stated that the species he regarded as *C. auricilia* was in fact *Argyria sticticraspis* Hampson, and the species he designated as *Diatraea* sp. was actually *auricilia*, Thereafter, he considered the species in the genus *Diatraea*. But, *Diatraea* Guilding is confined to the New World species, therefore this species cannot be placed under that genus and thus considered under *Chilotraea* Kapur (1950). Bleszynski and Collins (1962) considered the genus *Chilotraea* of Kapur as a synonym of the genus *Chilo.*

Redescription: Head with small and distinct ocellus. Forward produced face with or without small point. Labial palpus length about 3 times (in male) to 4 times (in female) of that of the diameter of the eye. Ground colour of wings yellowish to brownish; variably covered with small spots of brown scales; discal dot observed; subterminal line has a row of metallic scales, present close to termen; median line and subterminal line have same colouration; shiny golden coloured fringe; terminal dots of considerable size. Wing coupling frenate type with a single spine in males and three spines in females. In forewing, Sc and R_1 passes near each other without fusing and proceed as separate veins. R_2 arises from the radial sector before the upper end of the cell. R_3 originates from the upper corner in the anterior of the cell and then seperates into R_3 and R_4. R_5 takes its origin from near the anterior angle of the cell. M_1 originates from the RS after the angle of the cell. M_2 and M_3 are separate, both emerge from the common stalk observed at the posterior end of the cell. Hind wing slightly brownish, veins SC+R_1 and RS originate free to a limited extent, but near to beyond the cell, they anastomose but again diverges to form SC+R1 and RS. M_1 arises as a free vein, connects to RS by a small branch and again separates as M_1. Both M_2 and M_3 originate from a single short stalk after the cell. A_1, A_2 and A_3 are present.

Male genitalia with large saccus; two arms of juxta-plate with symmetrical ends and does not reach the costal angle of valva near the base; well defined, cone shaped projection on aedeagus near the apex; long ventral arm, notched apex; small bulb like basal projection. Female genitalia having ostial pouch somewhat delineated from ductus bursae, sclerotization is moderate; small sized; signum absent.

Material examined: INDIA: Bihar: Pusa, 2♂ and 8♀, 6.ii.1916, on sugarcane, coll. Haq; INDIA: Hyderabad, 3♂ and 9♀, 10.v.1988 on sugarcane, coll. Hassan.

Distribution: India, Bangladesh, East Malaysia, Hong Kong, Indonesia, Myanmar, Nepal, Papua New Guinea, Philippines, Sri Lanka, Taiwan, Thailand, Vietnam (Bleszynski, 1970; David and Easwaramoorthy, 1990; Harris, 1990).

Host plants: *Oryza sativa, Saccharum officinarum*, *Sorgum biolor, Zea mays* (Bleszynski, 1970; Huang et al., 1985; Chundurwar, 1989; Harris, 1990).

Remarks: *Chilo auricilius* and *C. polychrysus* are morphologically similar *C. polychrysus* has a shorter labial palpus (Kalshoven, 1981) compare to *C. auricilius*. Pars basalis notched in *C. polychrysus* but not in *C. auricilius*; in *C. polychrysus* arms of juxta plate are not completely symmetrical, whereas in *C. auricilius* they are symmetrical. In females of *C. polychrysus polychrusus* a heavily sclerotized region proximal to the ostial pouch is found on the ductus bursae, which is not the case with *C. auricilius*. Similar results were observed by Bleszynski (1970).

3. *Chilo infuscatellus* Snellen, 1890 [Figs. 5, 6, 29, 42]

Chilo infuscatellus Snellen 1890: 94, Shibuya 1928b: 54, Bleszynski, 1962b: 111, 1965: 116, 1969: 15; *Argyria sticticraspis* Hampson 1919: 449, Gupta 1940: 788, Isaac and Rao 1941: 799; Isaac and Venkatraman 1941: 806 [syn. Kapur 1950]; *Argyria coniorata* Hampson 1919: 449 [syn. Fletcher 1928]; *Diatraea calamina* Hampson 1919: 544 [syn. Kapur 1950];

Diatraea auricilia (Dudgeon): Fletcher and Ghosh 1920: 387; *Diatraea shariinensis* Eguchi 1933: 3 [syn. Kapur 1950]; *Chilo tadzhikiellus* Gerasimov 1949: 704; *Proceras infuscatellus* (Snellen): Kalshoven 1950: 413; *Chilotraea infuscatellus* (Snellen): Kapur 1950: 404.

Kapur (1950) synonymised *Chilotraea infuscatellus* with *Argyria sticticraspis* Hampson and also with *Diatraea calmina* Hampson. The specimens of *Diatraea shariinensis* Eguchi, as well as the figures given by Eguchi (1933) also agree in structural details with *infuscatellus*; which was also synonymised by Kapur (1950) as *Chilotraea infuscatellus*. Bleszynski and Collins (1962) recently considered the genus *Chilotraea* of Kapur as a synonym of the genus *Chilo*.

Redescription: Ocelli easily noticeable and well developed. Labial palpus length about 3 times (in male) to 3.5 times (in female) of the diameter of the eye. Face rounded; the anterior part of the head protrudes slightly beyond the eye. Fore wing ground-colour is drab, from pale yellowish to light brownish; discal dot reduced; transverse lines are not consistent; terminal dots are observed; absence of metallic scales. Frenate type wing coupling with a single tough frenulum in males and tripartite in females. In forewing, Sc and R_1 passes near each other without fusing and proceed as separate veins. R_2 takes its origin from the anterior angle of the cell. R_3 originates from the upper corner in the anterior of the cell. It then separates into R_3 and R_4. R_5 takes its origin from near the anterior angle of the cell. M_1 originates from the RS after the angle of the cell. M_2 and M_3 are separate and free, both emerge from the common stalk observed at the posterior end of the cell. Hind wing white coloured with a silk like texture in females. The veins SC +R_1 and RS originate free to a limited extent, but near to beyond the cell, they anastomose but again diverges to form SC + R_1 and RS. M_1 arises as a free vein, connects to RS by a small branch and again comes out as M_1. Both, M_2 and M_3 originate from a single short stalk after the cell. A_1, A_2 and A_3 are present.

Male genitalia having slight presence of pars basalis, juxta symmetrical, juxta arms are close to the basal-costal angle of valva; toothed strengthening present on both arms; ventral part of aedeagus with conspicuous swelling; cornuti single, tapering and large. Female genitalia with ostial pouch sclerotized and delineated from ductus bursae; anterior portion presents a deep incision; signum lamellate, median ridge present on signum.

Material examined: India: Orissa: Cuttack, 5♂ and 8♀, 10.viii.1960, at light coll. Misra; INDIA: Uttar Pradesh: Cawnpur, 6♂ and 5♀, 18.viii.1914, on sugarcane coll. E.S.Daniel.

Distribution: India, Bangladesh, China, Afghanistan, Indonesia, Korea, Malaysia, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines, Sri Lanka, Tadzhikistan, Taiwan, Thailand, Timor, Vietnam (Carl, 1962; Bleszynski, 1970; Chundurwar, 1989; David and Easwaramoorthy, 1990; Harris, 1990; Neupane, 1990).

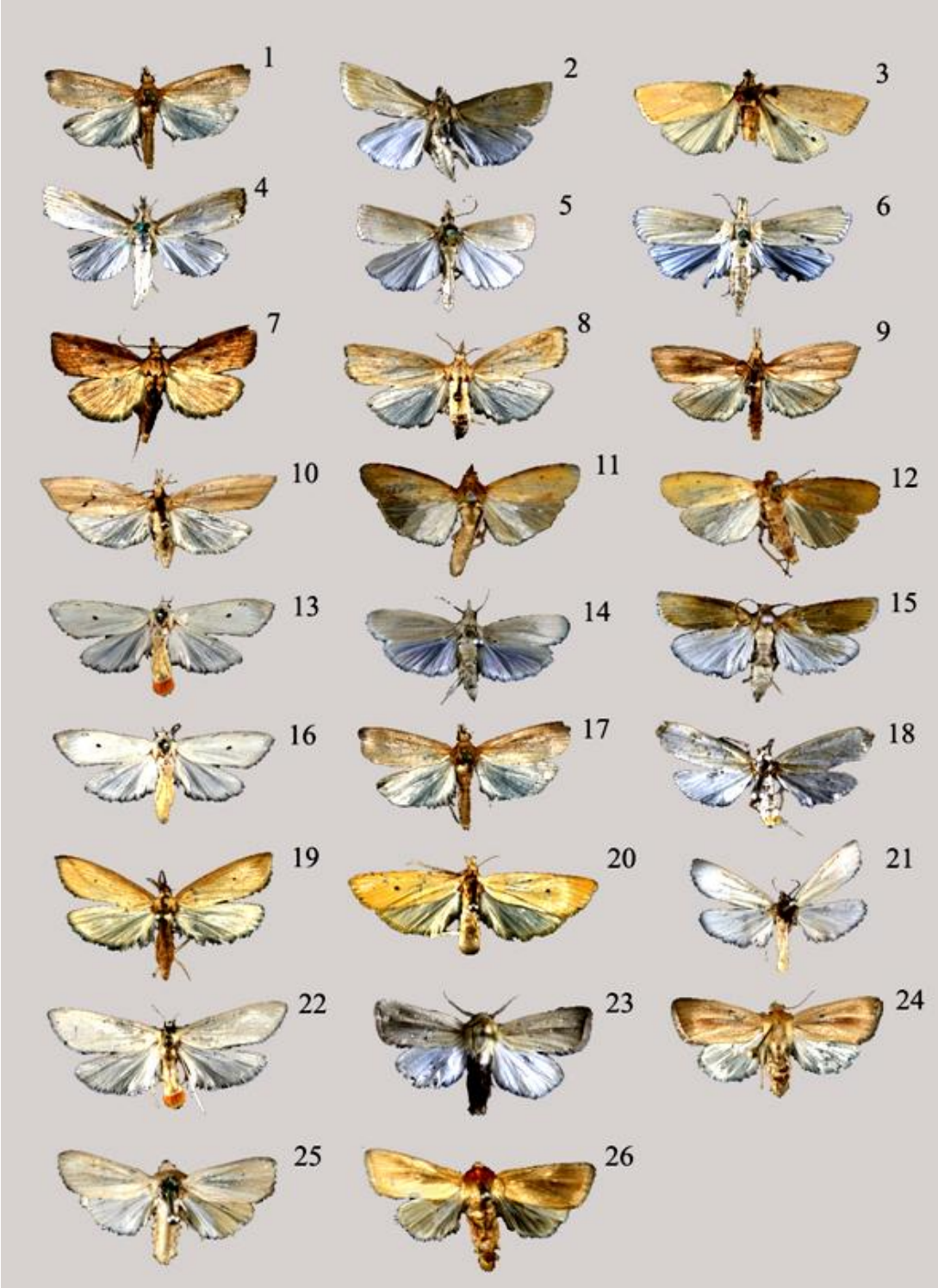
Host plants: *Andropogon sorghum, Avena sativa, Cynodon dactylon, Cyperus rotundus, Echinochloa colonum, Hordeum vulgare, Oryza sativa, Panicum* spp., *Rottboellia compressa, S. officinarum, S. spontaneum, Saccharum fuscum, Sorghum bicolor, Zea mays* (Bleszynski, 1970).

Remarks: *C. infuscatellus* and *C. auricilius* are similar in terms of the frons being smooth, produced forward, and corneous point not observed. But they can be differentiated based on the wing venation, in *C. infuscatellus* R_2 arises from the anterior corner of cell, but in *C. auricilius* R_2 arises from RS before the cell's upper angle (Puri, 1957). Aedeagus has a ventral arm in *C. auricilius* absent in *C. infuscatellus*. In the female genitalia, a lamellate signum present in *C. infuscatellus*, absent in *C. auricilius* (Bleszynski, 1970).

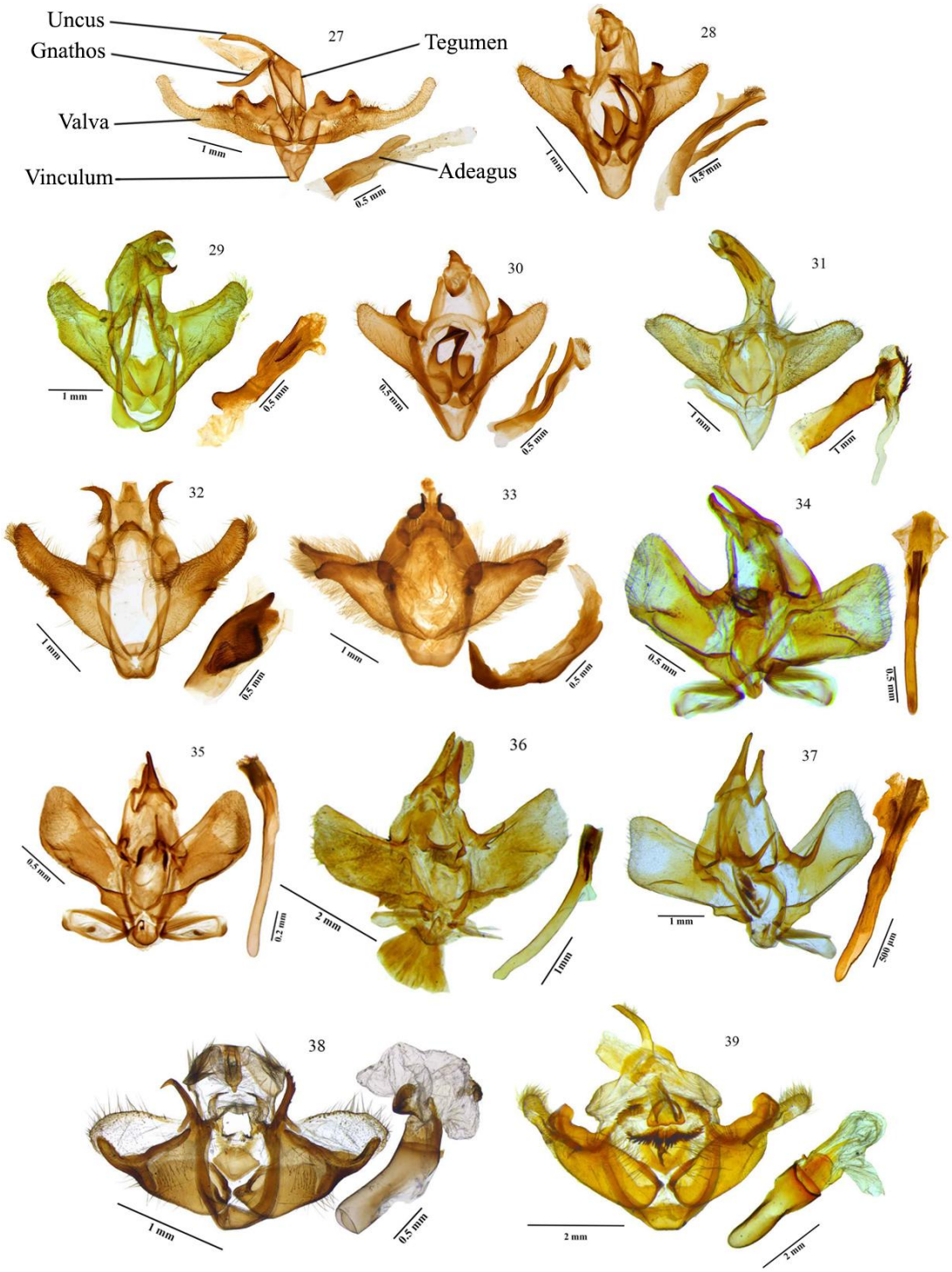
4. *Chilo partellus* (Swinhoe, 1885) [Figs. 7, 8, 30, 43]

Crambus zonellus Swinhoe 1884: 528; *Crambus partellus* Swinhoe 1885: 879; *Chilo simplex* (Butler): Hampson 1896a: 957, Hampson 1896b: 26, Rebel 1901: 259; *Diatraea calamina* Hampson 1919: 544; *Chilo zonellus* (Swinhoe) Fletcher, 1928; *Argyria lutulentalis* Tams 1932: 127; *Chilo zonellus* (Swinhoe): Gupta 1940: 806; Isaac and Venkatraman 1941: 810 [larva, pupa]; Kapur 1950: 399; *Chilo partellus* (Swinhoe): Bleszynski and Collins 1962: 243; Bleszynski 1965: 119; 1970: 126.

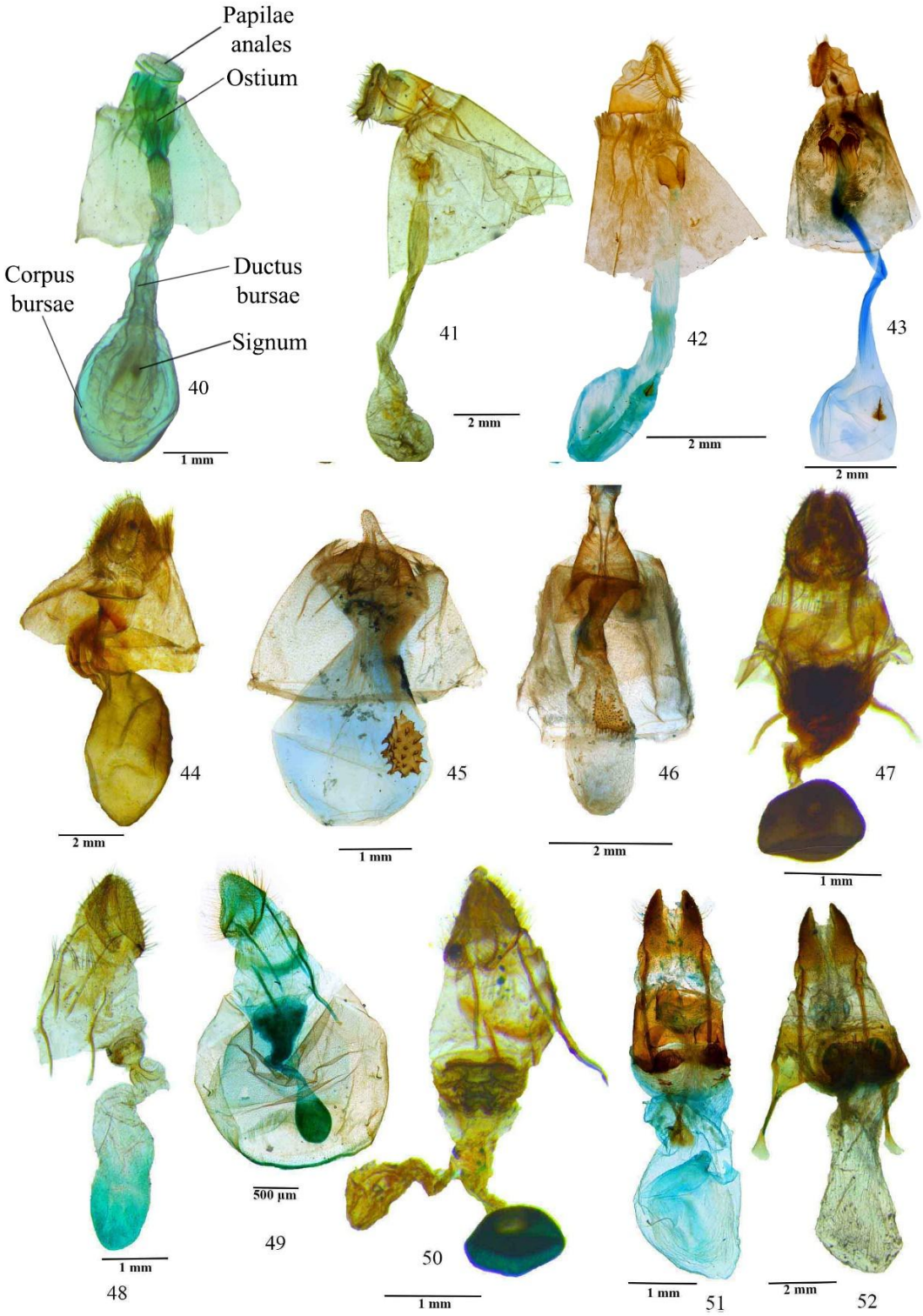
Hampson (1895, 1896) synonymised *Crambus zonellus* and *Crambus partellus* with *Chilo simplex* Butler. Fletcher (1928) considered *C. simplex* and *Chilo zonellus* to be separate species, and regarded *Chilo partellus* as a synonym of *C. zonellus*. Bleszynski (1970) revised all known species of *Chilo*, and in it, *Chilo zonellus* (Swinhoe), was considered a synonym of *C. partellus*. At present, therefore *C. partellus* is the valid name for the spotted stem borer.



Figs. 1-26. Adult habitus: 1. *B. steniellus* male, 2. *B. steniellus* female, 3.*C. auricilius* male, 4.*C. auricilius* female, 5. *C. infuscatellus* male, 6. *C. infuscatellus* female, 7. *C. partellus* male, 8. *C. partellus* female, 9. *C. sacchariphagus* male, 10. *C. sacchariphagus* female, 11. *E. aurifusellus* male, 12. *E. aurifusellus* female, 13. *E. depressella* male, 14. *E. depressella* female, 15. *S. excerptalis* male, 16. *S. excerptalis* female, 17. *S. gilviberbis* male, 18. *S. gilviberbis* female, 19. *S. incertulas* male, 20. *S. incertulas* female, 21. *S. nivella* male, 22. *S. nivella* female, 23. *Se. inferens* male, 24. *Se. inferens* female, 25. *Se. uniformis* male, 26. *Se. uniformis male* female.



Figs. 27-39. Male genitalia and aedeagus: 27. *B. steniellus*, 28. *C. auricilius*, 29. *C. infuscatellus*, 30. *C. partellus*, 31. *C. sacchariphagus*, 32. *E. aurifusellus*, 33. *E. depressella*, 34. *S. excerptalis,* 35.*S. gilviberbis*, 36. *S. incertulas*, 37. *S. nivella*, 38. *Se. inferens*, 39. *Se. uniformis*



Figs. 40-52. Female genitalia: 40. *B. steniellus*, 41. *C. auricilius*, 42. *C. infuscatellus*, 43. *C. partellus*, 44. *C. sacchariphagus*, 45. *E. aurifusellus*, 46. *E. depressella*, 47. *S. excerptalis*, 48. *S. gilviberbis*, 49. *S. incertulas*, 50. *S. nivella*, 51. *Se. inferens*, 52. *Se. uniformis*

Redescription: Well-developed ocellus. Face cone shaped anteriorly, having a definite hard point; slight ventral ridge present. Labial palpus about 3 times (in male) to 3.5 times (in female) in length compared to that of the diameter of the eye. Forewing dirty brown to straw brown coloured. Subterminal line brown coloured, thin; median line not distinct; presence of discal dot; no metallic scales on wing. Wing coupling frenate type. Sc and R1 do not fuse. Vein SC remains free and borders the costal margin. In forewing, Sc and R_1 passes near each other without fusing and proceed as separate veins. R_2 takes its origin from the anterior angle of the cell. R_3 originates from the upper corner in the anterior of the cell. It then separates into R_3 and R_4. R_5 takes its origin from near the anterior angle of the cell. M_1 originates from the RS after the angle of the cell. M_2 and M_3 are separate and free, both emerge from the common stalk observed at the posterior end of the cell. Hind wing greyish in colour. The veins SC +R_1 and RS originate free to a limited extent, but near to beyond the cell, they anastomose but again diverges to form SC + R_1 and RS. M_1 arises as a free vein, connects to RS by a small branch and again comes out as M_1. Part of M_1 that comes out seems disconnected from the main stalk of M_1. Both M_2 and M_3 originate from a single short stalk after the cell. A_1, A_2 and A_3 are present.

Male genitalia with tapering projection present on costa; symmetrical juxta-plate, central part of juxta plate large, arms of juxta stout and does not cross the costa, arms of juxta with sub-apical tooth; aedeagus having ventral arm and basal projection. Female genitalia with heavy sclerotization in ostial pouch; delicately longitudinal wrinkled; well demarcated from ductus bursae; deeply notch present; signum present having lamellar shape with a median ridge.

Material examined: India: New Delhi, 8♂ and 5♀, 10.viii.2019, Mercury vapour lamp, coll. Dey; India: Assam, 11♂ and 7♀, 18.ix.2019, pupa from maize plant, coll. Shashank.

Distribution: Afghanistan, Bangladesh, Botswana, Cambodia, Cameroon, Comoros, Congo, Ethiopia, India, Indonesia, Kenya, Laos, Madagascar, Malawi, Mozambique, Nepal, Pakistan, Rwanda, Somalia, South Africa, Sri Lanka, Sudan, Swaziland, Tanzania, Taiwan, Thailand, Togo, Uganda, Vietnam, Zambia, Zimbabwe (Bleszynski, 1970; Harris, 1989; Maes, 1998; Overholt, 1998).

Host plants: *Eleusine coracana, Hyparrhenia rufa, Oryza sativa, Panicum maximum, Pennisetum glaucum, P. purpureum, Rottboelia compressa, Saccharum officinarum, S. arundinaceum, S. halepense, S. spontaneum, S. sudanense, S. verticilliflorum, S.vulgare, Vossia cuspidate,* Wheat*, Zea mays* (Bleszynski, 1970; Chundurwar, 1989; Maes, 1998).

Remarks: In terms of female genitalia, *C. partellus* and *C. tamsi* are quite similar. The two are differentiated by the ostial pouch, in *C. tamsi* it is elongated and comparatively small, but rounded in *C. partellus*. *C. partellus* is also similar to *C. orichalcociliellus*. But, *C. orichalcociliellus* has a sub-terminal line of shiny, golden yellow specks on the forewing and the hind wing colour is cream-yellow but in *C. partellus* the hindwing dirty white or greyish. In the female genitalia, the signum in *C. orichalcociliellus* is scobinate whereas in *C. partellus* the signum is lamellate and has a median ridge (Bleszynski, 1970).

5. *Chilo sacchariphagus* (Bojer, 1856) [Figs. 9, 10, 31, 44]

Proceras sacchariphagus Bojer 1856: unnumbered, Tams 1942: 67, Kapur 1950: 412, Kalshoven 1950: 411; *Borer saccharellus* Guenée 1862: unnumbered [syn. Tams 1942]; *Chilo mauriciellus* Walker 1863: 141. [syn. Tams 1942]; *Chilo venosatus* Walker 1863: 144 [syn. Bleszynski 1970]; *Diatraea striatalis* Snellen 1890: 98, 1891: 349 [syn. Hampson 1896b]; *Diatraea mauriciella* (Walker): Hampson 1896b: 953; *Diatraea venosata* (Walker): Hampson 1896b: 954; *Diatraea mauriciella* (Walker); Vinson 1941: 39, 1942: 39; *Proceras venosatus* (Walker): Kapur 1950: 413, Bleszynski 1962a: 9; *Chilo sacchariphagus* (Bojer): Bleszynski 1966: 494, 1969: 18, 1970: 182.

Bojer (1856) described the species as *Proceras sacchariphagus*. Hampson (1895) considered a species from Mauritius, under the name *D. mauriciella* separate from *D. striatalis*, and that was considered synonymous to a related species *D. venosatus* Walker occurring in Borneo, Malaya, China, India, etc. Later these three names were regarded as synonymous.

Fletcher (1914) reported *Diatraea venosata* Hampson, from south India. Tams (1942) considered it as a synonym of *Proceras sacchariphagus* Bojer. Kapur (1950), renamed the Indian specimen as "*Proceras indicus*", and considered it different from *Diatraea venosata* Hampson and *Proceras sacchariphagus* Bojer. However, Bleszynski (1970) considered *Proceras indicus* (sensu Kapur, 1950) as a subspecies of *P. sacchariphagus* Bojer as *Chilo sacchariphagus indicus* (Kapur) (Arora, 2000).

Redescription: Frons almost flat or subrounded, face do not protrude beyond compound eyes. Ventral ridge not observed. Ocellus reduced. Labial palpus three (in males) to about four (in females) times in length as compared to the diameter of compound eye. Fore wing light brownish coloured. Streaks present between and on the veins and dark spots present on termen. R_1 anastomosed with Sc. Sc meets the costal margin at a distance greater than two-thirds of the wing length. R_2 arise from beyond the upper angle of cell. R_3 and R_4 are stalked. R_5 and M_1 diverge distally from upper angle of cell; M_2 and M_3 diverge distally from lower angle of cell; Cu_1 not close to M_3. Hind wing whitish in colour. Hindwing, $Sc+R_1$ meets the costal margin near the wing apex. RS originates close to the upper angle of the cell and anastomose with $Sc+R_1$ at 2/3rd of the wing length and diverges to reach the wing margin. M_1 diverge distally from upper angle of cell; M_2 and M_3 diverge distally from lower angle of cell. M_2 and M_3 diverge distally from lower angle of cell; Cu_1 not close to M_3. A_1, A_2 and A_3 complete.

Male genitalia having uncus shaped like beak, gnathos sclerotised and almost equal in length as the uncus. Pars basalis is not present. Valva tapers slightly towards the apex into a blunt margin; juxta-plate short, broad, deeply notched, juxta arms are tapering and lack teeth. V-shaped saccus present. Ventral arm and basal process absent in aedeagus; vesica has row of strong cornuti. Female genitalia with papilae anales shaped like funnel. Ostial pouch quite delineated from ductus bursae, longitudinal ribs having heavy sclerotization; corpus bursae oblong shaped and longer compared to ductus bursae. Signum absent.

Material examined: India: Bihar: Pusa, 4♂ and 3♀, 28.ix.1917, sorghum stem; INDIA: Bihar: Pusa, 7♂ and 4♀, 27.viii.1917 on sugarcane, coll. R.S.

Distribution: India, Bangladesh, Comoros, China, Indonesia, Japan, Madagascar, Malaysia, Mauritius, Mozambique, Philippines, Singapore, Sri Lanka, Taiwan, Thailand (Bleszynski, 1970; Williams, 1983; Facknath, 1989; David and Easwaramoorthy, 1990; Leslie, 1994; Suasa-ard, 2000).

Host plants: *Saccharum officinarum*, wild *Saccharum* spp., rarely on maize and sorghum (Betbeder-Matibet and Malinge, 1968; Williams, 1983).

Remarks: This species has three different subspecies *viz. C. sacchariphagus sacchariphagus* (Bojer), *C. sacchariphagus indicus* (Kapur) and *C. sacchariphagus stramineellus* (Caradja, 1932). The male genitalia of *C. s. stramineellus* has a broader aedeagus compared to *C. s. sacchariphagus*, and the apical part has scobinations which are not seen in *C. s. sacchariphagus*. In the female genitalia of *C. s. stramineellus,* ductus bursae twisted and having a distinct elongated sclerite which is not found in *C. s. sacchariphagus*. Aedeagus of *C. s. indicus* is also broader compared to *C. s. sacchariphagus*. However, the female genitalia of *C. s. indicus* is similar to that of *C. s. sacchariphagus* (Bleszynski, 1970).

6. *Emmalocera aurifusellus* (Walker, 1866) [Figs. 11, 12, 32, 45]

Crambus aurifusellus Walker 1866: 35

The species was first described as *Crambus aurifusellus* by Francis Walker in 1866. It was transferred to *Emmalocera* by Hampson (1918).

Redescription: Head with orange tinge. Frons having a tuft of scales. Labial palpi porrect. Second joint of labial palpi hollowed out to receive the brush like maxillary palpi. Middle and hind tibia are fringed with hairs on the outer side. Forewings with the apex rounded. Ground colour golden yellow. The base has a reddish-orange spot. The costal fascia extending before base to the apex. R_2 arise from before the cell. R_3 and R_4 stalked. Cu1A and Cu1B arise from a common stalk. Hindwing whitish with a yellowish tinge. Vein R_2 emerge from the angle of the cell. M_2, M_3, Cu1A and Cu1B arise from a common stalk from which Cu1A and Cu1B diverge out before the posterior angle of the cell.

Male genitalia with uncus lobes long, curved and pointed apically. Uncus lobes with hair-like setae. Gnathos arms stout with the middle part broad, distal process narrow, elongated, pointed. Tegumen sclerotized, hexagonal in shape. Valva narrowed to half of its length, then both the margins run parellal to a rounded apex; Costal region of valva covered with long setae. Juxta small, plate-shaped, subovate. Saccus rounded rectangular. Aedeagus short and stout. Female genitalia with ductus bursae short. Corpus bursae globose shaped. Corpus bursae increases in diameter cross section up to two-third of it from the ductus bursae, remaining portion hemispherical shaped. The signum present, signum almost circular shaped sclerotised plate covered with spines.

Material examined: India: Bihar: Pusa, 1♂ and 1♀, 11.ix.1929, wild sugarcane, coll. Menon.

Distribution: India (Mathew, 2006)

Host plant: *Saccharum spontaneum* (from label data)

Remarks: In the genus *Emmalocera*, there are 67 species worldwide. It can be distinguished from other species of *Emmalocera* by its male genitalia where the uncus lobes are long, curved and pointed apically and having hair-like setae. Gnathos arms are stout with the middle part broad. Valva narrowed to half of its length, then both the margins run parallel to a rounded apex and aedeagus short and stout. In E. *depressella* the uncus lobes are short and apically pointed and valva narrowed towards apex. In *E. aurifusellus* females, the corpus bursae globose shaped with an almost circular plate like signum covered with spines. In *E. depressella* the shape of the signum is ovate. The detailed species list is provided by Nuss et al. (2003-2020).

7. *Emmalocera depressella* (Swinhoe, 1885) [Figs. 13, 14, 33, 46]

Melissoblaptes depressellus Swinhoe 1885: 876; *Polyocha depressella* Hampson 1896: 63; *Papua sacharella* Dudgeon 1977.

The species was first described as *Melissoblaptes depressella* by Swinhoe in 1885. Hampson (1896) transferred it under *Polyocha depressella*. In 1977, *Polyocha depressella* was transferred to *Papua* and later on to *Emmalocera* (Hampson, 1918).

Redescription: Frons slightly protruded and rounded in shape. Well-developed ocelli. Antennae serrated. Porrect labial palpi, labial palpi has hollowed out region for receiving maxillary palpi. Outer side of middle and hind tibia are fringed with scales. Wing coupling frenate, frenulum spine single in both sexes. In forewing, SC and R_1 remain wide apart and do not fuse. R_2 arises from the before the upper end of the cell. R_2 arises much before the upper angle of the cell. R_3 originates from the upper corner in the anterior of the cell. It then separates into R_3 and R_4. M_1 originates from the RS after the angle of the cell. M_2 and M_3 are separate and free, both emerge from the common stalk observed at the posterior end of the cell. Hindwing whitish in colour. SC + R_1 and RS diverge out from a common stalk. From this common stalk, M_1 also originates. M_2, M_3, Cu1A and Cu1B arise from a common stalk from which Cu1A and Cu1B diverge out before the posterior angle of the cell.

Male genitalia with uncus lobes short, pointed apically. Gnathos arms slender, distal process narrow, elongated, pointed. Tegumen weakly sclerotized. Valva basally broad and conspicously narrowed towards apex; valva densely covered with long hairs. Juxta plate-shaped, broader than long, subovate. Saccus moderate sized with the distal region flat. Aedeagus longer than the valva, curved on one side. Female genitalia with ovipositor has an anterior notch. Genital chamber present laterally. Formed as an infolded pocket, the opening of which forms the ostium bursae. Corpus bursae bag like in shape. Signum present and elliptical sclerotised plate with prickled body.

Matrial examined: India: Delhi, 3♂ and 8♀, 16.vii.1938, on sugarcane, coll. H. L. Bhatia; India: Delhi, 9♂ and 5♀, 31.viii.1940 on sugarcane, coll. R Saran.

Distribution: India, Afghanistan, Bangladesh, Bhutan, China, Hong Kong, Indonesia, Japan, Kampuchea, Laos, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Sulawesi, Taiwan, Thailand, Vietnam (Srikanth, 2014).

Host plants: *Andropogon sorghum, Erianthus munja*, *Erianthus sara*, *Peinsetum purpureum, Saccharum officinarum*, *S. ravennae*, *S. spontaneum*, *Sclerostachya fusca*, *Sorghum halepense*, *S. vulgare* (Srikanth, 2014).

Remarks: Compared to moth borers of genera *Scirpophaga, Chilo, Bissetia* dealt in the present study, the wings of *E. depresella* are narrower. It can be differentiated from species of *Chilo* and *Bissetia* from the SC and R_1 being free and spaced wide apart. The vein R_2 also arises long before the upper corner of the cell and vein R_5 is not present (Puri, 1957). In male genitalia, the aedeagus is distinctly curved. In female genitalia, the signum is an ovate shaped patch with spines.

8. *Scirpophaga excerptalis* (Walker, 1863) [Figs. 15, 16, 34, 47]

Chilo excerptalis Walker, 1863: 142; *Scirpophaga monostigma* Zeller, 1863: 3, Hampson, 1895: 913, 1896: 46 [partim]; de Joannis, 1929: 608; *Scirpophaga butyrota* Meyrick, 1889: 520; *Scirpophaga intacta* Snellen, 1890: 94, Hampson, 1895: 913, 1896: 46; *Scirpophaga excerptalis* (Walker) Hampson, 1895: 913, Leech, 1901: 402 [partim], Butani, 1970: 169; *Topeutis* [*sic*] *rhodoproctalis* Hampson, 19196: 319; *Tryporyza butyrota* (Meyrick) Common, 1960: 340.

The species was initially described as a species in

Chilo. Shibuya (1928) studied the Schoenobiinae of Taiwan and listed four species in *Scirpophaga*: *praelata*, *nivella*, *excerptalis* and *brunnescens*, and also provided a key to separate these species by using the colour of the forewing and of the anal tuft. In the revision of the Old-World species of *Scirpophaga* complex Lewvanich (1981) describes the name as *Scirpophaga exceptalis*.

Redescription: Spherical frons. Close to the ocellus, on each side a cheatosema. Filiform type antenna having fine serrations. Dorsal region of antenna has smooth scales, ventral region with delicate hairs. Proboscis reduced. Labial and maxillary palpi are porrect. Maxillary palpi extends no more than half of the labial palpi. Wings white coloured. Both cubital and subcostal retinaculum in male and only cubital retinaculum in female. In forewing, Vein R_1 anastomoses with Sc. Vein R_2 free, originates near upper angle of the cell. Veins R_3 and R_4 are stalked. From the upper angle of the cell originates vein R_5, it diverges terminally from R_4. M_1 basally approximated to R_5. M_2 almost parallel to M_1 and arise from above the lower angle of the cell. M_3 arises from the lower angle of the cell. Cu1A originates before the lower angle of the cell. Short CuP vein observed at the wing margin. Complete 1A present. On the hindwing, Sc + R_1 ends near the apex of the wing on the costa, veins Rs and M_1 arise simultaneously from the upper angle of the cell. Veins M_2 and M_3 originate close to each other from above the lower angle of the cell. CuA1 originates in advance to the lower angle of the cell and CuA2 almost from the middle of the cell. 1A+2A and 3A are complete, 3A short.

Abdomen with tuft of scales on 7th abdominal sternite Females have orange coloured anal tuft on the 7th abdominal segment. Male genitalia with uncus of moderate length, gnathos slightly curved at tip. The subteguminal process like a long spine, tegumen with X-shaped thickening, distal end of the valva expanded. Aedeagus slender, vesica has coarse spines. Juxta in the shape a sclerotised plate. Female genitalia with ostium bursae is broad, strongly sclerotized, and wrinkled in texture and appears as a compact mass. The ductus bursae membranous and corpus bursae have dense spines. Ductus seminalis originates from ductus bursae and is comparatively nearer to ostium bursae than that of corpus bursae.

Material examined: India: Bihar, 2♂ and 9♀, 14.iii.1926, on sugarcane, coll. Misra; India: Dwarka, 5♂ and 11♀, 10.v.1927 on sugarcane, coll. Ayyar; India: Dwarka, 4♂ and 4♀, 10.v.1933 on sugarcane, coll. Prasad.

Distribution: India, Australia, Bangladesh, Bhutan, Britain, China, Indonesia, Ireland, Japan, Java, Malaysia, Nepal, Pakistan, Papua New Guinea, Philippines, Singapore, Solomon Islands, Sri Lanka, Taiwan, Thailand, Vietnam, West Malaysia (Arora, 2000; Chen and Wu, 2014).

Host plants: *Chloris barbata, Echinochloa colona, Erianthus arundinaceum, Naranga prophyrocoma, Panicum* sp., *Pennisetum purpureum, Saccharum officinarum, S. spontaneum, S. munja, S. ravennae, Sclerostachya fusca, Sorghum bicolor, S. halepense* (Arora, 2000).

Remarks: *S. excerptalis* and *S. nivella* have similar external appearance. However, the difference lies in the labial palpi which is 1.5-2 times in length compared to the diameter of the compound eye in *S. excerptalis* whereas in *S. nivella* it is much shorter (1.3 times that of the diameter of compound eye). The vein R_1 in forewing is anastomosed with SC in *S. excerptalis* but in *S. nivella* it is free. *S. excerptalis* has a single spine in frenulum as opposed to *S. nivella* having two bristles. Furthermore, the anal tuft is ocherous in *S. nivella* while in *S. excerptalis* it is ocherous (Lewvanich, 1981).

9. *Scirpophaga gilviberbis* Zeller, 1863 [Figs. 17, 18, 35, 48]

Scirpophaga gilviberbis Zeller, 1863:2 Walker, 1864:968; Moore, 1867: 666; Hampson, 1895:913; 1896:46 (partim); de Joannis, 1929: 607; *Niphadoses gilviberbis* (Zeller) Common, 1960: 327; Kapur, 1967: 6, 22.

Zeller (1863) redescribed the genus *Scirpophaga* in which he included the species *S. gilviberbis*. Lewvanich (1981) recognised *S. gilviberbis* as a valid name. Common (1960) placed *S. gilviberbis* in the genus *Niphadoses*. Lewvanich (1981) also has shown that *S. gilviberbis* does not belong in *Niphadoses* based om the forewing venation, difference of the scales on the labial palpus and the genitalia.

Redescription: Spherically shaped frons. Presence of cheatosema near ocellus. Filiform antenna with fine serrations. Dorsal region of antenna has smooth scales, ventral region with fine hairs. Proboscis reduced. Both labial and maxillary palpi porrect. Maxillary palpi shorter than half of labial palpi. Frenate type wing coupling, both cubital and subcostal retinaculum observed in male. Subcostal retinaculum absent in females and frenulum single bristled. Forewings are

ocherous in males and white in females. In forewing, vein R_1 not anastomosing with Sc, vein R_2 free, originates near upper angle of the cell. R_3 and R_4 are stalked. Vein R_5 diverges terminally from R_4 and originates from the upper angle of the cell. M_1 basally approximated to R_5. M_2 almost parallel to M_1 and arise from above the lower angle of the cell. M_3 emanates from the lower angle of the cell. Cu1A takes its origin in advance to the lower angle of the cell. Short CuP vein developed at the wing margin, 1A complete. Hindwings white coloured in both sexes. On the hindwing, Sc + R_1 terminates near the apex of the wing on the costa, veins Rs and M_1 arise simultaneously from the upper angle of the cell. Veins M_2 and M_3 originate close to each other from above the lower angle of the cell. CuA1 originates in advance to the lower angle of the cell and CuA2 almost from the middle of the cell. 1A+2A and 3A are complete, 3A short.

Abdomen like a thin cylinder in males and a tuft of scales observed on the on the 7th abdominal sternite. Females have greyish white anal tuft on the 7th abdominal segment. Male genitalia with long and slender uncus and gnathos, the arms of gnathos converge gradually from the middle to a pointed apex; flattened subteguminal process having smooth and rounded margin. The costal and ventral margins of valva almost straight and parallel to each other, outer margin rounded; aedeagus slender. Female genitalia having broad ostium bursae. Ductus bursae membranous, antrum absent. Portion between ductus seminalis and ostium bursae have sclerotized plates. Cross section of the plates shows a U shape. Small spines present in corpus bursae, spines densely present in basal two-thirds.

Material examined: India: Bihar: Pusa, 1♂ and 3♀, 14.iii.1926, on sugarcane, coll. Pillai; India: Dwarka, 7♂ and 4♀, 10.v.1927 on sugarcane, coll. Prasad.

Distribution: India, Java; Myanmar; Singapore; Sri Lanka; Sulawesi; Thailand; and Vietnam (Arora, 2000).

Host plants: *Oryza sativa, Saccharum officinarum* (Arora, 2000)

Remarks: The male individuals resemble that of *S. nivella* and *S. incertulas* as all the three species have similar markings on forewings. However, the genitalia of both sexes in *S. gilviberbis* are quite distinct from the other two species. The females have frenulum with a single bristle, and have no antrum in ductus bursae. In males, the sclerotised thickening in the tegumen roughly triangular shaped (Lewvanich, 1981).

10. *Scirpophaga incertulas* (Walker, 1863) [Figs. 19, 20, 36, 49]

Chilo incertulas Walker, 1863: 143; *Catagela ladmotella* Walker, 1863: 192; *Schoenobius punctellus* Zeller, 1863: 4; *Schoenobius minutellus* Zeller, 1863: 5; *Tipanaea bipunctifera* Walker, 18636: 523; *Chilo gratiosellus* Walker, 1864: 967; *Apurima gratiosella* (Walker) Butler, 1880: 690; *Schoenobius bipunctifera* (Walker) Moore, 1886: 385, Leech, 1901: 403; *Catagela admotella* Walker; Moore, 1886: 386; *Schoenobius bipunctiferus* (Walker); Hampson, 1895: 915; *Schoenobius incertulas* (Walker) Hampson, 1895: 916, 1896: 48, Jepson, 1954: 9, Martin, 1958: 187; *Schoenobius bipunctifer* (Walker); Hampson, 1896a: 48, Strand, 1918: 262; *Schoenobius incertellus* (Walker); Shiraki, 1917: 1-256, Fletcher, 1932: 276, Shibuya, 1928: 63, deJoannis, 1929: 609, Marumo, 1934: 18; *Schoenobius bipunctifer* ab. *quadripunctellifera* Strand, 1918: 263; *Tryporyza incertulas* (Walker) Common, 1960: 341; Kapur, 1967: 6, 23.

Initially the species was placed in the genus *Chilo*. Walker (1863) considered the male as *Catagela admotella* and the female as *Tipanaea bipunctifera*. Zeller (1863) described the male of *Scirpophaga incertulas* as *minutellus* and the female as *punctellus*. *Catagela admotella* and *minutellus* were synonymised with *incertulus* by Hampson (1895). The species *punctellus* and *bipunctifera* were synonymised by Shiraki (1917) with *incertulas*. Lewvanich (1981) describes the name as *Scirpophaga exceptalis.*

Redescription: Spherical frons. Ocellus presents beside compound eyes. Close to the ocellus, on each side a cheatosema. Filiform type antenna having fine serrations. Dorsal region of antenna has smooth scales, ventral region with delicate hairs. Proboscis reduced. Labial and maxillary palpi are porrect. Maxillary palpi extends no more than half of the labial palpi. Labial palpi about 3 times in length compared to the diameter of compound eye. Frenulum double-bristled in females. Both cubital and subcostal retinaculum in male and only cubital retinaculum in female. Forewing ochreous, have one dark fuscous spot on the lower angle of the cell. In forewing with vein R_1 curving towards Sc. Vein R_2 free, originates near upper angle of the cell. R_3 and R_4 are stalked. From the upper angle of the cell originates R_5, it diverges terminally from R_4. M_1 basally approximated to R_5. M_2 almost parallel to M_1 and arise from above the lower angle of the cell. M_3 emanates from the lower angle of the cell. Cu1A originates before the lower

angle of the cell. Short CuP vein developed at the wing margin; 1A complete. Hindwing white coloured. On the hindwing, Sc + R_1 terminates near the apex of the wing on the costa, veins Rs and M_1 arise simultaneously from the upper angle of the cell. Veins M2 and M3 originate close to each other from above the lower angle of the cell. CuA1 originates in advance to the lower angle of the cell and CuA2 almost from the middle of the cell. 1A+2A and 3A are complete, 3A short and straight. Males have slender abdomen and females have pale yellow coloured anal tuft. Male genitalia with uncus and gnathos long, slender; tegumen somewhat triangular and sclerotised; subteguminal process spine like and bifid; aedeagus slender, two curved spined cornuti are present. Female genitalia having ostium bursae is broad and membranous, strongly wrinkled. Basal three-fourth of corpus bursae is lined with spines.

Material examined: India: Bihar: Chandradharpur, 8♀, 17. x.1928, Rice stubbles coll. Bose; India: New Delhi, 1♂, 15.xiii.1991 Mercury vapour lamp coll. R.S.; India: Bihar: Pusa, 7♀ 26.ix.1998, Mercury vapour lamp coll. Z.H. Khan.

Distribution: India, Afghanistan, Bangladesh, Borneo, China, Japan, Java, Myanmar, Nepal, Philippines, Singapore, Sri Lanka, Sulawesi, Sumatra, Thailand, Vietnam, West Malaysia (Chen and Wu, 2014).

Host plants: *Oryza sativa* (Fletcher and Ghosh, 1920)

Remarks: *S. incertulas* resembles *S. innotata*, however, *S. innotata* has white wings without any spots while in *S. incertulas*, the wings are ocherous to pale yellow and having a dark fuscous spot. Additionally, in male genitalia of *S. innotata*, the sugteguminal process single spine whereas in *S. incertulas* it is double spine (Lewvanich, 1981).

11. *Scirpophaga nivella* (Fabricius, 1794) [Figs. 21, 22, 37, 50]

Tinea nivella Fabricius, 1794: 296, Zimsen, 1964: 577; *Crambus niveus* (Fabricius) Fabricius, 1798: 472, Zimsen, 1964: 577; *Scirpophaga chrysorrhoa* Zeller, 1863: 1; Hampson, 1895: 913, 1896: 46 (Partim), Leech, 1901: 401 (Partim), Martin, 1958: 189; Common, 1960: 314; *Scirpophaga auriflua* Zeller, 1863: 2, Moore, 1867: 666; 1886: 387; Hampson, 1895: 913; 1896: 46 (Partim); *Scirpophaga brunnescens* Moore, 1888: 225; *Schoenobius celidias* Meyrick, 1894: 475; Hampson, 1895: 916 (as a synonym of *Schoenobius adjurellus* Walker); *Schoenobius brunnescens* (Moore) Hampson, 1895: 916, 1896: 48, Caradja, 1925: 45, de Joannis, 1929: 609; *Crambus nivella* (Fabricius) Aurivillius, 1898: 169, *Apurima nivella* (Fabricius) Aurivillius, 1898: 173; *Scirpophaga euclastalis* Strand, 1918: 262; *Scirpophaga nivella* (Fabricius) Shibuya, 1928: 61, pi. 4, Fig. 27 (Partim), de Joannis, 1929: 607.

It was initially described as *Tinea nivella* by Fabricius. Shibuya (1928) provided a key for separating *praelata*, *nivella*, *excerptalis* and *brunnescens*. According to Lewvanich (1981), S. nivella and S. *chrysorrhoa* synonymous.

Redescription: Spherical frons. Ocellus present beside compound eyes. cheatosema present. Filiform type antenna having fine serrations. Dorsal region of antenna has smooth scales, ventral region with delicate hairs. Proboscis reduced. Labial and maxillary palpi porrect. Maxillary palpi extends no more than half of the labial palpi. Labial palpi about 1.3 times in length compared to the diameter of compound eye. Frenulum double-bristled in females. Both cubital and subcostal retinaculum in male and only cubital retinaculum in female. Forewing ocherous. In forewing, vein R_1 does not anastomose with Sc. Vein R_2 free, originates near upper angle of the cell. R_3 and R_4 are stalked. From the upper angle of the cell originates R_5, it diverges terminally from R_4. M_1 basally approximated to R_5. M_2 almost parallel to M_1 and arise from above the lower angle of the cell. M_3 emanates from the lower angle of the cell. Cu1A originates before the lower angle of the cell. Short CuP vein developed at the wing margin; 1A complete. Hindwing white coloured. On the hindwing, Sc + R_1 terminates near the apex of the wing on the costa, veins Rs and M_1 arise simultaneously from the upper angle of the cell. Veins M2 and M3 originate close to each other from above the lower angle of the cell. CuA1 originates in advance to the lower angle of the cell and CuA2 almost from the middle of the cell. 1A+2A and 3A are complete, 3A short and straight.

Males have slender abdomen. Females have ocherous yellow coloured anal tuft. Male genitalia with uncus tapering, socii longer than uncus and tapering. Gnathos arms converging abruptly. Large, flattened subteguminal process having sinuous margin; elongated valva., aedeagus simple; cornuti present one fourth from the apex. Female genitalia having broad and membranous and wrinkled ostium bursae. Antrum present in ductus bursae. The portion from corpus bursase to ductus seminalis usually annulated laterally.

Material examined: India: Bihar: Darbhanga, 1♂, 26.ii.1972, On paddy, coll. D.P.Singh; India: Bihar: Pusa, 3♂ and 1♀, 5.xi.1983, Mercury vapour lamp coll. Hassan; India: New Delhi, 1♂ and 2♀, 18.ix.1991, Mercury vapour lamp, coll. Menon.

Distribution: India, Aru Island, Australia, Bangladesh, China, Fiji, Java, Borneo, Myanmar, Nepal, New Caledonia, New Guinea, Philippines, Singapore, Sri Lanka, Sumatra, Thailand, Timor, Vietnam, West Malaysia (Chen and Wu, 2014)

Host plants: *Imperata cylindrica, Ischaemum rugosum, Miscanthus sinensis, Oryza sativa*, *Phragmites longivalvis, Typha capensis* (Moritsugu, 1931)

Remarks: The males of *S. nivella* and *S. incertulas* have similar markings on wings, but in *S. nivella*, the labial and maxillary palpi are shorter. The forewing colour somewhat shiny in *S. nivella* as opposed to dull colour in *S. incertulas*. The adults of *S. nivella* are also similar to *S. excerptalis,* but in the later the forewing R1 anastomosed with Sc while in the former it is free. The number of bristles in the wing in *S. nivella* is two whereas in *S. excerptalis* it a single bristle only (Lewvanich, 1981)

12. *Sesamia inferens* (Dudgeon, 1905) [Figs. 23, 24, 38, 51]

Leucania inferens Walker, 1856, List Specimens lepid. Insects Colln Br. Mus., 9:105; *Leucania proscripta* Walker, 1856, Ibid., 9:106; *Sesamia tranquilaris* Butler, 1880: 674; *Nonagria gracilis* Butler, 1880: 675; *Sesamia albiciliata* Snellen, 1880, Tijdschr. Ent., 23: 44; *Nonagria innocens* Butler, 1881: 173.

Sesamia inferens was first described as *Leucania inferens* in 1856 by Walker. Walker also described *Leucania proscripta* from East Indies. Both the species were synonymised as *Sesamia inferens* by Hampson (1910).

Redescription: Brownish yellow coloured antenna, about 8 mm long. The antenna exhibits sexual dimorphism. Flagellum in male antenna has cylindrical segments from the bases of which emerge lateral outgrowths. Flagellum looks vertebra shape from a dorsoventral view. In females, the segments at the base of the flagellum are rounded and flat and remaining segments are square shaped and flattened. Length of labial palpi is almost twice the length of its distal segment. Entire tibiae are scattered irregularly with short and stout setae. Buff yellow coloured forewing. The costal and anal margins are almost equal in length and apical margin rounded. Wing coupling frenate type with males having one spine in frenulum and females having three. SC and R_1 remain wide apart and do not fuse. R_2 arises from the before the upper end of the cell. R_3 R_4 and R_5 arises from a common stalk which joins with an extension of R_2 and forms a cell over the main cell. R_5 fuses with the extension of R_2 and closes the cell. M_1 arise from the lateral side of the main cell. Hindwing is whitish in colour. SC + R_1 and RS diverge out from a common stalk. M_1 arises from RS at the angle of the cell. M_3 and M_4 arise from a common stalk beyond the cell. A_1, A_2 and A_3 are present.

Male genitalia have relatively large uncus. Tegumen broad with prominent peniculi. Apex of the valva rounded and having an acute costal process. Strong harpe with a projection at base of costa. Female genitalia with papilae anales highly sclerotised, they are anteriorly fused and posteriorly separated. A mid-ventral pocket represents the genital chamber. Ductus bursae broad and corpus bursae sac like subrounded structure having a conical point. Signum present and spine like.

Material examined: India: New Delhi, 1♂ and 7♀, 18.ix.2019 Mercury vapour lamp, coll. Dey; India: New Delhi, 8♂ and 12♀, 3.xi.2019, Mercury vapour lamp, coll. Dey; India: Assam, 3♂ and 9♀, 26.ii.2020, Mercury vapour lamp coll. Dey

Distribution: India, Bangladesh, Cambodia, China, Indonesia, Japan, Korea, Laos, Malaysia, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, Vietnam (Rao and Nagaraja, 1969; Kalshoven, 1981; Cheng, 1994; Kuniata, 1994; Morris and Waterhouse, 2001).

Host plants: *Andropogon nardus, A. schaenathus*, *Avena sativa*, *Beckmannia syzigachne*, *Calamagrostis epigejos*, *Coelorachis glandulosa*, *Cyperus japonicus*, *C. rotundus*, *Echinochloa crus-galli*, *E. frumentacea*, *E. stagnina*, *E. villosa, Elaeis guineensis*, *Eleusine coracana*, *Eragrostis major, Erianthus arundinaceus, Eriochloa annulata, E. villosa, Hordeum vulgare, Hymenache sp., Ischaemum rugosum, Miscanthus sacchariflorus, M. sinensis, Oryza latifolia, O. sativa, Panicum maximum, Paspalum scrobiculatum, P. thunbergii, Phragmites communis, P. karka, Rottboellia compressa, Rumex crispus, Saccharum spontaneum, Scirpus affinis, S. grossus, Setaria italica, Setaria rubiginosa, Sorghum halpense, S. sudanensis, Teosinte* sp., *Triticum aestivum* L. *Zea mays* (Azuma and Oshiro, 1969; Rao and Nagaraja, 1969; Kalshoven, 1981; Hasan

and Cervancia, 1986; Shah and Garg, 1986; Garg, 1988; Jacob, 1995; Li, 1993).

Remarks: From analyzing the male genitalia of *Se. inferens* it becomes clear that it does not share a close relationship with the African complex of *Sesamia*. The costal process in African complex is apically bifid, unlike in *Se. inferens*. *S. grisescens* Warren (New Guinea, Seram) and *S. arfaki* Bethune-Baker (New Guinea) have male genitalia similar to that of *Se. inferens* (Wu, 1981).

13. *Sesamia uniformis* (Dudgeon 1905) [Figs. 25, 26, 39, 52]

Nonagria uniformis Dudgeon 1905

The species was first described as *Nonagria uniformis* by Dudgeon in 1905. It was reamed as *Sesamia uniformis* by Hampson (1910).

Redescription: Males have antenna with short fasciculate cilia, females have simple antenna. Thorax having a buff suffusion and is buff coloured. Entire tibiae scattered irregularly with short and stout setae. Inner side of foretibia in males is dark brown but not in females. Forewing uniform ocherous having few fuscous cells mostly on the cell and its inner and outer margins. These include a sub-basal patch present below the cell; a small spot present antemedially; a fuscous fascia longitudinally, occurring partly within the cell along its lower margin and extending beyond the cell to termen; a conspicuous fuscous spot present on the lower angle of the cell, and another small spot above it present in the middle of discocellulars; Hindwing white coloured.

Male genitalia with uncus simple and curved. Costal margin of valva broadly sclerotised having a broad costal spine with a triangular apex. Aedeagus short and slender; cornuti absent. Juxta having a rounded medial projection, having spines. The lower margin of the ventral expansion of the vinculum straight. Female genitalia having bursa copulatrix broad with a somewhat pointed apex, short ductus bursae. Moderately large anteostial pad. Ostium sclerotised. Posterior to the ostium a moderately sclerotised band on the ostial segment.

Material examined: India: Lyallpur, 8♂ and 5♀, 31.viii.1934 on wild sugarcane, coll. R Saran

Distribution: India, Pakistan, Philippines (Rao and Nagaraja, 1969)

Host plants: *Erianthus arundinaceus*, *Oryza sativa*, *Saccharum spontaneum*, *Sorghum bicolor*, *Triticum aestivum*, *Zea mays* (Rao and Nagaraja, 1969).

Remarks: *Se. uniformis* can be differentiated from *Se. inferens* by means of the relatively darker colour in forewings. In the male genitalia of *Se. uniformis* a broad costal spine is present as opposed to a with darker forewings and a costal flange rather than an acute costal process as in *Se. inferens*. The lower margin of the ventral expansion in *Se. uniformis* is flat as opposed to *Se. inferens* which is rounded. Our study reveals the morphological differences in genitalia in details. Earlier worker has only produced adult images and discussed the characters of adults.

Keys for species

A stemborer having the tympanum on metathorax belongs to the Superfamily Noctuoidea, but if the tympanum is on the first abdominal sternite the stemborer is a member of the Superfamily Pyraloidea. *Sesamia* is the only genus which is a member of the superfamily Noctuoidea which is dealt in this paper. The genus *Sesamia* is characterised by a minute, aborted proboscis, upturned palpi with 2nd segment reaching about the middle of frons, thorax and base of the abdomen clothed with dense hairs, tibia fringed with long hairs. In the Superfamily Pyraloidea, the tympanum is present in the first sternite of abdomen. Four genera are dealt with in this study: *Bissetia*, *Chilo*, *Emmalocera* and *Scirpophaga*. The keys to separate the four genera based on morphology is provided:

1. Praecinctorium present..……..…… 2

- Praecinctorium absent ……..…….*Emmalocera*

2. Ocelli present ……...…...…… 3

- Ocelli absent ……..…….. *Bissetia*

3. Presence of Coremata in males and lobe-like strongly setose papillae anales ……..... ……...….*Scirpophaga*

- No Coremata in males and no lobe-like strongly setose papillae anales ……..…...…… *Chilo*

I. Key to the species of *Chilo*

a. Based on male genitalia:

1. Aedeagus with long conspicuous ventral arm …..... .....……..... 2

- Aedeagus without long conspicuous ventral arm …… ...….....……..... 3

2. Arms of juxta sollowen near apices..... .....*C. auricilius*

- Arms of juxta short and tapering with a distinct notch …….....….....…...*C. partellus*

3. Vesica with a row of strong cornuti……..... .....*C. sacchariphagus*

- Cornuti single, tapering and large .....…….. .....*C. infuscatellus*

b. Based on female genitalia:

1. Signum absent.....2

- Signum present 3

2. Ostial pouch somewhat delineated from ductus bursae, sclerotization is moderate ……..... .....*C. auricilius*

- Ostial pouch quite delineated from ductus bursae, longitudinal ribs having heavy sclerotization..... ..... *C. sacchariphagus*

3. Anterior portion of ostial pouch presents a deep incision ..... *C. infuscatellus*

- Ostial pouch delicately longitudinal wrinkled and anterior portion of is notched ……..… .....*C. partellus*

II. Key to the species of *Scirpophaga*

a. Based on male genitalia:

1. Tegumen with dorsal sclerotized thickening rectangular; subteguminal process flattened, plate-like. 2

- Tegumen with dorsal sclerotized thickening triangular or more or less X-shaped; subteguminal process lobed or spine like..... 3

2. Gnathos arms converging gradually, subteguminal process rounded…..... *S. gilviberbis*

- Gnathos arms converging abruptly, subteguminal process with strong sinuous margin ……..... .. ..*S. nivella*

3. Tegumen with dorsal sclerotized thickening triangular .....*S. incertulas*

- Tegumen with dorsal sclerotized thickening X-shaped ..... *S. excerptalis*

b. Based on female genitalia:

1. Antrum present and strongly sclerotized..... .....*S. nivella*

- Antrum absent 2

2. Corpus bursae completely lined with dense spines .....*S. excerptalis*

- Corpus bursae partly lined with dense spines 3

3. Corpus bursae usually lined with dense spines in the basal 2/3..... *S. gilviberbis*

-Corpus bursae usually lined with dense spines in the basal 3/4……..... *S. incertulas*

III. Key to the species of *Emmalocera*

a. Based on male genitalia:

1. Uncus lobes long, pointed apically with stout gnathos…….....…. *E. aurifusellus*

- Uncus lobes short, pointed apically with slender gnathos ……..…..…….. *E. depressella*

b. Based on female genitalia:

1. Signum elliptical sclerotised plate with prickled body…….....….*E. depressella*

- Signum almost circular shaped sclerotised plate with spiny body ….....……. *E. aurifusellus*

III. Key to the species of *Sesamia*

a. Based on male genitalia:

1. Juxta having a rounded medial projection, having spines ……..……. *Se. uniformis*

-Juxta not as above..... *Se. inferens*

b. Based on female genitalia:

1. Ductus bursae broad and corpus bursae sac like subrounded structure having a conical point ….....…… *Se. inferens*

- Ductus bursae not as broad and corpus bursae with a somewhat pointed apex .....…… .....……..…. *Se. uniformis*

ACKNOWLEDGEMENTS

The authors are grateful to the Head, Division of Entomology; Dr. Naresh M. Meshram, Senior Scientist, Division of Entomology; Dr. S. Subramanian, Principal Scientist, Division of Entomology; Dr. Vignesh M., Scientist, Division of Genetics, Indian Agricultural Research Institute, New Delhi; Dr. S.V.A.C.R. Mithra, Scientist, National Institute of Plant Biotechnology, New Delhi and Dr. Andrew Mitchell, Senior Research Scientist, Entomology, Australian Museum Research Institute. The PG school, ICAR- IARI is acknowledged

for the financial assistance to Adrish Dey in the form of ICAR-AIEEA(PG) fellowship.

AUTHOR CONTRIBUTION STATEMENT: AD: Conducted research, written manuscript, SPR: Conceptualized, planned the work and corrected manuscript.

CONFLICTS OF INTEREST: The authors declare that they have no conflicts of interest.

REFERENCES

Arora G S. 2000. Studies on some Indian Pyralid species of economic importance Part I Crambinae, Schoenobiinae, Nymphulinae, Phycitinae and Galleriinae (Lepidoptera: Pyralidae). Records of the Zoological Survey of India, Kolkata. 149 pp.

Azuma S, Oshiro Y. 1969. Studies on the insect pests of sugar cane in the Ryukyu Islands IV: On the pink borer *Sesamia inferens* Walker. Bulletin of Ryukyu Agricultural Experiment Station 5: 1-22.

Betbeder-Matibet M, Malinge P. 1968. Un succès de la lutte biologique: contrôl de Proceras sacchariphagus Boj. "borer ponctue" de la canne à sucre à madagascar par un parasite introduït Apanteles flavipes Cam. Agronomie Tropicale 22: 1196-1220.

Bisset G A. 1939. A new species of the genus *Chilo* (Lep., Pyralidae). Proceedings. The Royal Entomological Society of London Series B, Taxonomy, Oxford, UK, 8(3). pp. 47-48.

Błeszyński S, Collins R J. 1962. A short catalogue of the world species of the family Crambidae (Lepidoptera). Acta zoologica cracoviensia 7:197-389.

Bleszynski S. 1970. A revision of the world species of *Chilo* Zincken (Lepidoptera: Pyralidae). Bulletin of the British Museum (Natural History) Entomology 25: 101-195.

Butler A G. 1879. On the collection of Lepidoptera from Cachar, N.E. India. Transactions of the entomological Society of London 21: 19-76.

Carl K. 1962. Graminaceous moth-borers in West Pakistan. Technical Bulletin of the Commonwealth Institute of Biological Control 2: 29-76.

Chen F Q, Wu C S. 2014. Taxonomic review of the subfamily Schoenobiinae (Lepidoptera: Pyraloidea: Crambidae) from China. 动物分类学报 39(2): 162-208.

Cheng W Y. 1994. Biology, Pest Status and Control Measure Relationships of Sugar Cane Insect Pests. Proceedings. Second Sugarcane Entomology Workshop, South Africa. pp. 97-106.

Chundurwar R D. 1989. Sorghum stem borers in India and Southeast Asia. International Workshop on Sorghum Stemborers, ICRISAT, India. pp. 19-25.

Common I F B. 1960. A revision of the Australian stem borers hitherto referred to *Schoenobius* and *Scirpophaga* (Lepidoptera: Pyralidae, Schoenobiinae). Australian Journal of Zoology 8 (2): 307-347.

Cotes E C. 1889-1891. The sugarcane borer moth. Indian Museum Notes 1: 22-29.

David H, Easwaramoorthy S. 1990. Biological control of *Chilo* spp. in sugarcane. Insect Science and its Application 11: 733-748.

Eguchi M. 1933. Biological studies of *Diatraea shariiensis*. Journal of agriculture experimental station Chosen 1933: 1-20.

Facknath S. 1989. Biological control of sugar-cane pests in Mauritius: A case study. Insect Science and its Application 10: 809-813.

Fletcher T B, Ghosh C C. 1920. Borers in Sugar-cane, Rice, etc. Proceedings. Third Entomological Meeting, Pusa, 1919. pp. 354-517.

Fletcher T B. 1914. Some south Indian insects and other animals of importance considered especially from an economic point of view. Superintendent Government Press, Madras.

Fletcher T. B. 1928. Report of the Imperial Entomologist. Scientific reports of the Agricultural Research Institute, Pusa 1926-27. pp. 56-67.

Garg D K. 1988. Host range and overwintering of rice pink stem borer (PSB) in a hilly region of India. International Rice Research Newsletter 13(2): 23-24.

Ghai S, Ramamurthy V V, Gupta S L. 1979. Lepidopterous pests associated with rice crop in India. Indian Journal of Entomology 41(1): 65-90.

Hampson G F. 1895. On the classification of the Schoenobiinae and Crambinae, two subfamilies of moths of the family Pyralidae. Proceedings. Zoological Society of London, 1895. pp. 897-974.

Hampson G F. 1912. The moths of India. Journal of the Bombay Natural History Society 21: 1222-1272.

Hampson G F. 1918. A Classification of the Pyralidae, subfamily Hypsotropinae. Proceedings. Zoological Society of London, 1918. pp. 55-131.

Hampson G F. 1896. The Fauna of British India including Ceylon and Burma, Moths Volume- IV, London. 594 pp.

Hampson GF. 1910. Catalogue of the Lepidoptera Phalaenae in the collection of the British Museum, Volume- IX Noctuidae, London. pp. 327-332.

Harris K M. 1990. Biology of *Chilo* species. Insect Science and its Application 11(4-5): 467-477.

Hasan N, Cervancia C R. 1986. Insect pest colonization and succession in wheat *Triticum aestivum* L. Philippine Entomologist 6: 581-587.

Huang R H, Huang P Q, Xiong C J. 1985. Studies on the occurrence of *Chilo auricilius* Dudgeon in Yibing Prefecture, Shichuan. Insect Knowledge 22: 104-106.

Jacob S A, Kochu B M. 1995. *Sesamia inferens* Walker - a new pest of oil palm seedlings in India. Planter 71(831): 265-266.

Kalshoven L G E. 1981. Pest of Crops in Indonesia. P.T. Ichtiar Baru - van Hoeve, Jakarta.

Kapur A P. 1950. The Identity of some Crambinae associated with Sugarcane in India and of certain Species related to them (Lepidoptera: Pyralidae). Transactions of the Royal Entomological Society of London 11: 101.

Klots A B. 1965. Lepidoptera. Taxonomist's Glossary of Genitalia in Insects. Munksgaard. pp 115–130.

Kollar V. 1844-1848. Lepidoptera. Hugel "Kaschmir und das Reich der siek", Stuttgart. pp. 249-865.

Kuniata L S. 1994. Pest status, biology and effective control measures of sugar cane stalk borers in the Australian, Indonesian and Pacific Island sugar cane growing regions. Proceedings. Second ISSCT Sugarcane Entomology Workshop, Mount Edgecombe, South Africa. pp. 83-96.

Lee T R, Anderson S J, Tran-Nguyen L T, Sallam N, Le Ru B P, Conlong D, Powell K, Ward A, Mitchell A. 2019. Towards a global DNA barcode reference library for quarantine identifications of lepidopteran stemborers, with an emphasis on sugarcane pests. Scientific reports 9(1):7039.

Lefroy H M. 1909. Indian insect life-Lepidoptera-Butterflies and Moths. Vol. II. Agricultural Research Institute, Pusa, India. pp. 397-786.

Leslie G W. 1994. Pest status, biology, and effective control measures of sugarcane stalk borers in Africa and surrounding island. Proceedings. Second ISSCT Sugarcane Entomology Workshop, Mount Edgecombe, South Africa. pp. 61-73.

Lewvanich A. 1981. A revision of the Old-World species of *Scirpophaga* (Lepidoptera: Pyralidae). Bulletin of the British Museum Natural History (Entomology) 42(4): 185–298.

Li H K. 1993. Studies on the entomopathogenic fungi infecting reed stem borers. Chinese Journal of Biological Control 9: 188.

Maes K. 1998. Pyraloidea: Crambidae, Pyralidae. African cereal stem borers: economic importance, taxonomy, natural enemies and control. CAB International, Wallingford, UK. 530 pp.

Mathew G. 2006. An inventory of Indian Pyralids (Lepidoptera: Pyralidae). Zoos' Print Journal 21(5): 2245-2258.

Moore F. 1865. On the lepidopterous insects of Bengal. Proceedings. Zoological Society of London, 1865. pp. 822.

Moore F. 1884-1887. The Lepidoptera of Ceylon (Vol. 3). L. Reeve and Company, London, UK.

Moritsugu A. 1931. Studies on the top borer of sugar-cane in Formosa. Reports of the Department of Agriculture Government Research Institute Formosa 50: 56.

Morris H, Waterhouse D F. 2001. The Distribution and Importance of Arthropod Pests and Weeds of Agriculture in Myanmar. ACIAR Monograph, ACIAR, Canberra. 67 pp.

Neupane F P. 1990. Status and control of *Chilo* spp. on cereal crops in southern Asia. International Journal of Tropical Insect Science 11(4-5): 501-534.

Nuss M, Landry B, Mally R, Vegliante F, Tränkner A, Bauer F, Hayden J, Segerer A, Schouten R, Li H, Trofimova T, Solis M A, De Prins J, Speidel W. 2003–2020. Global Information System on Pyraloidea.

Overholt W A. 1998. Biological control. Polaszek A (eds). African cereal stem borers: economic importance, taxonomy, natural enemies and control. CAB International, Wallingford, UK. 530 pp.

Pruthi H S. 1969. Textbook on Agricultural Entomology. ICAR, New Delhi. 977 pp.

Puri V D. 1957. Studies on the anatomy of the sugarcane moth borers. Proceedings. Indian Academy of Sciences Section B, Bangalore, May 1945. pp. 196-215.

Rao V P, Nagaraja H. 1969. *Sesamia* species as pests of sugar cane. Williams J R, Metcalfe J R, Mungomery R W, Mathes R (eds). Pests of sugar cane. Elsevier: London. 207-223 pp.

Shah N K, Garg D K. 1986. Pest complex of ragi *Eleusine coracana* G. in hills of Uttar Pradesh. Indian Journal of Entomology 48: 116-119.

Shibuya J. 1928. The systematic study on the Formosan Pyralidae. Journal of the Graduate School of Agriculture, Hokkaido University 22 (1): 1-300.

Shiraki T. 1917. Paddy borer *Schoenobius incertulas* Walker. Government of Formosa, Report of the Taihoku Agricultural Experiment Station. pp. 256.

Srikanth J, Easwaramoorthy S, Jalali S K. 2016. A 100 years of biological control of sugarcane pests in India: review and perspective. CAB Reviews 11(13): 1-32.

Suasa-ard W, Allsopp P G. 2000. Sugarcane pest management strategies in the New Millennium. Proceedings. IV ISSCT Sugarcane Entomology Workshop, Mount Edgecombe, 2000. pp. 7-10.

Vallée G C, Muñoz D S, Sankoff D. 2016. Economic importance, taxonomic representation and scientific priority as drivers of genome sequencing projects. BMC Genomics 17: 125–133.

Walker F. 1863. List of the Specimens of Lepidopterous Insects in the Collection of the British Museum. 28: Tortricites and tinedites.

Williams J R. 1983. The sugar cane stem borer (*Chilo sacchariphagus*) in Mauritius. Revue agricole et sucrière de l'Ile Maurice 62: 5-23.

Wu J T. 1981. An unrecorded sugarcane pest, *Sesamia uniformis* Dudgeon (Lepidoptera, Noctuidae). Journal of South China Agricultural University 2(3): 14-20.

Zeller P C. 1863. Chilonidarum et Crambidarum genera et species. Wiegandt, Berlin. 56 pp.

(Manuscript Received: December, 2020; Revised: March, 2021;
Accepted: March, 2021; Online Published: July, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20417

Indian Journal of Entomology 84(1): 24-28 (2022) DoI.: 10.55446/IJE.2021.29

BROODLAC QUALITY ASSESSMENT AND FORECASTING OF CRAWLER EMERGENCE IN INDIAN LAC INSECT *KERRIA LACCA*

Mohanasundaram A*, Sharma K K, Verma Sweta, Anees K[1] and Mishra Rashmi

ICAR- Indian Institute of Natural Resins and Gums, Ranchi 834010, Jharkhand, India
[1]ICAR- Indian Institute of Spices Research, Kozhikode 673012, Kerala, India
*Email: mohaniinrg@gmail.com (corresponding author)

ABSTRACT

Assessment of quality and freshness of broodlac produced by the Indian lac insect *Kerria lacca* (Kerr) is an important parameter in its pricing. The present study provides an assessment of broodlac quality with 25, 50, 75 and 100% of lac encrustation harvested from summer (baisakhi), rainy (katki) on palas, winter (aghani) on ber, and summer season (jethwi) on kusum. The curve fitting model based on the rate of weight reduction can be used for prediction of freshness. Among the four lac crops, maximum rate of reduction was observed with summer kusmi (jethwi) and rangeeni (baisakhi) crops, and a good quality of broodlac was observed with katki crop on palas. Crawler emergence, stages of yellow spots and number of days for actual crawler emergence varied in different seasons. The present study differentiates the embryonic development into six stages with yellow spots through microscopic images. This reveals that the stage 1 coincides with earlier defined stage 2 and 3, and stage 2, 3, 4 and 5 are of stages 4, 5, 6 and 7 and 8, respectively.

Key words: *Kerria lacca*, broodlac, freshness, lac encrustation, crawler emergence, forecast, yellow spot, baisakhi, jethwi, katki, aghani, palas, ber, kusum, model, weight reduction, embryonic development, yellow spots, stages

Indian lac insect *Kerria lacca* (Kerr) is broadly distinguished as two strains i.e. kusmi and rangeeni which differ by host preference, lifecycle pattern, the quality and amount of lac produced. In case of two crops of kusmi strains are: summer season/ Jethwi (harvested in June/July) and winter season/ Aghani (harvested in January/ February) while that of Rangeeni, are: rainy season/ Katki (harvested in October/ November) and summer season/ Baisakhi (harvested in May/ June). Quality of brood used is an important criterion for raising the lac crop, as it affects the yield significantly. This broodlac quality is influenced by a number of factors such as predator population in the brood, degree of parasitization (Chowdhury et al., 1971), thickness of encrustation, extent of settlement, choice of the host plant on which lac grows and various climatic factors like temperature, rainfall, humidity, wind etc. (Nicholsan, 1925). Of the climatic factors, temperature is most important affecting broodlac production (Bhagat and Mishra, 2002; Sharma, 2007). Beside this, productivity and broodlac quality is also influenced by the pest incidence that includes lepidopteron predators viz., *Eublemma amabilis* Moore and *Psuedohypatopa* (*Holcocera*) *pulverea* Meyr. and an array of species of parasitoids. It is estimated that associated harmful fauna causes 50% loss (Malhotra and Katiyar, 1979).

Encrustation thickness is also an important parameter to evaluate the broodlac quality. Assessment of quality and freshness of broodlac is crucial to control its pricing and yield of next crop. It is related to density of living females and thus a good indicator of number of lac larvae/ unit brood weight/ length. Male population varies greatly depending upon level of crowding (Purkayastha and Krishnan, 1964) and even with site of inoculation. Biological parameters *viz.*, yield of resin, fecundity, sex ratio varied significantly both quantitatively and qualitatively (Mishra et al., 2000). Studies on broodlac quality in relation to thickness of host branch and lac encrustation are documented (Ghosal et al., 2011). Ghosal and Meena (2019) also reported that many factors influence the quality of broodlac viz., source of broodlac, % coverage by encrustation, and compactness of encrustation. Besides maintaining good broodlac quality, the knowledge of crop maturity and forecast of larval emergence has special importance in lac cultivation. Early harvested lac crop results in under developed or weak first instar larvae that die soon whereas late harvested lac crop results in quick emergence of larvae so that the farmer does not get sufficient time to inoculate other trees (Jaiswal and Sharma, 2010). The knowledge of crop maturity and forecast of crawler emergence has special

importance in lac cultivation. Therefore, this study using different quality of broodlac for quality assessment and to devise an accurate method for forecasting of crawler emergence.

MATERIALS AND METHODS

Study was undertaken using the both strains (rangeeni and kusmi), with different quality of broodlac depending on the degree of lac encrustation, from palas, ber and kusum viz., 25 (T_1), 50 (T_2), 75 (T_3) and 100% (T_4) lac encrustation, harvested during baisakhi 2015-16 and 2016-17 (palas), katki 2015 and 2016 (palas), aghani 2015-16 and 2016-17 (ber) and jethwi, 2016 and 2017 (kusum) for two consecutive years. Equal quantities (1 kg) of broodlac were taken from the four categories of treatments in the Borosil glass beaker and covered with muslin cloth and kept for crawlers emergence. The broodlac was observed for weight reduction and quantity of crawler emergence on daily basis up to one month. Forecast study was conducted using both strains (rangeeni and kusmi) in different crop seasons (baisakhi, katki, aghani and jethwi) for two years, i.e. 2015-16 to 2016-17. Lac insect female cells were collected and grouped into six stages (Stage 0, 1, 2, 3, 4 and 5) based on appearance of yellow spot. Images of female cell with yellow spot appearance were taken and developing embryo in the mother cells was observed under microscope. Time lag relation (in days) between initiation and number of days for crawler emergence were analyzed statistically and different stages of yellow spot appearance were correlated with embryonic development and actual crawler emergence for improved and accurate forecasting. The study was conducted in the Genetics and Breeding Laboratory at ICAR-Indian Institute of Natural Resins and Gums, Namkum, Ranchi. Data of two years were pooled for statistical analysis using techniques of ANOVA (Panse and Sukhatme, 1967). Data of forecasting of crawler emergence was analyzed by one factor while the data of broodlac quality assessment study were analyzed by two factor ANOVA in complete randomized block design (CRBD) using OPStat Package. The significance among treatment means were judged by critical difference (CD, p=0.05).

RESULTS AND DISCUSSION

Broodlac quality study with different quality of broodlac viz., 25, 50, 75 and 100% lac encrustation harvested from baisakhi, katki on Palas, aghani on ber and jethwi on kusum revealed significant difference in crawler emergence. Maximum lac crawlers (1.69 and 0.49 g) emerged on 4th day after harvesting (DAH) of broodlac in T_4 (100 %), respectively followed by 5th and 6th DAH of broodlac in T_3 (75 %) and T_2 (50 %). Among the four treatments, maximum crawlers (2.84 g crawlers) emerged in T_4 (100 %) followed by T_3 (75 %), T_2 (50 %) T_1 (25 %). Crawler emergence started from 2nd DAH and continued up to 25th DAH of broodlac. Most of the crawlers emerged up to 16th days after harvesting of broodlac. Crawler emergence varied from 0.48 to 1.69, 0.13 to 0.37 and 0.01 to 0.09 gram during 1 to 7, 8-16 and 17-25 days, respectively of kusum broodlac during jethwi crops. In Aghani crop, lac crawlers emerged significantly more (1.13 g) on 10th DAH of broodlac followed by 6th and 9th DAH of broodlac. Quality of broodlac was poor in baisakhi crop than other three lac crops based upon emergence of crawlers. Crawler emergence started from 3rd DAH of broodlac and maximum quantity of crawlers recorded up to 10th DAH of broodlac. Similarly, for katki crops crawler emergence started from 3rd DAH of broodlac and continued up to 26th DAH of broodlac. Crawler emergence varied from 0.01 to 0.57 g between 13 to 26th DAH of broodlac. Maximum quantity of lac crawlers (1.12 g) were collected on 11th DAH of broodlac followed by 12th (1.11 g) and 10th (0.95 g) DAH of broodlac during katki crops. Quality of broodlac was good based upon more quantity emergence of crawlers (1.84 g) as recorded in katki crops (Table 1). Ghosal et al. (2011) found that diameter (thickness) of 85% of lac sticks of host were within the range 0.5-0.8 cm in case of kusum trees; lac sticks with diameter of 0.6 to 0.8 cm produced good quality broodlac and also found that thickness of broodlac encrustation was the most important factor for lac insect settlement. Ghosal and Meena (2019) observed that length of lac insect settlement was 73% and reduced significantly due to long hours of transportation and poor packaging, leading to poor broodlac quality.

To address the freshness assessment of the broodlac, the rate of weight reduction was taken as an index. Rate of reduction in weight in categories viz., 25, 50, 75 and 100% lac encrustation was calculated and observed that in kusum (2.72, 2.86, 3.44 and 3.59%/ day with R^2 value of 0. 94, 0.96, 0.95 and 0.92, respectively); and in jethwi crops, ber (1.16, 1.29, 1.55 and 1.59 %/ day with R^2 value of 0.95, 0.90, 0.95 and 0.86, respectively) during aghani crops, palas (2.42, 2.01, 1.63 and 2.03%/ day with R^2 value of 0.88, 0.90, 0.84 and 0.92, respectively) during baisakhi crops and palas (1.31, 1.24, 2.08 and 1.90%/ day with R^2 value of 0.87, 0.90, 0.82 and 0.75, respectively) during katki crops

Table 1. Crawler emergence of different quality of broodlac in different season

Days	Quality of broodlac on different host plant																			
	Kusum during Jethwi					Ber during Aghani					Palas during Baisakhi					Palas during Katki				
	25	50	75	100	Mean	25	50	75	100	Mean	25	50	75	100	Mean	25	50	75	100	Mean
1	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	
2	0.15	0.46	0.76	1.43	0.7															
3						0.02	0.09	0.14	0.11	0.09	0.06	0.07	0.12	0.14	0.1	0.55	0.86	1	1.26	0.92
4	0.62	1.35	1.94	2.84	1.69	0.04	0.22	0.34	0.49	0.27	0.05	0.07	0.21	0.16	0.12					
5	0.59	0.82	1.43	1.73	1.14						0.04	0.11	0.17	0.22	0.13	0.28	0.42	0.71	1.11	0.63
6	0.42	0.83	1.24	1.57	1.02	0.57	0.56	1.11	1.3	0.88	0.18	0.34	0.36	0.54	0.35	0.3	0.35	0.62	0.85	0.53
7	0.23	0.47	0.54	0.69	0.48	0.59	0.42	0.78	0.76	0.64	0.05	0.14	0.17	0.19	0.14					
8	0.2	0.35	0.53	0.41	0.37	0.58	0.54	0.81	1.15	0.77	0.1	0.11	0.09	0.12	0.11	0.52	0.58	0.93	1.45	0.87
9	0.14	0.21	0.38	0.27	0.25	0.63	0.76	0.71	1.32	0.86										
10	0.08	0.26	0.26	0.19	0.2	0.61	0.92	1.07	1.94	0.13	0.05	0.09	0.08	0.22	0.11	0.53	0.49	1.14	1.63	0.95
11	0.11	0.16	0.24	0.23	0.19						0.02	0.03	0.02	0.03	0.03	0.66	0.85	1.35	1.61	1.12
12	0.07	0.1	0.16	0.2	0.13	0.34	0.54	0.63	1.16	0.67	0.02	0.01	0.01	0.01	0.01	0.28	0.94	1.17	2.05	1.11
13	0.08	0.12	0.19	0.18	0.14	0.35	0.64	0.74	1.24	0.74	0.01	0.01	0.01	0.01	0.01	0.15	0.26	0.53	1.15	0.52
14	0.09	0.1	0.12	0.14	0.11	0.08	0.16	0.17	0.3	0.18	0.01	0	0.01	0.01	0.01	0.24	0.36	0.59	1.07	0.57
15						0.07	0.1	0.06	0.25	0.12	0.01	0.01	0	0	0.01	0.15	0.25	0.4	0.59	0.35
16	0.12	0.1	0.14	0.2	0.14	0.05	0.08	0.05	0.19	0.09	0.01	0.01	0.01	0.01	0.01					
17	0.05	0.09	0.1	0.12	0.09						0	0.01	0.01	0.01	0.01	0.11	0.17	0.37	0.44	0.27
18	0.04	0.08	0.08	0.09	0.07											0.1	0.13	0.21	0.38	0.2
19	0.04	0.07	0.06	0.09	0.07	0.05	0.07	0.08	0.13	0.08										
20	0.04	0.09	0.06	0.1	0.08											0.05	0.12	0.12	0.17	0.11
21	0.04	0.05	0.05	0.09	0.06	0.01	0.01	0	0.04							0.04	0.04	0.07	0.07	0.06
22						0.01	0	0	0.02							0.01	0.04	0.06	0.05	0.04
23	0.01	0.01	0.08	0.12	0.06															
24	0	0.01	0.01	0.05	0.02															
25	0.01	0	0.01	0.01	0.01											0.01	0.03	0.04	0.04	0.03
26																0	0.01	0.02	0.02	0.01
Mean	0.14	0.26	0.38	0.49		0.22	0.28	0.37	0.58		0.04	0.06	0.08	0.1		0.22	0.33	0.52	0.77	
	A	B	A×B			A	B	A×B			A	B	A×B			A	B	A×B		
C.D	0.039	0.039	0.185			0.057	0.121	0.243			0.011	0.021	0.042			0.09	0.191	0.382		
SE(m)	0.02	0.047	0.094			0.02	0.043	0.087			0.005	0.011	0.021			0.046	0.097	0.193		

*A- Quality of broodlac; *B –Days; *C- Quality of broodlac (A)× (B)

(Figs. 1 to 4). The study also revealed that the rate of reduction in broodlac weight became near constant after 11, 15, 10, 14 days during jethwi, aghani, baisakhi and katki crops, respectively. This curve fitting model based on the rate of weight reduction can be used for prediction of freshness of broodlac. Time lag relation (in days) between initiation of crawler emergence and different stages of yellow spots varied greatly. Number of days for actual crawler emergence also varied in different seasons. The number of days for actual crawler emergence was maximum during aghani season crop for stage 0 (18.80± 2.62) as the crop maturity time (January/ February) falls during winter months. During katki season crop, the lowest number of days was observed for actual crawler emergence in different stages of

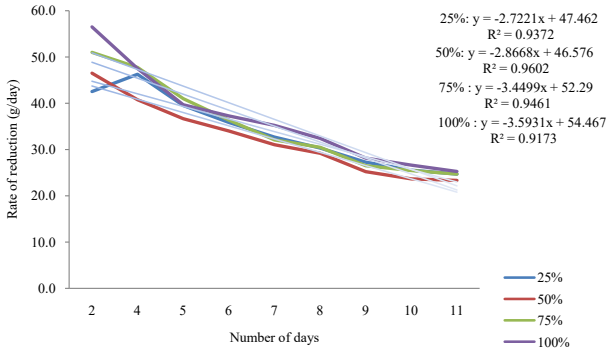


Fig. 1. Weight reduction vs quality of kusum broodlac (jethwi crop)

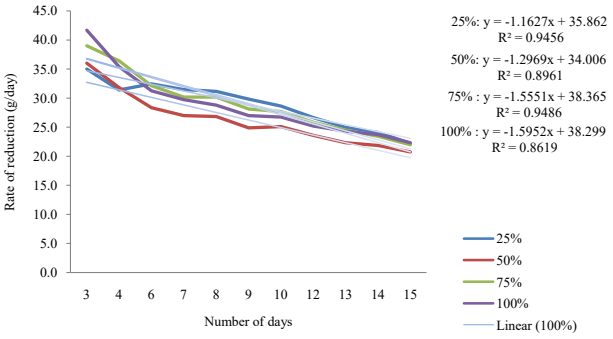


Fig. 2. Weight reduction vs quality of ber broodlac (aghani crop)

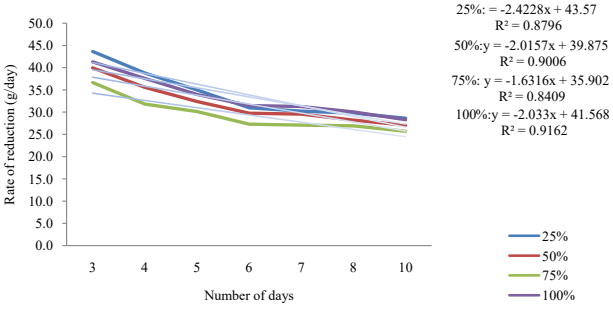


Fig. 3. Weight reduction vs quality of palas broodlac (baishaki crop)

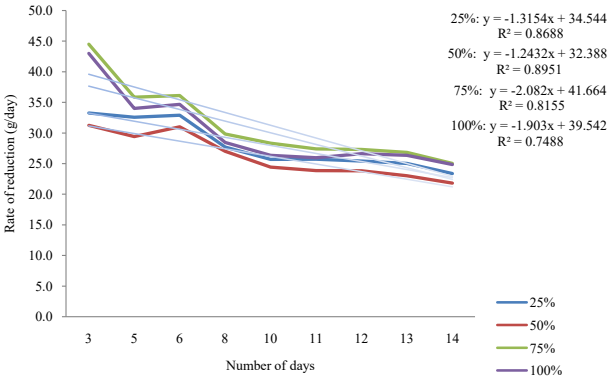


Fig. 4. Weight reduction vs quality of palas broodlac (katki crop)

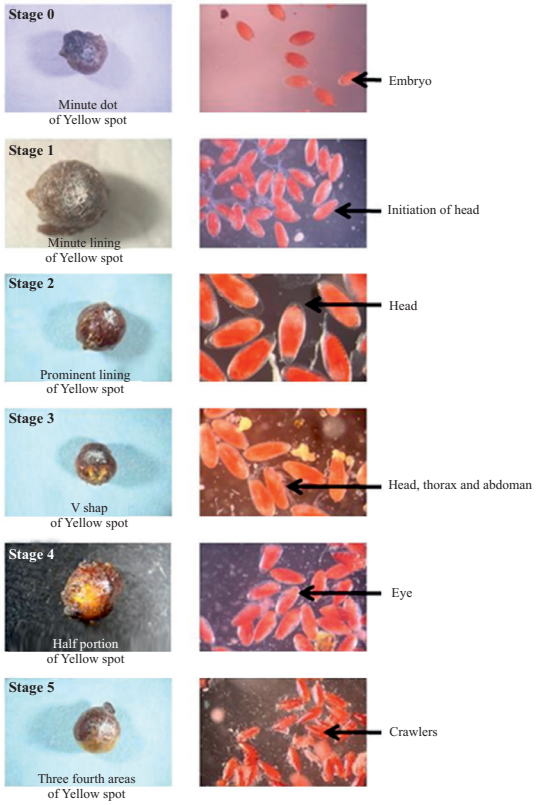


Fig. 5. Stages of yellow spots and embryonic development of lac crawlers

Table 2. Time lag correlation - stages of lac insect vs. no. of days taken before initiation of crawler emergence

Stages	No. of days taken before initiation of crawler emergence			
	Baisakhi	Katki	Aghani	Jethwi
Stage 0	13.13± 3.06	9.33± 1.60	18.80± 2.62	11.24± 1.82
Stage 1	6.97± 1.29	7.14± 1.08	13.12± 2.22	8.89± 1.87
Stage 2	5.45± 1.63	6.33± 1.56	12.28± 1.52	6.50± 2.56
Stage 3	3.90± 1.06	4.53± 0.99	5.30± 1.42	5.33± 1.66
Stage 4	2.67± 0.74	2.84± 0.88	4.91± 1.33	3.85± 1.09
Stage 5	1.68± 0.43	1.39± 0.40	1.93± 0.66	1.30± 0.50
C.D.	0.82	0.547	0.806	0.892
SE(m)	0.294	0.196	0.289	0.319

yellow spots that varied from 9.33± 1.60 (stage 0) to 1.39±0.40 (stage 5) due to short duration (four months) of lac crop (Table 2).

Different stages of embryonic development and female cell with yellow spot appearance are depicted in Fig. 5. Elongated embryos were observed at stage zero and initiation of head begins by Stage 1. Head of the embryo was distinctly visible and body formation began in stage 2. Head, thorax and abdomen were clearly visible in stage 3. The eyes became distinct at stage 4. Fully developed crawlers which were enclosed by a membrane were clearly visible at Stage 5. Previous study of embryonic development by Jaiswal and Sharma, (2010) reported nine stages of embryonic development and yellow spots in hand drawn diagram whereas in present study embryonic development is differentiated into six stages and yellow spots through microscopic images. Present study of stage 1 coincides with earlier study of stage 2 and 3. Similarly, stage 2, 3, 4 and 5 are as like in stage 4, 5, 6 and 7 and 8 of previous study by Jaiswal and Sharma (2010).

Lac insect crawler emergence profile is directly related to quality of broodlac. Broodlac which harbors very less quantity of crawlers due to lesser encrustation and/or high pest infestation will have direct impact on next crop productivity. In the present study, good quality of broodlac reported during katki season on palas. The curve fitting model based on the rate of weight reduction can be used for prediction of freshness of broodlac samples. Among the four lac crops, maximum rate of reduction in weight of broodlac was calculated in summer kusmi (jethwi) and rangeeni (baisakhi) crops than kusmi winter (aghani) and rangeeni rainy (katki) season crop**.** Beside this, as all the lac cells even on the same twig are not found in the same stage of development, results of this study revealed that the broodlac used for next season inoculation should be harvested from tree after cells have reached at least the stage 4 in baisakhi, katki and jethwi whereas in aghani should be harvested in stage 5 (when crawler emergence starts) as depicted in photographic image developmental stage. It would result in maximum emergence of crawlers without affecting the vitality of majority of the insects and their young ones resulting in better performance and higher lac yield.

ACKNOWLEDGEMENTS

The authors thank the Director, ICAR- Indian Institute of Natural Resins and Gums, Ranchi for providing facilities. This work was financially supported by Network Project on Conservation of Lac Insect Genetic Resources, Indian Council of Agricultural Research, New Delhi.

REFERENCES

Bhagat M L, Mishra Y D. 2002. Abiotic factors affecting lac productivity. Kumar K K, Ramani R, Sharma K K (eds.). Recent advances in lac culture. pp.64-68. Indian Lac Research Institute, Namkum, Ranchi.

Chowdhury M K, Sen P, Bhattacharya A. 1971. Studies on the relationship between the density of lac insect, *Kerria lacca* (Kerr) (Homoptera: Coccidae) and chalcid parasitization. Indian Journal of Entomology 33(2): 180-182.

Ghosal S, Meena S C. 2019. Factors affecting lac insect settlement. Indian Forester 145(12): 1212 -1213.

Ghosal S, Ramani R, Mishra Y D. 2011. Influence of thickness of branch, *phunki* scrap weight, weighted living cell and *kusmi* encrustation thickness on broodlac quality. Annals of Entomology 29(1): 1-5.

Jaiswal A K, Sharma K K. 2010. Forecast of larval emergence and crop harvesting. K K Sharma, R Ramani (eds.) recent advances in lac cultures. ICAR-Indian Institute of Natural Resins and Gums, Ranchi, pp. 57-62.

Malhotra C P, Katiyar R N. 1979. Chemical control of the lac predator *Eublemma amabilis* Moore II. Relative toxicity of the various insecticides against the predatory caterpillars. Indian Journal of Entomology 41: 187-190.

Mishra Y D, Sushil S N, Bhattacharya A, Kumar S. 2000. Variability in lac productivity and related attributes of *Kerria* spp. (Homoptera: Tachardiidae) on Ber (*Z. mauritiana*). Journal of Entomological Research 24(1):19-26.

Nicholson J W. 1925. Some notes on lac cultivation. Indian Forester 51(10): 483-498.

Panse V G, Sukhatme P V. 1967. Statistical methods for agricultural workers. 2nd Edn. ICAR New Delhi. 381 pp.

Purkayastha B K, Krishnan Y S. 1964. Determination of optimum amount of broodlac requirement for crop inoculation and proper time of harvesting for maximizing yield on palas in *baisakhi* season. Indian Agriculture 8: 55-60.

Sharma K K. 2007. Lac insect-host plant interaction: Implications on quantity and quality of lac. Bhattacharya A, Jaiswal A K, Prasad N, Pal G (eds.). Model training course on advanced lac production, storage and application technology for employment and income generation. Indian Lac Research Institute, Namkum, Ranchi. pp. 41-48.

(Manuscript Received: December, 2020; Revised: March, 2021;
Accepted: March, 2021; Online Published: July, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20423

Indian Journal of Entomology 84(1): 29-33 (2022) DoI.: 10.55446/IJE.2021.30

SURVIVAL AND VIRULENCE OF NATIVE STRAINS OF *STEINERNEMA CARPOCAPSAE* AND *HETERORHABDITIS BACTERIOPHORA* IN FORMULATIONS

Seenivasan Nagachandrabose

Department of Nematology, Tamil Nadu Agricultural University,
Coimbatore 641003, Tamil Nadu, India
Email: seeni_nema@yahoo.com

ABSTRACT

In this study, entomopathogenic nematodes (EPN) isolated from cotton ecosystem viz., *Steinernema carpocapsae* (strain APKS2) and *Heterorhabditis bacteriophora* (strain KKMH1) were evaluated in formulations of alginate gel, talc, sponge and water concentrates. The survival or longevity of infective juveniles (IJs) in these formulations was evaluated under in vitro at storage temperatures of 5 and 25 °C. Simultaneously, virulence of these stored EPN infective juveniles (IJs) was evaluated against the spotted boll worm *Earias vitella* through in vitro bioassays. The results revealed that *S. carpocapsae* (APKS2) and *H. bacteriophora* (KKMH1) formulated in alginate gel survived 70- 100% up to 3 months with 55-100% infectivity at 5°C and survived 52- 100% with 42.5- 100% virulence for 2.5 months at 25°C. In talc formulation, these EPN remained alive to an extent of 55- 100% with 70-100% virulence at 5°C and stayed alive 45-100% with 52.5- 100% virulence at 25°C for 2 months. In sponge formulation, EPN strains survived 55-100% with 67.5-100% infectivity for 7 weeks at 5°C, but with 50-100% survivals and 62.5-100% virulence at 25°C. EPN strain *S. carpocapsae* (APKS2) can be stored in water at 5°C up to 8 weeks with viability of 50% and infectivity 60%. At 25°C, it can be stored for 5 weeks with survival of 62% and infectivity of 62.5- 100 %. It is inferred from the results that alginate and talc formulations at storage temperature of 5°C is better for long term storage of *S. carpocapsae* strain APKS2 and *H. bacteriophora* strain KKMH1. Thus, the results revealed that *S. carpocapsae* (strain APKS2) and *H. bacteriophora* (strain KKMH1) can be formulated in sponges for use within 2 months and can be kept as water concentrate if they would be utilized in 2-3 weeks.

Key words: *Earias vittella*, *Steinernema carpocapsae*, *Heterorhabditis bacteriophora,* formulations, alginate gel, talc, sponge and water concentrates, survival, virulence, storage temperature, viability, infectivity

Cotton (*Gossypium hirsutum*: Malvacea), popularly known as 'white gold', is an important cash crop of India. One of the prime challenges to attain high cotton production is damage caused by insect pests. The spotted boll worm *Earias vitella* (Lepidoptera: Noctuidae) is one of the most important pests affecting the cotton plants and it can cause yield loss of up to 50% (Dhaliwal et al., 2010). The habit of developing resistance to many insecticides including Bt transgenic cotton necessitate to find out an alternate strategy to manage *E. vitella*. In this situation, exploitation of naturally occurring entomopathogenic nematodes (EPN) from two families viz, Heterorhabditidae and Steinernematidae to develop biopesticide for the control of cotton bollworms is an ecologically sound approach. The infectivity of EPN species *Steinernema carpocapsae* (Weiser), *S. riobravus* Cabanillas and Poinar and *S. feltiae* (Weiser) on spotted boll worm *Earias insulana* was established from American continent (Glazer, 1997). Exploring indigenous EPN in cotton fields of Tamil Nadu in India, Seenivasan et al. (2012) recovered 27 strains belonging to 16 *S. carpocapsae*, 3 *Steinernema siamkayai* Stock, Somsook and Reid, 1 *Steinernema monticolum* Stock, Choo and Kaya and 7 *Heterorhabditis bacteriophora* Poinar from cotton ecosystem. Later, Seenivasan and Sivakumar (2012) established that strains of APKS2 (*S. carpocapsae)* and KKMH1 (*H. bacteriophora)* showed the advantages such as more virulence against *E. vittella* (Seenivasan and Sivakumar, 2014; Seenivasan, 2020). Recently, these EPN mass production under in vitro solid culture was standardized (Seenivasan, 2017). However, the successful use of these EPN strains as potential biopesticide against cotton bollworms is possible only after standardization of suitable formulation. EPN are widely formulated using either solid or semiliquid substrates immediately after they multiplied in vitro culture techniques. Formulation of infective juveniles (IJs) of EPN is very essential to enhance the storage or shelf life and for easy transport and handling. In a better formulation, the mortality of IJs is little and IJs are more virulent until they have to reach the end user or field. Hence, the present study was

carried out with the following objectives; i) to study the survival of *H. bacteriophora* strain KKMH1 and *S. carpocapsae* strain APKS2 formulated in alginate gel, talc and sponge in comparison to the IJs in water at refrigerated condition (5°C) and incubator at 25°C and ii) to study the virulence of the different formulations of *S. carpocapsae* APKS2 and *H. bacteriophora* KKMH1 against *E. vitella.*

MATERIALS AND METHODS

Two EPN strains namely APKS2 (*S. carpocapsae*) and KKMH1 (*H. bacteriophora)*, were taken from the Department of Nematology, Tamil Nadu Agricultural University (TNAU), Coimbatore. They were multiplied by in vitro solid culture technique using on modified Wouts medium as per Seenivasan (2017). Freshly harvested IJs were used for making different formulations. The test insect larvae *E. vittella* was collected from a standing cotton crop at TNAU farm and from the farmer's fields at Thondamuthur village in Coimbatore district of Tamil Nadu, India. They were sorted out and the fourth instar larvae of uniform size were used in the laboratory experiments. The alginate gel formulation of the IJs of *S. carpocapse* (APKS2) and *H. bacteriophora* (KKMH1) were prepared after the method given by Navon et al. (2002). Wettable powder and polyether-polyurethane sponge formulations was prepared after Divya et al. (2011). Freshly harvested lJs concentrated to 50,000 IJs/ ml was considered as water formulation. Each four formulations of *S. carpocapse* (APKS2) and *H. bacteriophora* (KKMH1) were stored at 5 and at 25°C. At weekly intervals, each formulation at two different temperatures were taken and used for survival and virulence test. For survival test, 1 g from alginate or talc and 1 ml from sponge or water were randomly taken and diluted in 10 ml distilled water. Three 1 ml subsample from each 10 ml suspension was used to count survival rate of IJs. The live and dead IJs were examined and counted under a stereozoom microscope (Kozo Zoom 645). The IJs were considered dead if they did not move on probing with a fine needle.

For virulence test, 1 g from alginate or talc and 1 ml from sponge or water were randomly taken, diluted in 2 ml distilled water and used as inoculum at 2 ml/ test unit. The test was conducted in 6-cm-diam petri dishes lined with moist filter paper disc. Five 4th instar larvae of *E. vitella* were put in petri dishes lined with filter paper. Then 2 ml of EPN suspension were applied to the petri dishes. Control plates received only 2 ml distilled water. The dishes were sealed with para-film, arranged in a completely randomized design (CRD) and incubated at room temperature. Each formulation at each temperature consisted of five replicates (One Petri dish = one replicate). After 4 days, larval mortality was recorded. The dead insects were dissected in Ringer's solution to confirm the death by EPN. Insect mortality was corrected according to the control treatment values using Abbott's formula (Abbott, 1925). Percentage data were arc sine transformed before analysis. Survival and virulence differences at weekly intervals from 1- 12 weeks for each formulation and at each temperature were detected through analysis of variance (ANOVA) and differences between time intervals were compared using Tukey's HSD (honestly significant difference) test. The software used for analysis was SPSS 16.0 for Windows (SPSS Inc., Chicago, IL, USA). Differences among means in all experiments were considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

Alginate gel: In this formulation, *S. carpocapsae* (APKS2) and *H. bacteriophora* (KKMH1) survived longer up to 12 weeks with 70.2-76.1% survival at 5°C. At 25°C, APKS2 survived up to 62.0% until 12th week, but KKMH1 survived 38%. The results are similar to the findings of Grewal (2002) and Umamaheswari et al. (2006). EPN stored at low temperature (5°C) survived longer than at high temperature (25°C). Accumulation of more trehalose is attributed as a survival mechanism of IJs of EPN at low temperatures (Jagdale and Grewal, 2007). Infectivity was 100% up to 6-7 weeks when they stored at 5°C. The infectivity of both strains gradually decreased, but caused more than 50% mortality up to 12 weeks when they stored at 5°C. At 25°C, APKS2 has 52.5% infectivity when they stored for 12 weeks, but infectivity declined up to 25% for KKMH1. The reason for the less infectivity of KKMH1 at 12 weeks is attributed to its lowest survival rate (38%) recorded after 12 weeks (Table 1).

Talc formulation: In this, *S. carpocapsae* (APKS2) survived longer up to 10 weeks with 50% survival at 5°C, but at 25°C, 50% survival was found only for 8 weeks (Table 1). Hugar (2010) first tried the talc powder to formulate *H. indica.* This study showed that talc formulation retains survivability of *S. carpocapsae* and *H. bacteriophora* for >50% up to 2 months. Grewal (2000) reported that induced partial anhydrobiosis in *S. carpocapsae* by gradual desiccation. Hence, it is speculated that the wet talc formulations of the present EPN strains might have undergone partial anhydrobiosis during storage causing enhanced survival. Infectivity was 100% for APKS2 up to 5 weeks when they stored

Table 1. Survival and virulence of IJs of *S. carpocapsae* (APKS2) and *H. bacteriophora* (KKMH1)-formulated in alginate, talc, sponge and water

Period Weeks	Survival rate of IJs stored at 5°C (%)		Mortality of *Earias vitella* caused by IJs stored at 5°C (%)		Survival rate of IJs stored at 25°C (%)		Mortality of *Earias vitella* caused by IJs stored at 25°C (%)	
	APKS2	KKMH1	APKS2	KKMH1	APKS2	KKMH1	APKS2	KKMH1
I. Alginate gel								
1	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a
2	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a
3	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	95.3± 1.3 (81.1) b	92.7± 0.9 (77.8) b	100± 0.0 (94.2) a	100± 0.0 (94.2) a
4	92.5± 1.7 (77.6) b	90.3± 0.7 (75.2) b	100± 0.0 (94.2) a	100± 0.0 (94.2) a	95.0± 1.5 (80.7) b	90.0± 1.1 (74.9) b	100± 0.0 (94.2) a	100± 0.0 (94.2) a
5	92.0± 1.2 (77.0) b	90.0± 1.1 (74.9) b	100± 0.0 (94.2) a	100± 0.0 (94.2) a	90.0± 1.7 (74.9) cb	82.0± 1.7 (67.9) c	100± 0.0 (94.2) a	92.5± 0.8 (77.6) b
6	92.0± 1.9 (77.0) b	82.3± 2.4 (68.1) c	100± 0.0 (94.2) a	100± 0.0 (94.2) a	85.0± 2.2 (70.3) c	76.0± 2.3 (63.5) cd	97.5± 0.7 (84.7) b	90.0± 1.1 (74.9) b
7	90.3± 1.7 (75.2) b	80.7± 3.4 (66.9) e	100± 0.0 (94.2) a	92.5± 2.3 (77.6) b	82.0± 2.3 (67.9) c	75.0± 2.1 (62.8) d	92.5± 1.3 (77.6) c	87.5± 1.3 (72.5) cb
8	85.7± 2.4 (70.9) bc	80.3± 2.6 (66.6) c	92.5± 1.3 (77.6) b	90.0± 1.6 (74.9) b	80.0± 2.1 (66.4) c	70.0± 2.7 (59.4) d	87.5± 1.7 (72.5) cd	82.5± 1.6 (68.3) c
9	80.3± 2.7 (66.6) c	78.7± 2.3 (65.4) c	82.5± 2.1 (68.3) c	87.5± 2.7 (72.5) b	77.0± 3.7 (64.2) dc	62.0± 3.3 (54.3) e	75.0± 2.3 (62.8) e	70.0± 2.7 (59.4) d
10	80.0± 2.1 (66.4) c	77.3± 3.7 (64.4) c	70.5± 2.4 (59.7) d	75.0± 2.5 (62.8) c	70.0± 3.1 (59.4) de	52.0± 3.1 (48.3) f	62.5± 2.7 (54.7) f	42.5± 3.5 (42.6) e
11	77.3± 2.6 (64.3) c	74.3± 3.1 (62.3) cd	65.0± 3.8 (56.2) de	67.5± 3.1 (57.8) c	65.0± 3.3 (56.2) e	46.0± 3.3 (44.7) f	60.0± 3.8 (53.1) f	40.0± 3.2 (41.0) e
12	76.1± 3.2 (63.5) c	70.2± 2.6 (59.6) d	62.5± 3.2 (54.7) e	55.0± 3.4 (50.1) d	62.0± 3.9 (54.3) e	38.0± 3.9 (39.8) gf	52.5± 3.4 (48.6) gf	25.0± 3.7 (31.4) f
II. Talc powder								
1	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a
2	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a
3	100± 0.0 (94.2) a	95.0± 0.6 (80.7) b	100± 0.0 (94.2) a	100± 0.0 (94.2) a	97.0± 0.3 (83.8) b	96.0± 0.5 (82.1) b	100± 0.0 (94.2) a	100± 0.0 (94.2) a
4	95.0± 0.7 (80.7) b	95.0± 0.3 (80.7) b	100± 0.0 (94.2) a	100± 0.0 (94.2) a	95.0± 0.5 (80.7) b	95.0± 0.3 (80.7) b	100± 0.0 (94.2) a	100± 0.0 (94.2) a
5	90.0± 0.9 (74.9) c	85.0± 0.9 (70.3) c	100± 0.0 (94.2) a	97.5± 0.3 (84.7) b	87.0± 1.5 (72.1) c	82.0± 0.7 (67.9) c	95.0± 0.3 (80.7) b	92.5± 0.7 (77.6) b
6	85.0± 1.1 (70.3) cd	75.0± 1.6 (62.8) d	95.0± 0.6 (80.7) b	90.0± 0.5 (74.9) c	70.0± 1.7 (59.4) d	70.0± 2.3 (59.4) d	85.0± 0.8 (70.3) c	82.5± 0.9 (68.3) c
7	70.0± 2.3 (59.4) e	62.0± 1.7 (54.3) e	82.5± 0.9 (68.3) c	77.5± 1.3 (64.5) d	60.0± 2.9 (53.1) e	55.0± 3.1 (50.1) e	70.0± 1.7 (59.4) d	67.5± 2.4 (57.8) d
8	60.0± 2.7 (53.1) f	55.0± 2.1 (50.1) e	75.0± 1.1 (62.8) d	70.0± 1.1 (59.4) d	55.0± 2.7 (50.1) e	45.0± 1.7 (44.1) f	62.5± 3.4 (54.7) d	52.5± 3.3 (48.6) e
9	55.0± 2.5 (50.1) ef	40.0± 2.3 (41.0) f	67.5± 1.3 (57.8) e	57.5± 1.3 (51.6) e	45.0± 3.2 (44.1) f	30.0± 1.3 (34.7) g	57.5± 2.1 (51.6) ed	40.0± 1.5 (41.0) f
10	50.0± 3.4 (47.1) f	40.0± 2.1 (41.0) f	60.0± 2.6 (53.1) fe	50.0± 2.3 (47.1) fe	35.0± 1.7 (37.9) g	10.0± 0.7 (19.3) h	50.0± 1.6 (47.1) e	15.0± 0.7 (23.8) g
11	45.0± 3.1 (44.1) fg	30.0± 3.2 (34.7) g	52.5± 1.4 (48.6) g	42.5± 3.5 (42.6) g	20.0± 2.1 (27.8) h	0.0± 0.0 (0) i	22.5± 0.7 (29.6) f	0.0± 0.0 (0) h
12	40.0± 3.3 (41.0) g	25.0± 2.7 (31.4) g	50.0± 1.7 (47.1) g	35.0± 2.7 (37.9) hg	10.0± 1.6 (19.3) i	0.0± 0.0 (0) i	5.0± 0.3 (13.5) g	0.0± 0.0 (0) h

(contd...)

(contd. Table 1)

III. Polyurethane sponge								
1	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100 ± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a
2	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a
3	100± 0.0 (94.2) a	97.0± 0.0 (83.8) b	100± 0.0 (94.2) a	100± 0.0 (94.2) a	97.0± 0.3 (83.8) b	92.0± 0.5 (77.0) b	100± 0.0 (94.2) a	100± 0.0 (94.2) a
4	95.7± 0.4 (81.7) b	90.0± 0.7 (74.9) c	100± 0.0 (94.2) a	100± 0.0 (94.2) a	90.0± 0.7 (74.9) c	84.0± 1.3 (69.5) c	100± 0.0 (94.2) a	95.0± 0.7 (80.7) b
5	85.0± 0.9 (70.3) c	80.0± 1.1 (66.4) d	92.5± 0.8 (77.6) b	90.0± 0.6 (74.9) b	82.0± 1.1 (67.9) d	82.0± 1.5 (67.9) c	90.0± 1.1 (74.9) b	90.0± 0.9 (74.9) c
6	80.0± 1.3 (66.4) dc	65.0± 1.7 (56.2) e	90.0± 0.7 (74.9) b	77.5± 1.3 (64.5) c	70.0± 2.3 (59.4) e	65.0± 3.0 (56.2) d	80.0± 1.4 (66.4) c	77.5± 1.3 (64.5) d
7	60.0± 3.2 (53.1) e	55.0± 3.0 (50.1) fe	72.0± 1.4 (60.7) c	67.5± 2.1 (57.8) d	55.0± 1.9 (50.1) f	50.0± 1.6 (47.1) e	67.5± 2.7 (57.8) d	62.5± 2.1 (54.7) e
8	50.0± 2.7 (47.1) f	50.0± 2.1 (47.1) f	60.0± 2.5 (53.1) d	55.0± 1.7 (50.1) e	40.0± 3.0 (41.0) g	40.0± 0.8 (41.0) f	55.0± 3.2 (50.1) e	50.0± 2.5 (47.1) f
9	45.0± 1.3 (44.1) f	30.0± 1.1 (34.7) g	50.0± 3.1 (47.1) e	40.0± 1.1 (41.0) f	32.0± 1.1 (36.0) hg	45.0± 1.7 (44.1) ef	45.0± 1.6 (44.1) f	20.0± 0.8 (27.8) g
10	30.0± 0.7 (34.7) g	10.0± 0.7 (19.3) h	40.0± 2.3 (41.0) f	0.0± 0.0 (0) g	12.0± 0.7 (21.2) i	0.0± 0.0 (0) g	5.0± 0.3 (13.5) g	0.0± 0.0 (0) h
11	20.0± 0.7 (27.8) h	0.0± 0.0 (0) i	25.0± 1.1 (31.4) g	0.0± 0.0 (0) g	0.0± 0.0 (0) j	0.0± 0.0 (0) g	0.0± 0.0 (0) h	0.0± 0.0 (0) h
12	10.0± 0.5 (19.3) i	0.0± 0.0 (0) i	0.0± 0.0 (0) h	0.0± 0.0 (0) g	0.0± 0.0 (0) j	0.0± 0.0 (0) g	0.0± 0.0 (0) h	0.0± 0.0 (0) h
IV. Water								
1	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a
2	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	100± 0.0 (94.2) a	96.0± 0.3 (82.1) b	100± 0.0 (94.2) a	100± 0.0 (94.2) a
3	92.0± 0.7 (77.0) b	85.0± 0.9 (70.3) b	100± 0.0 (94.2) a	100± 0.0 (94.2) a	90.0± 0.6 (74.9) b	80.0± 1.1 (66.4) c	100± 0.0 (94.2) a	92.5± 0.5 (77.6) b
4	90.0± 1.1 (74.9) b	70.0± 1.6 (59.4) c	100± 0.0 (94.2) a	85.0± 0.8 (70.3) b	80.0± 1.2 (66.4) c	72.0± 1.8 (60.7) d	90.0± 0.7 (74.9) b	80.0± 1.4 (66.4) c
5	80.0± 1.7 (66.4) c	65.0± 2.4 (56.2) c	90.0± 0.7 (74.9) b	77.5± 1.3 (64.5) c	62.0± 1.8 (54.3) d	60.0± 2.4 (53.1) e	77.5± 1.6 (64.5) c	70.0± 2.1 (59.4) d
6	65.0± 3.1 (56.2) d	50.0± 2.1 (47.1) d	70.0± 1.5 (59.4) c	60.0± 2.9 (53.1) d	45.0± 2.7 (44.1) e	45.0± 2.6 (44.1) f	65.0± 2.3 (56.2) d	65.0± 2.9 (56.2) d
7	55.0± 2.5 (50.1) e	43.0± 2.7 (42.9) e	65.0± 3.2 (56.2) c	55.0± 1.8 (50.1) d	32.0± 1.3 (36.0) f	25.0± 1.3 (31.4) g	50.0± 3.0 (47.1) e	50.0± 2.3 (47.1) e
8	50.0± 2.1 (47.1) fe	25.0± .0.9 (31.4) f	60.0± 2.6 (53.1) dc	37.5± 1.1 (39.5) e	30.0± 0.9 (34.7) f	10.0± 0.5 (19.3) h	45.0± 2.1 (44.1) ef	40.0± 1.4 (41.0) f
9	45.0± 2.4 (44.1) f	12.0± 0.5 (21.2) g	50.0± 2.1 (47.1) e	0.0± 0.0 (0) f	12.0± 0.5 (21.2) g	0.0± 0.0 (0) i	40.0± 1.7 (41.0) f	0.0± 0.0 (0) g
10	36.0± 1.3 (38.6) g	0.0± 0.0 (0) h	0.0± 0.0 (0) f	0.0± 0.0 (0) f	0.0± 0.0 (0) h	0.0± 0.0 (0) i	0.0± 0.0 (0) g	0.0± 0.0 (0) g
11	25.0± 1.5 (31.4) h	0.0± 0.0 (0) h	0.0± 0.0 (0) f	0.0± 0.0 (0) f	0.0± 0.0 (0) h	0.0± 0.0 (0) i	0.0± 0.0 (0) g	0.0± 0.0 (0) g
12	± 0.0 (0) i	± 0.0 (0) h	0.0± 0.0 (0) f	0.0± 0.0 (0) f	0.0± 0.0 (0) h	0.0± 0.0 (0) i	0.0± 0.0 (0) g	0.0± 0.0 (0) g

Means (± SD) followed by same letter in columns not significantly different at p<0.05 (Tukey's HSD test). Figures in parentheses arc sine transformed values.

at 5°C where as 4 weeks for KKMH1 (Table 1). The virulence of talc formulated *Steinernema seemae* against *Helicoverpa armigera* (up to 62% mortality) by Ali and Asif (2011) corroborate the present observations. In general, the survival and virulence were relatively lower in talc when compared to gel formulation.

Sponge formulation: In this formulation, both EPNs survived up to 8 weeks with 50-55% survival at 5°C, but at 25°C >50% survival found only up to 7 weeks. In sponge formulation EPN survival gradually decreased with increase of storage time and this effect was drastic at 25°C storage. The low survival at high

temperature may be due to rapid loss of water from sponge formulations. Infectivity was 100% up to 4 weeks when they stored at 5°C. At 25°C, these revealed 50-55% infectivity when stored for 8 weeks (Table 1). These results are in line with Hugar (2010) who observed 80% mortality of *H. armigera* with sponge formulated 60 days old *H. indica* stored at 10°C, but 36% mortality when stored at 28°C.

Water: In water, test EPNs survived 50% for 8 weeks at 5°C, but at 25°C, 62% survival found only for 5 weeks. The 100% survival was observed up to 2 weeks at both 5 and 25°C (Table 1). The results showed that the tested strains could be stored in plain water for short-term. Divya et al. (2011) also recorded observations close to the present ones such as 70% survival of *H. indica* up to 5 weeks. Infectivity was 100% for APKS2 up to 4 weeks when they stored at 5°C whereas 3 weeks when it was stored at 25 °C. APKS2 and KKMH1 showed 50% infectivity when stored for 7 weeks (Table 1). It indicates that virulence of the EPNs maintained better, though their survival rate decreases drastically. In addition, at low temperature (5°C) virulence was prolonged for long period up to 1 month with 100% virulence. The reason for this might be due to the reduced activity of IJs and more conservation of energy reserve at low temperature than at high temperature (Grewal, 2000). It is concluded that *S. carpocapsae* (APKS2) and *H. bacteriophora* (KKMH1) should be formulated either alginate gel or talc powder for long term storage up to 3 months. For usage in 1-2 months these can be formulated in sponges and stored at 5°C. The *S. carpocapsae* (APKS2) and *H. bacteriophora* (KKMH1) need not be formulated in any special media and can be kept as water concentrate for immediate use within 14-21 days.

ACKNOWLEDGEMENTS

The author thanks the Life Science Research Board, Defense Research and Development Organization, New Delhi for the financial support through a grant (No. DLS/81/48222/LSRB-136/FSB/2007).

REFERENCES

Abbott W S. 1925. A method of computing the effectiveness of an insecticide. Journal of Economic Entomology 18: 265-267.

Ali S S, Asif M. 2011. Comparative field efficacy of dust formulation and liquid formulation of *Steinernema seemae* based biopesticide and other IPM options against *Helicoverpa armigera* (Hubner) Infesting Chickpea. Trends in Biosciences 4(1): 35-37.

Dhaliwal G S, Jindal V, Dhawan A K. 2010. Insect pest problems and crop losses: changing trends. Indian Journal of Ecology 37: 1-7.

Divya K, Sankar M, Marulasiddesha K N, Sambashiv R, Krupanidhi K. 2011. Formulation technology of entomopathogenic nematode for the control of the cotton boll worm, *Helicoverpa armigera*. Bioscience Discovery 2(2): 174-180.

Glazer I. 1997. Effects of infected insects on secondary invasion of steinernematid entomopathogenic nematodes. Parasitology 114: 597-604.

Grewal P S. 2000. Enhanced ambient storage stability of an entomopathogenic nematode through anhydrobiosis. Pest Management Science 56(5): 401-406.

Grewal P S. 2002. Formulation and Application Technology. In: Entomopathogenic nematology (ed.) R. Gaugler, CAB International, Wallingford, UK, pp. 266-287.

Hugar P S. 2010. Evaluation of EPN formulations, their shelf life and efficacy of *Heterorhabditis indica* (Heterorhabditidae: Nematoda) against economically important pests. Doctoral dissertation, UAS, Dharwad. p. 142.

Jagdale G B, Grewal P S. 2007. Storage temperature influences desiccation and ultra violet radiation tolerance of entomopathogenic nematodes. Journal of Thermal Biology 32(1): 20-27.

Navon A, Nagalakshmi V K, Shlomit L, Salame L. Glazer I. 2002. Effectiveness of entomopathogenic nematodes in an alginate gel formulation against lepidopterous pests. Biocontrol Science and Technology 12(6): 737-746.

Seenivasan N. 2017. Evaluation of different media for mass production of native strains of *Heterorhabditis bacteriophora* and *Steinernema carpocapsae* by *in vitro* solid culture. International Journal of Research Studies in Zoology 3(2): 45-50.

Seenivasan N. 2020. Virulence of native entomopathogenic nematodes to manage cotton insect pests *Helicoverpa armigera*, *Earias vittella* and *Spodoptera litura*. Journal of Cotton Research and Development 34(1): 84-91.

Seenivasan N, Sivakumar M. 2012. Bio-prospecting of naturally occurring entomopathogenic nematodes (Rhabditida: Steinernematidae and Heterorhabditidae) isolated from cotton fields at Tamil Nadu, India. Proceedings. 2nd International Symposium of Bio-Pesticides and Eco-toxicological Network (2nd IS-BioPEN): 24-26 September 2012, Bangkok, Thailand. p. 57.

Seenivasan N, Sivakumar M. 2014. Screening for environmental stress-tolerant entomopathogenic nematodes virulent against cotton bollworms. Phytoparasitica 42: 165-177.

Seenivasan N, Prabhu S, Makesh S, Sivakumar M. 2012. Natural occurrence of entomopathogenic nematode species (Rhabditida: Steinernematidae and Heterorhabditidae) in cotton fields of Tamil Nadu, India. Journal of Natural History 46: 2829-2843.

Umamaheswari R, Sivakumar M, Subramanian S. 2006. Survival and infectivity of entomopathogenic nematodes in alginate gel formulations against rice meal moth larva, *Corcyra cephalonica* Stainton. Natural Product Radiance 5: 95-98.

(Manuscript Received: November, 2020; Revised: March, 2021;
Accepted: March, 2021; Online Published: July, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20424

Indian Journal of Entomology 84(1): 34-37 (2022) DoI.: 10.55446/IJE.2021.336

BEHAVIOURAL RESPONSE OF PARASITOID *ENCARSIA GUADELOUPAE* VIGGIANI TO INFESTED HOST PLANTS OF RUGOSE SPIRALING WHITEFLY *ALEURODICUS RUGIOPERCULATUS* MARTIN

M Saranya and J S Kennedy

Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India
*Email: jskennedy@tnau.ac.in (corresponding author)

ABSTRACT

The rugose spiralling whitefly (RSW) *Aleurodicus rugioperculatus* Martin is an invasive pest of coconut in India. The behavioural response of its parasitoid *Encarsia guadeloupae* Viggiani (Hymenoptera: Aphelinidae) on healthy and RSW infested host plants of coconut, banana, sapota and guava has been assessed in this study using a six arm olfactometer. Parasitoids' attraction was maximum with the infested banana leaves (1.62± 0.28) followed by coconut (1.28± 0.20), guava (1.05± 0.24) and sapota (0.82± 0.24). The results obtained also reveal that *E. guadeloupae* can be mass reared on banana plants infested with RSW nymphs to enable better mass production of the parasitoid.

Key words: *Aleurodicus rugioperculatus*, *Encarsia guadeloupae*, behavioural response, infested, healthy leaves, coconut, banana, sapota, guava, host: parasitoid ratios, parasitisation potential

India is the third largest producer of coconut in the world with productivity of 9,815 nuts (www. india stat. com, 2020), and insect pests are the major constraint in its production. Sundararaj et al. (2020) inventoried 454 species of whiteflies under 66 genera from India, comprising five species under two genera in the subfamily Aleurodicinae Quaintance and Baker and 449 species under 64 genera in the subfamily Aleyrodinae Westwood. Six species namely, *Aleurocanthus arecae* David and Manjunatha (India), *Aleurodicus dispersus* Russell (Central America), *A. rugioperculatus* Martin (Central America), *Aleurotrachelus atratus* Hempel (Brazil), *Paraleyrodes bondari* Peracchi (Central America), and *P. minei* Iaccarino (Syria) are known to have invaded coconut gardens in India. (Selvaraj et al. 2019; Alfred Daniel et al., 2020). In India, rugose spiraling whitefly (RSW) *A. rugioperculatus* was first documented in the coconut farms of Pollachi, Tamil Nadu and Palakkad, Kerala during July-August 2016. Infestation of RSW was recorded in coconut (40-60 %) and banana leaves (25-40 %) (Selvaraj et al., 2017). During heavy infestation, 60-70 % of the fronds were infested with RSW the resulting honey dew leads to sooty mould and affect the photosynthetic activity. There was no economic crop loss (Chandrika Mohan et al., 2017) but indirectly affects the photosynthetic efficiency and nut quality in coconut (Sundararaj and Selvaraj, 2017).

Excessive application of synthetic pyrethroids causes resurgence-induced feeding damage of RSW, also insecticides use was difficult due to its high dispersal ability and polyphagous nature in addition to health hazards. Hence, biocontrol agents in particular *Encarsia guadeloupae* Viggiani can be extensively used against RSW in coconut (Chandrika Mohan et al., 2017). In India, the maximum parasitisation of *E. guadeloupae* had been observed on RSW to be as high as 60-70% (Ramani et al., 2002). However, detailed study on its behavioural response and parasitization efficiency when reared on different host plants is meagre. The present study analyses the behavioural response of *E. guadeloupae* on healthy and RSW infested host plants so as to identify the preferred alternate host of RSW for its mass culture.

MATERIALS AND METHODS

The host plants selected were coconut (Chowghat Orange Dwarf), banana (Ney Poovan), sapota (CO-2) and guava (L-49) chosen based on the severe infestation reported by Selvaraj et al. (2017). RSW-infested coconut leaflets were collected from the Tamil Nadu Agricultural University (TNAU) orchard, Coimbatore, Tamil Nadu (11.0123°N,76.9355°E), and released on to mud potted (41 cm dia) plants of coconut (2 years old), banana (6 months old), sapota (6 months old), and guava (6

months old). These were maintained in a separate mini nethouse (270x 150x 210 cm with a nylon net mesh sized of 120 micron). RSW culture was maintained in the Insectary, Department of Agricultural Entomology at 31± 2°C, 60-75% RH under a natural light condition. Stock culture of the parasitoid *E. guadeloupae* was established by collecting the adults using an aspirator from banana in the TNAU orchard. Banana plants were infested with RSW adults for oviposition and allowed to maintain until the development of desired nymphal stage (second). Then, *E. guadeloupae* (1 day old) adults were released onto these for 24-48 hr for oviposition. From these the parasitized pupae were covered with clip cage (5 cm dia x 3 cm height) in banana plant. Parasitoids collected from these clip cages using aspirator were released on successive RSW nymphal generations for further *Encarsia* development. Mass maintenance of *E. guadeloupae* was done in mini nethouse (270x 150x 210 cm with a nylon net mesh sized of 120 micron), Insectary, Department of Agricultural Entomology at 31± 2°C, 60-75% RH under natural light.

Encarsia guadeloupae adults were subjected to behavioural bioassay to study the influence of host plant and RSW volatiles using six-arm olfactometer. Behavioural response was studied for the healthy plants followed by RSW infested leaves of coconut, banana, sapota and guava plants. About 10 g of host leaves of these host plants were kept in the arm and was firmly closed with a lid. Out of six arms, two arms were treated as control. The inlet of the olfactometer on the top center place was connected to an aquarium pump (220-240v AC) to release the pressure. After five minutes of saturation of different host odours in the olfactometer, ten numbers of one-day-old parasitoids were released in the olfactometer through a central opening, which also served as an odour exit hole. Observations were made on the number of parasitoids settled in each arm at 10, 20, 30, 40, 50 and 60 MAR (minutes after release). The experiment was replicated ten times. Data obtained were subjected to ANOVA, and means compared using general linear model (GLM) with Tukey's HSD test. All the data analyses were performed by using IBM SPSS Statistics 22.

RESULTS AND DISCUSSION

Significant difference were observed in the attraction of parasitoids between the healthy and RSW infested host plants over control in terms of number attracted; no attraction was observed with healthy leaves and control up to ten minutes after release (10 MAR); at 20 MAR, same number of parasitoids (0.10± 0.10) were attracted to healthy leaves of coconut, banana and sapota and no attraction in guava and control. Increasing trend of parasitoid attraction to healthy leaves was observed at 20, 30 and 40 MAR and decreasing trend was observed at 50 and 60 MAR. Number of parasitoids attracted was maximum with healthy leaves of banana (0.16± 0.04) followed by coconut (0.11± 0.03), guava (0.06± 0.02) and sapota (0.06± 0.02). Six arm olfactometer results showed significant differences in the orientation of *E.guadeloupae* towards RSW infested host plants; significantly more number of parasitoids were attracted to banana (1.62± 0.28) leaves followed by coconut (1.28± 0.20); and it was less with sapota (0.82± 0.24); host preference was in the order of banana > coconut > guava > sapota > control (Table 1).

Encarsia guadeloupae preferred to move with RSW nymphal stage on banana leaves. Successful parasitism eventually depends on the host selection process involving a sequence of phases mediated by physical and chemical stimuli from the host insect and host plants. Plants release blends of volatile organic compounds (VOCs) in response to herbivore damage. Parasitoids use these herbivore-induced plant volatiles as indirect cues to locate their herbivore hosts (Zhang et al., 2004; Nisha and Kennedy, 2015). Parasitization efficiency is highly influenced by the physical and chemical structures of the host plant (Lopez Avila, 1988; Shishehbor and Brennan, 1995; Vet et al. 1980). Such physical structures include waxy covering, dense and rigid hairs, fibrous lamina, pubescent, trichomes and leaf surface area (Rajam et al., 1988; Gruenhagen and Perring, 2001; Oster, 1995). Parasitoids get trapped in trichome exudates of velvetleaf *Aboutilon theofrasti* which cause poor parasitism on whitefly *Bemisia tabaci* (Gruenhagen and Perring, 2001b; Kishinevsky et al., 2017).

Thus, the behavioural response of *E. guadeloupae* involves more attraction to the RSW infesting banana followed by coconut. This is in accordance with the fact that various female parasitoids efficiently utilize the plant odours induced by its herbivore to locate host plants that may carry their hosts (Vet and Dicke, 1992; Turlings and Benrey, 1998; Turlings and Wäckers, 2004; Tamo et al. 2006). The present results suggest that *E. guadeloupae* can be mass-reared on banana plants infested with RSW nymphs more efficiently for mass rearing in biological control.

Table 1. Behavioural response of *E. guadeloupae* on healthy and RSW infested host plants

Host plants	No. of parasitoids attracted (M ± SE)																	
	10 MAR		20 MAR		30 MAR		40 MAR		50MAR		60 MAR		Mean	
	H	I	H	I	H	I	H	I	H	I	H	I	H	I
Coconut	0.00 ± 0.00	0.50 ± 0.20	0.1 ± 0.10	1.20 ± 0.20	0.10 ± 0.10	1.50 ± 0.30	0.3 ± 0.10	2.00 ± 0.40	0.1 ± 0.10	1.40 ± 0.20	0.10 ± 0.00	1.10 ± 0.20	0.11 ± 0.03^{a}	1.28 ± 0.20^{cd}
Banana	0.00 ± 0.00	0.70±0.20	0.10 ±0.10	1.50 ± 0.30	0.20 ± 0.10	1.90 ± 0.40	0.40 ± 0.20	2.70 ± 0.40	0.20 ± 0.10	1.80 ± 0.30	0.10 ± 0.10	1.10 ± 0.20	0.16 ± 0.04^{a}	1.62 ± 0.28^{d}
Sapota	0.00 ± 0.00	0.20 ± 0.10	0.10 ±0.10	0.50 ± 0.20	0.10 ± 0.10	0.90 ± 0.40	0.10 ± 0.00	1.80 ± 0.50	0.10 ± 0.10	1.10 ± 0.20	0.00 ± 0.00	0.40 ± 0.20	0.06 ± 0.02^{a}	0.82 ± 0.24^{b}
Guava	0.00 ± 0.00	0.40 ± 0.20	0.00 ±0.00	0.70 ± 0.30	0.10 ± 0.10	1.10 ± 0.50	0.20 ± 0.10	2.00 ± 0.50	0.10 ± 0.10	1.40 ± 0.30	0.10 ± 0.00	0.70 ± 0.20	0.06 ± 0.02^{a}	1.05 ± 0.24^{bc}
Control	0.00 ± 0.00	0.00 ± 0.00	0.00 ±0.00	0.10 ± 0.10	0.00 ± 0.00	0.10 ± 0.10	0.00 ± 0.00	0.30 ± 0.20	0.00 ± 0.00	0.20 ± 0.10	0.00 ± 0.00	0.10 ± 0.10	0.00 ± 0.00^{b}	0.13 ± 0.04^{a}

MAR- Minutes After Release, H- Healthy; I- RSW infested leaves. Values with same lower case letters do not differ significantly according to Tukey HSD Test (F value =5.229 for healthy, and 37.036 for RSW infested; p <0.001 level of significance); Values in each column mean± SE.

ACKNOWLEDGEMENTS

This study was supported by Department of Science and Technology, Government of India- New Delhi, under grant GOI- DST (SERB) /EMR/2016/005815.

REFERENCES

Alfred Daniel J, Ashok K, Pavithran S, Ranjith M. 2020. A review on invasive insect pests in india and their predators and parasitoids. Journal of Experimental Zoology India 23(2): 987-1006.

Chandrika Mohan, Josephrajkumar A, Merin Babu, Prathibha P S, Krishnakumar V, Hegde V, Chowdappa P. 2017. Invasive rugose spiralling whitefly in coconut, Technical Bulletin No. 117 (Centenary Series 60), ICAR-CPCRI, Regional Station, Kayamkulam. 16 pp.

Gruenhagen N M, Perring T M. 2001. Impact of leaf trichomes on parasitoid behavior and parasitism of silverleaf whiteflies (Homptera: Aleyrodidae). Southwestern Entomologist 26(4): 279-90.

Kishinevsky M, Keasar T, Bar-Massada A. 2017. Parasitoid abundance on plants: effects of host abundance, plant species, and plant flowering state. Arthropod-Plant Interactions 11(2): 155-61.

Lopez Avila, A. 1988. A comparative study of four species of *Encarsia* (Hymenoptera: Aphelinidae) as potential control agents for *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae). Doctoral dissertation, Imperial College London (University of London).

Nisha R, Kennedy J S. 2015. Behaviour and evolutionary response of parasitoid *Acerophagus papayae* Noyes and Schauff using different olfactometers. International Journal of Scientific and Research Publications 329.

Oster N. 1995. Factors influencing the parasitization efficiency of the parasitic wasp *Encarsia transvena*. M Sc Thesis, Tel Aviv University. 76 pp.

Rajam B, Peter C, David BV. 1988. Influence of host plants on the parasitism of *Bemisia tabaci gennadius* (Homoptera: Alyrodidae) by *Encarsia* sp. Current Science. 57(22):1246-7.

Ramani S, Poorani J, Bhumannavar B S. 2002. Spiralling whitefly, *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae) in India. Biocontrol News and Information 23(2): 55-62.

Selvaraj K, Gupta A, Venkatesan T, Jalali S K, Ballal C R, Sundararaj R. 2017. First record of invasive rugose spiraling whitefly *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae) along with parasitoids in Karnataka. Journal of Biological Control 31(2): 74-78

Selvaraj K, Sundararaj R, Sumalatha B V. 2019. Invasion of the palm infesting whitefly, *Aleurotrachelus atratus* Hempel (Hemiptera: Aleyrodidae) in the Oriental region. Phytoparasitica 47(3): 327-332

Shishehbor P, Brennan, P A. 1995. Parasitism of *Trialeurodes ricini* by *Encarsia formosa*: Level of parasitism, development time and mortality on different host plants. Entomophaga 40(3-4): 299-305

Sundararaj R, Selvaraj K, Vimala D, Venkatesan T. 2020. Whiteflies (Hemiptera: Aleyrodidae) of India. Indian insects: Diversity and science. S Ramani, P Mohanraj, H M Yeshwanth (eds.) CRC Press, Tayler & Francis, UK. pp. 103-120.

Sundararaj R, Selvaraj K. 2017. Invasion of rugose spiraling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae): a potential threat to coconut in India. Phytoparasitica 45(1): 71-74.

Tamò C, Ricard I, Held M, Davison A C, Turlings T C J. 2006. A comparison of naive and conditioned responses of three generalist endoparasitoids of lepidopteran larvae to host-induced plant odours. Animal Biology 56: 205-220.

Turlings T C J, Benrey B. 1998. The effects of plant metabolites on the behavior and development of parasitic wasps. Écoscience 5: 321-333.

Turlings T C J, Wäckers F. 2004. Recruitment of predators and parasitoids by herbivore-injured plants. Advances in insect chemical ecology. R Carde, J G.Millar (eds.). Cambridge University Press, Cambridge. pp. 21-75.

Vet L E M, Dicke M. 1992. Ecology of infochemical use by natural enemies in a tritrophic context. Annual Review of Entomology 37: 141-172.

Vet L E M., Van Lenteren, J C, Woets J. 1980. The parasite-host relationship between *Encarsia formosa* (Hymenoptera: Aphelinidae) and *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae) IX. A review of the biological control of the greenhouse whitefly with suggestions for future research. Zeitschrift für Angewandte Entomologie 90(1-5): 26-51.

Zhang F, Toepfer S, Riley K, Kuhlmann U. 2004. Reproductive biology of *Celatoria compressa* (Diptera: Tachinidae), a parasitoid of *Diabrotica virgifera* (Coleoptera: Chrysomelidae). Biocontrol Science and Technology 14: 5-16.

(Manuscript Received: February, 2021; Revised: April, 2021;
Accepted: April, 2021; Online Published: July, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21037

Indian Journal of Entomology 84(1): 38-43 (2022) DoI.: 10.55446/IJE.2021.339

A COMPARATIVE STUDY ON NEST ARCHITECTURE AND LIFECYCLE OF TWO SMALL CARPENTER BEES *CERATINA SMARAGDULA* (F.) AND *CERATINA HIEROGLYPHICA* SMITH

Anusree Padmanabhan P S* and Mani Chellappan

Department of Agricultural Entomology; College of Agriculture, Vellanikkara,
Kerala Agricultural University (KAU), Thrissur 680656, Kerala, India
*Email: numy2993@gmail.com (corresponding author)

ABSTRACT

Small carpenter bees *Ceratina smaragdula* (F.) and *C. hieroglyphica* Smith (Xylocopinae: Apidae) are the major pollinators of many agricultural and horticultural crops. Nesting sites of these native bee pollinators were located at dried twigs of peacock flower tree *Caesalpinia pulcherrima*, and a total of 199 nests were collected from 2019-2021. Both species constructed linear nests at soft pithy region of stems with a maximum of 12 cm depth and individual cells ranged 6 to 10 mm in length which were separated with partitions of 2 to 4 mm. There were no significant differences in height of the nests constructed from ground level. The younger cells were near to the entrance, whereas the mature cells were arranged towards the innermost side. The nests of bees consisted of egg, larva, pupa and adult stages; and *C. smaragdula* took 15.51± 0.19 days while *C. hieroglyphica* took 15.93± 0.27 days for completion of larval period. Total pupal period of *C. smaragdula* ranged from 20.71± 0.26 days whereas *C. hieroglyphica* ranged from 18.56± 0.16 days. Total lifecycle for *C. smaragdula* and *C. hieroglyphica* took 49.15± 0.40 and 43.19± 0.58 days under laboratory conditions.

Key words: *Ceratina smaragdula*, *C. hieroglyphica*, *Caesalpinia pulcherrima,* bee pollinator, nest architecture, lifecycle, adult longevity, artificial nesting sites, active and full brood nest, polylectic bees, bee pollen

Bees (Hymenoptera: Apidae) are considered as the quintessential pollinators of terrestrial ecosystems (Ollerton et al., 2011). These provide key ecosystem services through pollinating wild flowers as well as numerous agricultural crops (Yogi and Khan, 2014). Except bees of genus *Apis*, all bees are known as non-*Apis* bees, wild bees or pollen bees (Aslam et al., 2017). Many species of bumble bees (*Bombus* spp.) and solitary bees (*Amegilla, Andrena, Ceratina, Halictus, Lasioglossum, Megachile, Nomia, Osmia* and *Xylocopa*) can be reared on large scale and managed for crop pollination (Abrol, 2012). Among these, the small carpenter bees (*Ceratina* Latreille) are widely distributed throughout the tropical and subtropical regions of the world (Michener, 1962).

The *Ceratina* bees are polylectic which are reported to be an excellent pollinator of wide range of crops viz., niger, safflower, linseed, mustard (Navatha and Sreedevi, 2015), alfalfa, winged bean, tomato, red gram, sunflower, raspberry, cranberry, apple (Mattu and Kumar, 2016), ridge gourd, brinjal, rape seed, carrot, marigold, safflower and yellow cosmos (Batra, 1967). *Ceratina binghami* construct their nests in dried tiny twigs and pruned pithy stems by making linear burrows in peacock flower tree *Caesalpinia pulcherrima* (L.) (Fabaceae) plants (Udayakumar and Shivalingaswamy, 2019); and *C. hieroglyphica* was found constructing their nests in pithy region of dried twigs of cashew tree *Anacardium occidentale* (L.) (Anacardiaceae) (Kaliaperumal, 2019). The females of *Ceratina* chew the central pith of selected twig and flies out to forage pollen and nectar. They mould the collected pollen into pollen masses to oviposit on them and close the cell by septum (Mclntosh, 1996). Mothers inspect the brood cells constructed by them and mostly found in the gallery between the entrance and the first brood cell often in a defensive position blocking the nest entrance to protect the broods from natural enemies (Rehan and Richards, 2010).

Bees are threatened due to destruction and fragmentation of their nesting habitats. One of the primary threats is the spread of urban settings as well as increased mechanization, all of which diminish nesting habitats such as the walls of mud houses, dried plant twigs and debris which are used by stem and cavity nesting bees (Shebl et al., 2018). Nesting biology and lifecycle of bees provides information about nesting sites and ecological requirements of bees that will help

to design the artificial nests for managed pollination of crops and appropriate tools to protect and maintain plant diversity and thereby improving agricultural productivity. A comparative study was undertaken to study the nesting biology and lifecycle of two small carpenter bees, *C. smaragdula* and *C. hieroglyphica* on *Caesalpinia pulcherrima* of which the results are explained herein.

MATERIALS AND METHODS

The study on nesting behavior and lifecycle of *C. smaragdula* and *C. hieroglyphica* was carried out in the University Campus of College of Agriculture, Vellanikkara as well as in the areas under Kerala Agricultural University (KAU), Thrissur, Kerala (10.54556N, 76.27323E) during October 2019 to January 2021. Regular surveys were conducted to locate the nests of *Ceratina* bees in the University Campus area. The nesting substrates having soft pithy or hollow stems *viz., Caesalpinia pulcherrima*, *Tecoma* sp., *Rosa* spp., *Peltophorum pterocarpum* and *Lantana* sp. were thoroughly monitored. A total of 199 nests were collected randomly from *C. pulcherrima*, with remnants of previously constructed cells within them. All the nests were collected during the evening hours so as to ensure the presence of adult bees inside. Nests were cut beyond 10-30 cm away from the tip of the twigs, so that no broods are harmed and nest entrance were covered with small cotton plugs to prevent the escape of adult bees from nests.

Individual nests were dissected carefully with a sharp blade to give gentle split lengthwise and classified into five categories according to Daly's (1966) classification (Rehan and Richards, 2010) viz., hibernacula nests, founding nests, active brood nests, full brood nests and mature brood nests according to the life stages of bees and conditions of nests constructed by the bees. Hibernacula nests are those with remnants of previously built nest cells with adult bees in them. Founding nests are with adult bees which are actively working for construction of new cells. Active brood nests always contain pollen masses in each constructed cells with freshly laid eggs or immature stages whereas full brood nests are those which contain various immature stages of bees with different proportion of pollen masses. Mature brood nests include the nests inhabited by adult bee interacting with their callow offsprings (Rehan and Richards, 2013).

The nest architecture of both the species of *Ceratina* including entrance diameter, thickness of nesting stem, occupied nest length, individual brood cell length, cell septum thickness, number of cells/ nest, number of immature stages/ nest, weight of pollen provision/ brood cell and number of adults in nest during collection were recorded. The immature stages of bees collected from the nests were reared at laboratory (28± 2°C, 75± 1% RH), where the split stems were tied properly with rubber bands and kept in rearing boxes with proper aeration. The stems were opened on a daily basis to observe developmental duration of different life stages (Udayakumar and Shivalingaswamy, 2019). A cotton swab soaked in 10% honey solution was kept in rearing boxes and the adult longevity was also recorded (Kaliaperumal, 2019). Descriptive statistics and two sample t-test was used to analyze the data with the software SPSS 21.

RESULTS AND DISCUSSION

Nest architecture: The small carpenter bees viz*.,* *C. smaragdula* (Fig. 1a) and *C. hieroglyphica* (Fig. 1b) were found to nest in soft pithy and dry stems of *C. pulcherrima* trees linearly. A total of 199 nests were collected from *C. pulcherrima* trees which were planted at a distance of 2 m. Out of 199 nests collected, 128 were inhabited by *C. smaragdula* and 71 nests by *C. hieroglyphica*. According to the classification of nests given by Daly (1966), nests were classified and counted separately, where *C. smaragdula* nests comprised of 19 hibernacula, 28 founding nests, 21 active brood nests, 15 full brood nests and 45 mature brood nests; *C. hieroglyphica* comprised of 8 hibernacula, 4 founding nests, 17 active brood nests, 11 full brood nests and 31 mature brood nests. The active and full brood nests of both the bee species were used to study the nest architecture (n=25).

The small carpenter bees *C. hieroglyphica* and *C.smaragdula* were found to construct linear nests in pruned dry pithy stems of *C. pulcherrima*, but was rarely found on freshly cut ends of plants. They were also observed constructing nests in various host plants viz*.,* *Tecoma* sp., *Croton* sp. and *Rosa* spp. According to Udayakumar and Shivalingaswamy (2019) small carpenter bee *C. binghami,* also nests on *C. pulcherrima*, *Adhatoda zeylanica* and *Adenanthera pavonina*. Ali et al (2016) reported the nesting activity of *C. smaragdula* in wooden stalks of Ravenna grass (*Saccharaum ravennae*). The nests of both species had only one entrance and the entrance diameter did not differ among *C. smaragdula* and *C. hieroglyphica* (two sample t-test, $t=0.848$, $p>0.05$) (Table 1). These observations are in line with the study of Yogi and

Khan (2014), where they reported that the nest entrance diameters of *Ceratina propinqua* and *C. simillima* had little difference in their nest architecture. Most of the nests were found with adult bees guarding their nests either showing their head or abdomen to ward off natural enemies and thereby protecting their young ones and these observations corroborate with those of Kaliaperumal (2019).

Preferences of bees towards twig thickness varied significantly ($t=^{-}3.365$, $p<0.05$) whereas, inner nest diameter showed only slight significant difference ($t=^{-}1.357$, $p>0.05$). Cells constructed inside were separated with pith of stem with a septum thickness of 3.1± 0.10 and 2.70± 0.08 in *C. smaragdula* and *C. hieroglyphica,* respectively. Kaliaperumal (2019) reported that the cell septum thickness of *C. hieroglyphica* ranged from 1.7± 0.48 mm. Cells constructed in individual nests were equal to the length of adult bees and were arranged continuously with one after another without any empty space between them. Individual cell length of both the species ranged 6 to 10 mm with slight significant difference in length ($t=^{-}5.139$, $p<0.05$), and these observations corroborate with those of Kaliaperumal (2019) who reported that *C. hieroglyphica* constructed their cells in cashew tree twigs with a length ranged from 7 to 8 mm. Both the species showed little significant difference in their nesting attributes viz., occupied cell length ($t=^{-}2.651$, $p>0.05$), cell septum thickness ($t=3.024$, $p>0.05$), number of cells/ nest ($t=^{-}1.568$, $p>0.05$) and number of immature stages/ nest ($t=^{-}1.672$, $p>0.05$). Most of the nests collected were found with one or two adult bees guarding their nests. Similarly, Batra (1976) reported the presence of old mother bee guarding their nests by buzzing loudly and blocking their nest entrance with the dorsum of their abdomen. Both the species constructed their nests at varied heights (*C. smaragdula*; 61.55± 5.34 and *C. hieroglyphica*; 63.42± 6.74 with no significant difference in their preference towards selection of nesting site from ground ($t=^{-}0.218$, $p>0.05$) (Table 1). These observations agree with those of Yogi and Khan (2014), who reported that there was no significant difference in height of nests from ground level for *C. propinqua* and *C. simillima.*

Lifecycle: The females of *C. smaragdula* as well as *C. hieroglyphica* bees placed their pollen provisions which is a mixture of pollen grains and nectar in individual cells constructed in their nest. The pollen provisions are yellow to orange (Fig. 1c) which weighs 14.80± 0.35 and 14.45± 0.33 (Mean± SE in mg; n=15) in *C. smaragdula* and *C. hieroglyphica,* respectively. Similar observations were reported by Ali et al. (2016) that the pollen provisions were brownish, viscous, rounded and soft with a length ranging from 0.5 to 0.6 cm. In the present study, length of pollen provisions measured 5136.56± 30.61 and 5068.74± 25.81 (Mean± SE in µm; n=15) with a width of 3069.45± 13.26 and 3089.93± 18.61 (Mean± SE in µm; n=15) in *C. smaragdula* and *C. hieroglyphica,* respectively.

The eggs are laid dorsally on pollen provision to ensure immediate availability of food for the larvae. Eggs are translucent white (Fig. 1d) with cylindrical shape and convexed ends. Eggs hatched in 3 to 5 days in both the species of bees with no significant difference (Two sample t-test; $t=2.861$; $p>0.05$) (Table 1). These results corroborate with those of Latha et al. (2020) who reported that *C. binghami* laid spindle shaped eggs on pollen balls which took four days for hatching into first instar larva. The first instar apodous larvae (Fig. 1e) are translucent white which actively fed on pollen provisions. Size of pollen mass varied in each cell of an active brood nest, where pollen masses were larger with early instars of larvae and vice-versa in cells with mature larvae. The first instar larvae are named as one by third size of pollen mass, which showed slight significant difference in their developmental days in *C. smaragdula* and *C. hieroglyphica* ($t=^{-}0.690$, $p<0.05$). The larva with two by third size of pollen mass (Fig. 1f) in both the species of bees showed significant difference in their development period ($t=0.695$, $p<0.05$), whereas larva with twice the size of pollen mass (Fig. 1g) did not show significant difference ($t=0.402$, $p>0.05$).

Udayakumar and Shivalingaswamy (2019) reported that *C. binghami* took a total larval period of 13.67± 1.63 days, as observed now, with that of *C. smaragdula* that took 15.51± 0.19 days and *C. hieroglyphica* took 15.93± 0.27 days. Pre-defecating larva (Fig. 1h) showed no significant difference in development time ($t=^{-}0.338$, $p>0.05$). Post defecating larva found in their cells with feces and were metamorphosed into white pupa. Pupa appeared with difference in eye colour viz., white, pale pink, pink, pale brown, brown and black (Fig. 1i-l) in accordance with the development period. Pupa with black eye showed difference in body pigmentation and these observations corroborate with those of Kaliaperumal (2019), who reported three consecutive type of pupae based on eye colour in *C. hieroglyphica* viz., creamy, brown and black. Both the species of bees did not show any significant difference in their pupal development period up to pink eyed stage. Pale brown

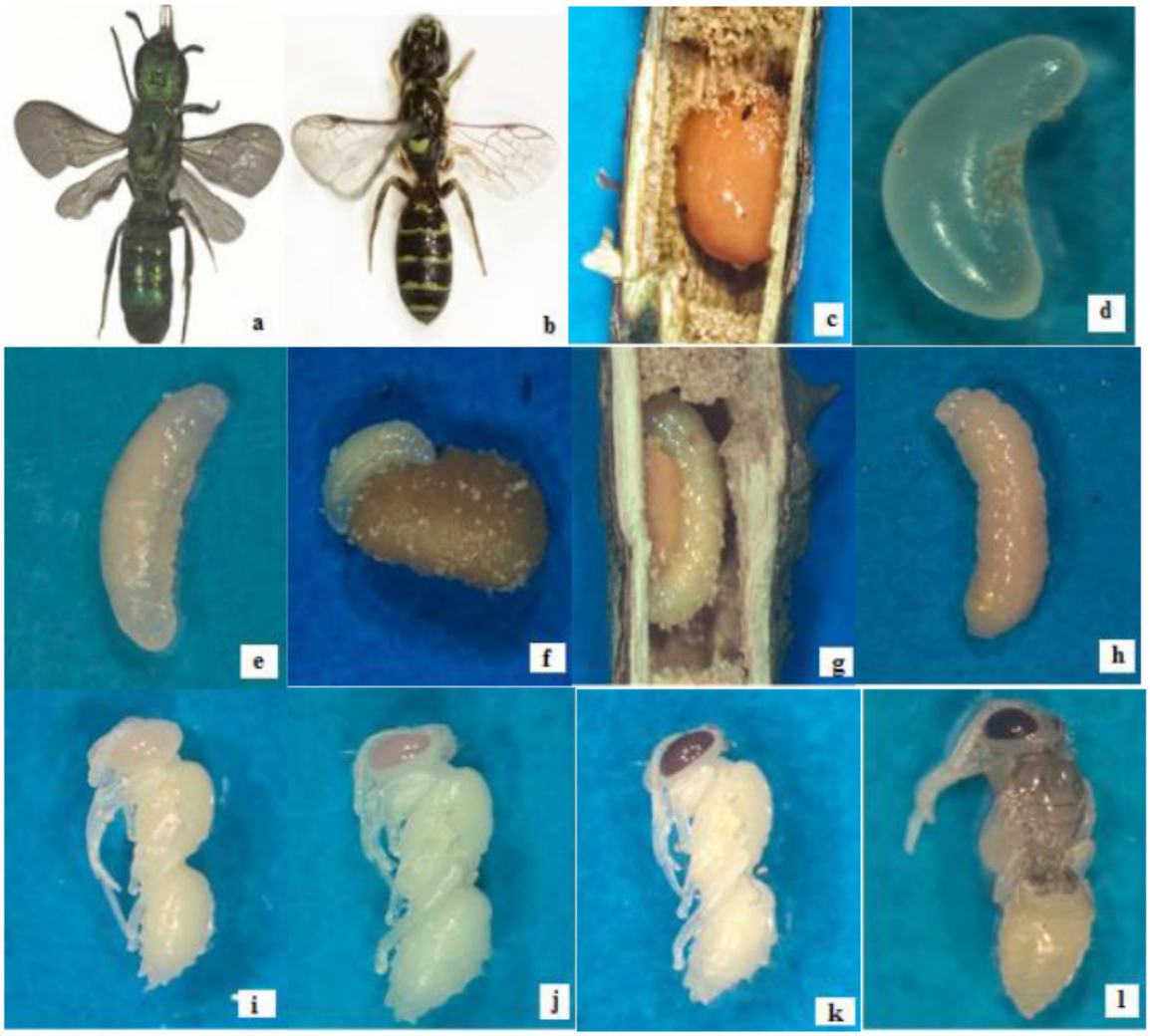


Fig. 1a-l. Carpenter bees; nest architecture and life stages; a. *C. smaragdula* adult; b. *C. hieroglyphica* adult; c. *C. smaragdula* nest with pollen provision; d. freshly laid egg by *C. hieroglyphica*; e. first instar larva of *C. smaragdula*; f. *C. hieroglyphica* larva with two third size of pollen ball; g. *C. hieroglyphica* larva with twice the size of pollen ball; h. pre-defecating larva of *C. smaragdula*; i. white eyed pupa of *C. smaragdula*; j. pink eyed pupa of *C. smaragdula*; k. brown eyed pupa of *C. smaragdula*; l. black eyed pupa of *C. hieroglyphica* with half body pigmentation.

eyed pupa of both species showed significant difference in their developmental days ($t=4.081$, $p<0.05$). Pupa with black eye showed significant difference in developmental period ($t=1.779$, $p<0.05$) which later attained varied body pigmentation. Pupa with three by fourth body ($t=5.791$, $p<0.05$) and with full body pigmentation ($t=2.857$, $p<0.05$) showed significant difference in developmental period (Table 1). Total pupal period of *C. smaragdula* ranged from 20.71± 0.26 days whereas *C. hieroglyphica* ranged from 18.56± 0.16 days. *C. smaragdula* showed an adult longevity of 8.55± 0.36 days, whereas *C. hieroglyphica* showed 4.82± 0.31 days which were not significantly different ($t=7.706$, $p>0.05$).

Total developmental period of both the bee species is not certain as observed now, and the adult longevity period may vary based on climate, host plants and various other factors. Ali et al. (2016) reported that *C. smaragdula* completed development within 28 to 32 days in Ravenna grass under laboratory conditions. In present study, *C. smaragdula* completed it in 45-54 days, and *C. hieroglyphica* within 43-53 days. Newly emerged adult bees were observed passing from their respective cell to uppermost cells so as to find their way out without disturbing other immature stages. Such a behavior is common for both the bee species, and these corroborate with the reports of Rau (1928) on *C. calcarata*, in which he stated that the oldest progeny

Table 1. Nest architecture and lifecycle of *Ceratina* spp.

Nest architecture (Mean± SE, n=25)		
Particulars	*C. smaragdula*	*C. hieroglyphica*
Entrance diameter (mm)	2.92± 0.07	3.00± 0.05
Twig thickness (mm)	8.08± 0.22	9.44± 0.33
Nest thickness (mm)	3.14± 0.06	3.33± 0.09
Occupied nest length (cm)	7.03± 0.47	8.82± 0.48
Cell septum thickness (mm)	3.1± 0.10	2.70± 0.08
Individual cell length (mm)	6.08± 0.53	4.32± 0.76
No. of cells/nest	4.92± 0.25	5.56± 0.31
No. of immatures/nest	4.68± 0.26	5.36± 0.31
No. of adult/nest	1.00± 0.05	0.80± 0.08
Height of nest from ground level (cm)	61.55± 5.34	63.42± 6.74
Lifecycle (Mean± SE, n=30)		
Life stage description	*C. smaragdula*	*C. hieroglyphica*
Egg	4.36± 0.12	3.87± 0.11
Larva		
One third of PB*	2.82± 0.09	2.91± 0.07
Two third of PB	2.74± 0.08	2.62± 0.14
Twice the size of PB	2.88± 0.08	2.83± 0.08
Pre-defecating larva	3.34± 0.06	3.38± 0.09
Post- defecating larva	3.71± 0.10	4.17± 0.15
Total larval period	15.51± 0.19	15.93± 0.27
Pupa		
White eyed pupa	2.93± 0.09	2.82± 0.10
Pale pink eyed pupa	1.32± 0.10	1.37± 0.07
Pink eyed pupa	1.09± 0.03	1.12± 0.04
Pale brown eyed pupa	1.61± 0.10	1.16± 0.04
Brown eyed pupa	1.36± 0.09	1.71± 0.08
Black eyed pupa	2.81± 0.09	3.02± 0.07
½ body pigmented pupa	3.01± 0.06	2.17± 0.04
¾ body pigmented	2.53± 0.14	1.53± 0.09
Full body pigmented	4.01± 0.08	3.62± 0.10
Total pupal period	20.71± 0.26	18.56± 0.16
Adult		
Adult longevity	8.55± 0.36	4.82± 0.31
Total lifecycle	49.15± 0.40	43.18± 0.58

*Pollen ball

at the base of the nests mature and begin to gnaw their way out before the others above them are ready. As these bees do not emerge laterally through side of the stem but vertically through all the other cells of the nests, they move through chewing apart the above cell septum. If the bee next to their cell is immature (Kapil, 1969) those were carefully moved down to the cell and new cap was made. If the bee next to the cell is mature, then elder bee passed it by and gnaw the cell septum of younger bees and the displacement process carried on till reaching up to the outermost cell.

The peacock flower tree *Caesalpinia pulcherrima* is found to be the most preferred nesting site of *C. smaragdula* and *C. hieroglyphica*. The dried pithy stems of *C. pulcherrima* can be used to trap these polylectic bees which not only help in conservation of these solitary pollen bees but also aid in better pollination services. These trees can also be planted as hedges in fields so that maximum utilization of pollination services can be obtained and better farm scaping is achieved. Thus, we need more landscape management practices to boost native pollinator densities by increasing habitat-carrying capacity.

REFERENCES

Abrol D P. 2012. Pollination biology: biodiversity conservation and agricultural production. Springer, New York. 792 pp.

Ali H, Alqarni A S, Shebl M, Engel M S. 2016. Notes on the nesting biology of the small carpenter bee *Ceratina smaragdula*

(Hymenoptera:Apidae) in northwestern Pakistan. Florida Entomologist 99(1): 89-93.

Aslam S, Rafi M A, Zia A. 2017. Non-Apis bees of family Apidae (Hymenoptera) from Potohar region of Pakistan. Journal of Entomology and Zoology Studies 5(2): 6-12.

Batra S W. 1976. Nests of *Ceratina, Pithitis* and *Braunsapis* from India (Hymenoptera: Anthophoridae). Oriental Insects 10(1): 1-9.

Daly H V. 1966. Biological studies on *Ceratina dallatorreana*, an alien bee in California which reproduces by parthenogenesis (Hymenoptera: Apoidea). Annals of the Entomological Society of America 59(6): 1138-1154.

Kaliaperumal V. 2019. Nest structure, development and natural enemies of *Ceratina hieroglyphica* Smith, a stem nesting bee colonizing cashew trees in hilly terrains. Journal of Apicultural Science 63(2): 223-232.

Kapil R P. 1969. Biology of *Ceratina binghami* Ckll. (Ceratinini: Hymenoptera). Journal of Research Punjab Agricultural University 6: 359-371.

Latha G S, Chinniah C, Shanthi M, Udayakumar A, Premalatha K, Aiyanathan A E K, Venkataraman N S. 2020. Nest infrastructure and biology of small carpenter bee, *Ceratina binghami* Cockerell (Hymenoptera: Apidae) in different host plants of Tamil Nadu, India. International Journal of Current Microbiology and Applied Sciences 9(2): 708-713.

Mattu V K, Kumar A. 2016. Diversity and relative abundance of solitary bees on *Jatropha curcas* crop in Sirmour and Solan Hills of Himachal Pradesh, India. International Journal of Science and Research 5(5): 1815-1818.

McIntosh M. 1996. Nest-substrate preferences of the twig-nesters *Ceratina acantha*, *Ceratina nanula* (Apidae) and *Pemphredon lethifer* (Sphecidae). Journal of the Kansas Entomological Society 69(4): 216-231.

Michener C D. 1962. The genus *Ceratina* in Australia, with notes on its nests (Hymenoptera: Apoidea). Journal of the Kansas Entomological Society 35(4): 414-421.

Navatha L, Sreedevi K. 2015. Pollinator diversity of solitary bees in oilseed crops. Current Biotica 8(4): 375-381.

Ollerton J, Price V, Armbruster W S, Memmott J, Watts S, Waser N M, Totland O, Goulson D, Alarcon R, Stout J C, Tarrant S. 2012. Overplaying the role of honey bees as pollinators: a comment on Aebi and Neumann (2011). Trends in Ecology and Evolution 27(3): 141-142.

Rau P. 1928. The nesting habits of the little carpenterbee, *Ceratina Calcarata*. Annals of the Entomological Society of America 21(3): 380-397.

Rehan S M, Richards M H. 2010. Nesting biology and subsociality in *Ceratina calcarata* (Hymenoptera: Apidae). The Canadian Entomologist 142(1): 65-74.

Rehan S M, Richards M H. 2013. Reproductive aggression and nestmate recognition in a subsocial bee. Animal Behaviour 85(4): 733-741.

Shebl M A, Hassan H A, Kamel S M, Osman M A, Engel M S. 2018. Biology of the mason bee *Osmia latreillei* (Hymenoptera: Megachilidae) under artificial nesting conditions in Egypt. Journal of Asia-Pacific Entomology 21(3): 754-759.

Udayakumar A, Shivalingaswamy T M. 2019. Nest architecture and life cycle of small carpenter bee, *Ceratina binghami* Cockerell (Xylocopinae: Apidae: Hymenoptera). Sociobiology 66(1): 61-65.

Yogi M K, Khan M S. 2014. Nesting biology of the small carpenter bees *Ceratina propinqua* and *Ceratina simillima* (Hymenoptera: Apidae). Animal Biology 64(2): 207-216.

(Manuscript Received: March, 2021; Revised: May, 2021;
Accepted: May, 2021; Online Published: July, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21071

Indian Journal of Entomology 84(1): 44-48 (2022) DoI.: 10.55446/IJE.2021.340

ARTIFICIAL T- PERCHES AS ATTRACTANT FOR INSECTIVOROUS BIRDS AGAINST *HELICOVERPA ARMIGERA* (HUBNER)

HARVEER KAUR, MANOJ KUMAR* AND AMIT CHOUDHARY[1]

Department of Zoology; [1]Department of Entomology,
Punjab Agricultural University, Ludhiana 141004, Punjab, India
*Email: mansnr@pau.edu (corresponding author)

ABSTRACT

Supplementing the foraging efficacy of insectivorous birds by installing artificial 'T- perches' can be used in controlling the cotton boll worm *Helicoverpa armigera* (Hubner) in berseem (Trifolium *alexandrinum* L) fodder crop. The present study explored this using T-perches placed at two heights (120 and 240 cm). A total of 22 bird species were observed, of which 15 species used 120 cm high perches while nine perched on 240 cm high one. Common myna was the most abundant with seasonal abundance of 31.75 and 35.96% on 120 and 240 cm perches, respectively. In all 12 species were observed in control field, out of which nine were found to be insectivorous. More diversity was observed in the fields installed with T- perches as compared to control field. Comparison of bird species in fields installed with 120 and 240 cm T-perches revealed more preference for 120 cm high one, may be because of low height of the berseem crop. These T-perches also proved effective in reducing the cotton boll worm *H. armigera* incidence- 3.50 larvae/ m^2 in fields installed with 120 cm perches; and 4.70 larvae/ m^2 in fields installed with 240 cm perches as against 6.85 larvae/ m^2 in control field). These results suggest that the perches are acting as attractants for birds and play an effective role in controlling *H. armigera*.

Key words: T-perches, berseem, fodder, *Helicoverpa armigera*, cotton, insectivorous birds, status, resident, migrant, diversity, seasonal abundance, high perches, height, common myna

Agriculture presently utilizes over 40% of total land area in the world (McLaughlin, 2011), and in India this sector occupies approximately 47% and > 70% of rural household is reliant on agriculture (Sutradhar et al., 2018). Punjab with just 1.5% area provides food to 13-14% of total Indian population (Anonymous, 2017). More than 10,000 species of birds are recognized by BirdLife International (Newton, 2003). 1210 species occur in India with 993 being land birds (Kler and Kumar, 2015). Of these, 328 occur in Punjab, reflecting an area of rich bird diversity (Jerath and Chadha, 2006). Land birds have close linkage with raised crops for feeding, breeding, nesting and roosting (Rey and Bullock, 2012). A total of 104 species of birds belonging to 16 orders and 52 families were observed at Punjab Agricultural University (Kler and Kumar, 2015). Majority of birds present in India are insectivorous and depend on such insects which are pests (Ali, 1996). The area with high shrub density will promote more insect diversity thus leading to high foraging opportunities for insectivorous birds (Kler and Kumar, 2015). Berseem or Egyptian clover (Trifolium *alexandrinum* L.) is an important fodder crop, grows very fast and it is also known to maintain soil fertility (Clark, 2007). It is infested by pests, of which the cotton boll worm *Helicoverpa armigera* (Hubner) is important, and can be managed by promoting their natural enemies. This helps sustainable agricultural management as it also promotes ecosystem services and biodiversity (Rey and Bullock, 2012). New practices are needed to promote IPM and reduce usage of pesticide. It can be easily implemented and inexpensive (Kuiper et al., 2000). Installing T-shaped perches encourages birds into the fields and helps in reduction of pest by ecofriendly methods. Artificial perches imitate bare trees which naturally prevails in landscape (Vogel et al., 2018; Kumar and Cheema, 2020). Also, structural complexity is promoted by artificial perches and it aids in increasing local bird diversity (Horgan et al., 2016). The present study has been undertaken to explore "T-perches" as a tool in attracting insectivorous bird species in berseem crop.

MATERIALS AND METHODS

The field experiment was conducted in the farms of the Village-Dyalpura, District-Ludhiana, Punjab, India during November 2019 to May 2020 ($30^0$49'41"N, $76^0$13'24"E, 260 masl). The berseem (*T. alexandrinum*) cultivar BL10 was raised as per approved Package and Practices of fodder crops, Directorate of Extension,

Punjab Agricultural University, Ludhiana (Anonymous, 2019). Berseem seeds were sown by broadcasting method in standing water. No application of pesticide was done. Experimental Design include the selection of three types of fields (in triplicate), out of which two (E1 & E2) were with installed perches and one control field (C) without perches. Two heights of perches were used i.e., 120 cm (E1) and 240 cm (E2). Selection of height was based on the criteria of crop height i.e., one close to crop (120 cm) and other higher (double) than the height of crop. These 'T-perches' were made of vertical wooden pole or stick of 1.5 cm dia, with two sticks arranged in the form of T-shape. Stick which forms the head of 'T' was smaller and 45 cm long, and joined with metallic wire, which is tied in the center of head region of perch. Perches were installed in field after one month of sowing, so that birds get accustomed with them, at 10 m distance from each other (Kler, 2005).

Different species of birds visiting the fields were recorded. Sampling method used was point count method and frequency of sampling was thrice a week. In experimental fields birds utilizing the perches were recorded where as in control fields only birds on the ground were observed. Birds were identified on the basis of visual observations which include their morphological characters such as colour, size, wings and rest of body parts observed with binocular and comparing with those described by Ali (1996). Nomenclature was followed as per Manakadan and Pittie (2001). For observations on *H. armigera*, five sampling plots (1m^2 each) i.e. four towards corners and one in the center of the field of were selected. Observations were made twice a week during March, manually by counting on the foliage of crop and the mean incidence worked out. The data were subjected to one-way ANOVA with SPSS software, with the seasonal abundance of avian species calculated by using formula: Ni/Nx 100, where Ni is the number of birds of the 'ith' species and N is the total number of birds.

RESULTS AND DISCUSSION

A total of 22 species were observed, of which 15 species were on 120 cm high perches, while 9 species were on 240 cm high ones, with the rest seen on the ground level; of the 15 species observed with 120 cm T-perches (E1), 11 were insectivorous. Common myna was the most abundant with seasonal abundance of 31.75% followed by black drongo (25.79%). Birds under five orders utilized 120 cm high perches- 9 belong to Passeriformes, 2 of Coraciformes and 1 each from Columbiformes, Bucerotiformes and Psittaciformes. In fields (E2) installed with 240 cm high T-perches there were nine species, out of which six were insectivorous, and common myna being the most abundant (35.96%) followed by the black drongo (28.24%). Jungle babbler and blue rock pigeon were the least abundant. Birds belonging to five orders utilized 240 cm high perches- 5 of Passeriformes and one each from Columiformes, Bucerotiformes, Psittaciformes and Coraciformes in E2 fields. Thus, more species were recorded in E1 as compared to E2, making 120 cm T-perches more suitable (Table 1). Similar findings with black drongo spending maximum time by utilizing perches are known (Gokula and Vijayan, 2007; Kaur and Kler, 2018). It may be because of the small height of berseem crop ranging from 30-80 cm (Clark, 2007). Avian species in control (C) fields amounted to 12, of which nine were insectivorous, but mostly ground foraging, such as cattle egret (most abundant- 21.88%) and red-wattled lapwing (13.29%); black ibis was the least abundant (1.28%); these belong to five orders- 5, 3, 2, 1 and 1 species under Passeriformes, Pelecaniformes, Columbiformes, Charadriformes and Gruiformes, respectively.

Asian pied starling, black ibis, cattle egret, eurasian collared-dove, indian pond heron and red-wattled lapwing are the species which do not utilize T-shaped perches. On examining the seasonal abundance of bird species in E1, E2 and C fields. There was a preferential trend towards 120 cm height (Table 2). This signifies the effectiveness of T-perches in attracting more bird species in fields by installing artificial T-perches and also these perches were able to attract more species on ground as compared to control field. Similar observations were made by Gokula and Vijayan (2007) that utilization of perch depends on its height and site as it plays important role in selection and predating in case of insectivorous birds. Effectiveness of heights of T-perches was found statistically significant for the months of March and April (Table 2). Based on the foraging habits and feeding guilds of bird species recorded in the fields and the birds utilizing perches, it was observed that insectivorous birds form dominant group (Table 1). On the basis of IUCN categories, all the birds observed during the study were in the category of least concern and observation based on resident status only 4 out of 22 were resident-migrant and others were resident ones (Kler and Kumar, 2015).

Observations on *H. armigera* incidence that occurred in berseem crop was made during March only, as its appeared by the end of February and declined in

Table 1. Seasonal abundance of avian species in agricultural fields of Punjab

Bird species	Scientific name	Order	Family	Status	Food	IUCN status	E1	E2	C
Asian pied starling	*Sturnus contra* L., 1758	Passeriformes	Sturnidae	R	I, F	LC	-	-	7.72
Black drongo	*Dicrurus macrocercus* Viellot, 1817	Passeriformes	Dicruridae	R	I	LC	25.79	28.24	2.13
Black ibis	*Pseudibis papillosa* (Temminck, 1824)	Pelecaniformes	Threskiornitiidae	R	I, G	LC	-	-	1.28
Blue rock pigeon	*Columba livia* Gmelin, 1789	Columbiformes	Columbidae	R	G	LC	1.45	1.66	4.56
Cattle egret	*Bubulcus ibis* (L., 1758)	Pelecaniformes	Ardeidae	RM	I, SI	LC	-	-	21.88
Common hoopoe	*Upupa epops* (L.,1758)	Bucerotiformes	Upupidae	RM	I	LC	0.35	3.63	-
Common myna	*Acridotheres tristis* (L., 1766)	Passeriformes	Sturnidae	R	I,F	LC	31.75	35.96	13.58
Common stone chat	*Saxicola torquata* (L., 1766)	Passeriformes	Turdinae	RM	I	LC	4.89	-	-
Common tailor bird	*Orthotomus sutorius* (Pennant,1769)	Passeriformes	Cisticolidae	R	I, H	LC	1.39	2.96	-
Eurasian collared dove	*Streptopelia decaocto* (Frivaldszky, 1838)	Columbiformes	Columbidae	R	G	LC	-	-	5.19
House crow	*Corvus splendens* Vieillot, 1817	Passeriformes	Corvidae	R	O	LC	4.81	14.17	15.19
Indian pond-heron	*Ardeola grayii* (Skyes, 1832)	Pelecaniformes	Ardeidae	R	I,SI,SV	LC	-	-	4
Indian roller	*Coracias benghalensis* (L.,1758)	Coraciformes	Coraciidae	R	I	LC	1.63	-	-
Jungle babbler	*Turdoides striatus* (Dumont, 1823)	Passeriformes	Timaliinae	R	I, F	LC	0.35	1.66	6.6
Oriental magpie-robin	*Copsychus saularis* (L., 1758)	Passeriformes	Turdinae	R	I	LC	2.72	-	-
Plain prinia	*Prinia inornata* (Skyes, 1832)	Passeriformes	Sylviinae	R	I	LC	1.74	-	-
Purple sunbird	*Nectarinia asiatica* (Latham, 1790)	Passeriformes	Nectariniidae	R	H	LC	6.64	-	-
Red-wattled lapwing	*Vanellus indicus* (Boddaert, 1783)	Charadriiformes	Charadriidae	R	I, SI	LC	-	-	13.29
Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	Psittaciformes	Psittacidae	R	F, G	LC	0.89	3.12	-
Streaked fantail warbler	*Cisticola juncidis* (Rafinesque, 1810)	Passeriformes	Sylviinae	RM	I	LC	7.06	-	-
White-breasted Kingfisher	*Halcyon smyrnensis* (L., 1758)	Coraciiformes	Alcedinidae	R	I, SV	LC	8.54	8.6	-
White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	Gruiformes	Rallidae	R	I, SI, H	LC	-	-	4.58

Status: R- Resident (bird species which remains on native place throughout the year); RM- Resident Migrant (bird species which migrates temporarily from their native) Food habit: I- Insectivorous; G- Granivorous; F- Frugivorous; H- Herbivorous; SI- Small Invertebrates; SV- Small vertebrat es; O-Omnivorous; IUCN status: LC- Least Concern

the beginning of April (Kumar and Cheema, 2020). Statistical analysis of these (from E1, E2 and C fields) using one way ANOVA showed significant difference ($p \leq 0.05$); it was low i.e. 3.50 (larvae/ $1m^2$) in fields installed with 120 cm perches and comparatively more number of bird species utilized these perches, among which major were insectivorous. Comparatively, more counts i.e. 4.7 (larvae/ m^2) in field having perch height of 240 cm and high pest population was observed in control field i.e. 6.85 (larvae/ m^2), suggesting that the perches do act as attractant to birds and play effective role in controlling the *H. armigera* in berseem (Table 2).

Table 2. Bird species diversity and incidence of *H. armigera* as influenced by T perches

Months	E1		E2		C		p-value
	No. of birds (on perch+ ground)= Total	MS*	No. of birds (on perch+ ground) =Total	MS	No. of birds (ground)	MS	
November 2019	3+5=8	0.31[a]	2+6=8	0.37[a]	5	0.3[a]	p=0.96
December 2019	4+7=11	0.71[a]	2+10=12	0.61[a]	11	0.84[a]	p=0.74
January 2020	4+11=15	1.47[a]	3+11=14	0.99[a]	11	0.89[a]	p=0.58
February 2020	5+9=14	1.42[a]	5+10=15	1.3[a]	10	0.89[a]	p=0.58
March 2020	7+11=18	2.8[a]	5+12=17	1.85[ab]	12	1.22[b]	p=0.04
April 2020	8+12=20	3.06[a]	5+11=16	1.84[ab]	11	1.04[b]	p=0.04
May 2020	3+8=11	1.47[a]	3+8=11	0.87[a]	7	0.89[a]	p=0.45
H. armigera incidence (mean) in different weeks of March 2020**							
Weeks	E1		E2		C		
1st	3.60		5.00		6.20		
2nd	4.20		4.40		5.80		
3rd	3.20		4.20		6.80		
4th	3.00		5.20		8.60		
Mean	3.50		4.70		6.85		

*MS- Mean value of analysis done by One-way ANOVA (p=0.05%); **f-value= 16.97, p-value= 0.00088.

Insectivorous birds are generalists and rely on structure of vegetation, abundance and distribution of prey which affects height selection by the birds (Ali et al., 2010). Common myna was in abundance in the field of cabbage with perches (Chand, 2005). Majority of birds visiting fields were insectivorous (8 species), one was granivorous (blue rock pigeon) and one was omnivorous (house crow). This observation derives support from the study of analysis of gut of black drongo, revealing it as the most efficient predator of *H. armigera* (Reinert, 1983; Yeishetty et al., 2005). Perches of trees were utilized by white-breasted kingfisher and black drongo in order to monitor their prey (Ali and Ripley, 1983). Black drongo perched individually as well as in group (Kaur and Kler, 2018). Among birds visiting field of chickpea, 70% used perches for their feeding (Vogel et al., 2018). Seven species of insectivorous birds were recorded in berseem field utilizing perches of 1 m height; birds perches do act as predation substrate which was maximum utilized by black drongo; common myna was the most abundant while red-wattled lapwing *Vanellus indicus* was the least abundant in berseem field as observed by Kumar and Cheema (2020). In tomato field, 5.71% insectivorous bird species were recorded during one hour, out of which 2.84 % birds utilized T-perches (Mehta et al., 2010). Similar findings had been known (Chand, 2005; Prabhakar et al., 2003). Common myna used perches maximum number of times in cauliflower fields, birds utilizing T-perches either jumped to the ground for predating the prey or moved away from the field (Chand, 2005). Fifty % reduction in larvae of castor semilooper (*Achaea janata)* by installation of 20 perches/ ha was observed (Prabhakar et al., 2003). Black drongo explores aerial and perch to site foraging guild in rice and wheat agroecosystem (Kler and Prashad, 2011). Black drongo preferred crop fields over orchards, as per observations by Sidhu and Kler (2018).

Comparison of bird species in E1 (fields installed with 120 cm T-perches) and E2 (fields installed with 240 cm T-perches) revealed that the E1 were more preferred then E2 in berseem crop which may be because of low height of the berseem. Statistically significant difference for bird diversity observed suggests that the perches do act as attractant to birds. Installation of artificial T-perches in the fields will certainly increase the feeding efficiency of insectivorous birds as there is shift in strategy of hunting or feeding by birds if perches are installed as before perch placement, aerial feeding is the only option left. T-perches also proved to be effective in controlling *H. armigera*. Thus, more bird diversity, and less incidence of pest observed in field installed with T- perches can certainly be used as an alternative, economic and ecofriendly IPM measure.

ACKNOWLEDGEMENTS

Authors thank the ICAR, New Delhi for financial support and Prof and Head, Department of Zoology, Punjab Agricultural University, Ludhiana for providing necessary facilities.

REFERENCES

Ali M S, Asokan S, Manikannan R, Nithyanandam T G. 2010. Foraging behaviour of selected birds in Cauvery Delta region of Nagapattinam District, Tamil Nadu, India. Journal of Threatened Taxa 2(2): 690-694.

Ali S. 1996. The book of Indian birds. Oxford University Press, Delhi. 354 pp.

Ali S, Ripley S D. 1983. Handbook of birds of the India and Pakistan. Oxford University Press, Delhi.

Anonymous. 2017. The future of food and agriculture- trends and challenge. Food and Agricultural Organization of United Nations, Cairo. pp. 4-7.

Anonymous. 2019. Package of practices for rabi crops, Punjab Agricultural University, Ludhiana. 172 pp.

Chand J. 2005. Evaluation of birds as predators of insect pests infesting cabbage and cauliflower. Master's Thesis, Punjab Agricultural University, Ludhiana.

Clark A. 2007. Managing crop profitably. Sustainable Agriculture Research and Education, Beltsville, MD. 248 pp.

Gokula V, Vijayan L. 2007. Foraging strategies of birds in partitioning of food resources in dry deciduous forest of Mudumalai Wildlife Sanctuary, Tamil Nadu, India. Scientific Transactions in Environment and Technovation 1(1): 36-42.

Horgan F G, Ramal A F, Villegas J M, Almazan M L P, Bernal C C, Jamoralin A, Arroyo C. 2016. Ecological engineering with high diversity vegetation patches enhances bird activity and ecosystem services in Philippines rice fields. Regional Environment Change, Berlin. 13 pp.

Jerath N, Chadha J. 2006. Biodiversity in Shivalik ecosystem of Punjab. Punjab State Council for Science and Technology, Chandigarh. 193 pp.

Kaur G, Kler T. 2018. Feeding behaviour and perching preference of black drongo (*Dicrurus macrocercus*) in Ludhiana district (Punjab). Journal of Entomology and Zoological Studies 6 (4): 232-39.

Kler T. 2005. 'T' Shape perches encourage insectivorous birds in cotton crop. Pestology 29 (2): 28-31.

Kler T K, Kumar M. 2015. Avian fauna in agricultural habitats of Punjab state. Agricultural Research Journal 52(3): 83-90.

Kler T K, Prashad R K. 2011. Bird composition in relation to phenological stages of wheat and rice crops. Agricultural Research Journal 48 (4): 163-71.

Kumar R, Cheema H K. 2020. Restricting lepidopteran herbivory through trap cropping and bird perches in Egyptian clover (*Trifolium alexandrium* L.). Egyptian Journal of Biological Pest Control 30: 1-8.

Kupier H A, Kleter G A, Noordam M Y. 2000. Risks of the release of transgenic herbicide-resistant plants with respect to humans, animals and the environment. Crop Protection 19: 773-78.

Manakadan R, Pittie A. 2001. Standardised common and scientific names of the birds of the Indian subcontinent. Buceros 6(1): i-ix, 1-38.

McLaughlin D W. 2011. Land, food and biodiversity. Biological Conservation 25(6): 25-37.

Mehta K S, Patyal S K, Rana R S, Sharma K C. 2010. Ecofriendly techniques for the management of *Helicoverpa armigera* (Hubner) in tomato. Journal of Biopesticides 3: 25-48.

Newton I. 2003. The speciation and biogeography of birds. Academic Press, London, UK. 668 pp.

Prabhakar M, Rao S M, Prasad Y G. 2003. Evaluation of bio-intensive integrated pest management modules against castor semilooper (*Achaea janata* Linn.). Indian Journal of Plant Protection 31(1): 56-58.

Reinert S E. 1983. Use of introduced perches by raptors: Experimental research and management implications. Raptor Research 18: 25-29.

Rey B J M, Bullock J M. 2012. Restoration of biodiversity and ecosystem services on agricultural land. Ecosystems 15: 883-889.

Sidhu S K, Kler T K. 2018. Avian composition and damage assessment in guava fruit crop at Punjab. Journal of Entomology and Zoological Studies 6(2): 2422-26.

Sutradhar S, Sarkar A M, Nayeem J, Jahan M S. 2018. Potassium hydroxide pulping of four non-woods. Bangladesh Journal of Science and Industrial Research 53(1):1-6.

Vogel H F, McCarron, Zocche J J. 2018. Use of artificial perches by birds in ecological restoration areas of the Cerrado and Atlantic Forest biomes in Brazil. Neotropical Biology and Conservation 13(1): 24-36.

Yeishetty S, Patil P V, Lingappa S. 2005. Role of insectivorous birds in the management of pigeonpea pod borer *Helicoverpa armigera* (Hubner). Indian Journal of Pulses Research 18(2): 226-229.

(Manuscript Received: May, 2021; Revised: June, 2021;
Accepted: June, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21106

Indian Journal of Entomology 84(1): 49-53 (2022) DoI.: 10.55446/IJE.2021.300

EFFECT OF FENVALERATE, λ-CYHALOTHRIN, QUINALPHOS AND THIAMETHOXAM ON LARVAL SURVIVAL IN HONEY BEE *APIS MELLIFERA* L.

Shushant Tuteja, Amandeep Singh Dhanju[1], Gurleen Kaur, Shyamli and Randeep Singh*

Plant Protection Division, PG Department of Agriculture,
Khalsa College, Amritsar, Punjab 143002, India
[1]Department of Agriculture, Khalsa College, Garhdiwala, Hoshiarpur 144207, Punjab, India
*Email: singhrandeep83@hotmail.com (corresponding author)

ABSTRACT

This study evaluates the effects of some insecticides on the survival of larvae of *Apis mellifera* L. The pyrethroids (fenvalerate and λ-cyhalothrin) caused maximum mortality at highest concentration (12.5 ppm), when compared to quinalphos and thiamethoxam. Fenvalerate was observed to be extremely toxic in its maximum concentration, as none among 1-2 days old treated larvae (after multiple exposures) survived after 24 hours (i.e., after 4th exposure. Lavae were observed to be tolerant to thiamethoxam as 66.67% survival was observed till emergence under similar conditions.

Key words: *Apis mellifera*, larvae, insecticides, pyrethroids, fenvalerate, λ-cyhalothrin, thiamethoxam, survival, pollen, honey, toxicity, survival, emergence, brood, multiple exposer

Honey bees are reliable and effective pollinators in many cultivated crops (McGregor, 1976; Klein et al., 2007). It is estimated that > 80% of flowers are pollinated by honey bees, thus are important for food production and for maintenance of wild plant ecosystems (Ollerton et al., 2011). Honey bees also provide us high value products such as honey, beeswax, royal jelly, propolis, pollen and bee venom (Tautz, 2008). The population of honey bees is however found to decline globally (Potts et al., 2010; González-Varo et al., 2013). Pesticides, pathogens and parasites are considered to be some of the major reasons behind this decline (Neumann and Carreck, 2010; Johnson et al., 2010; Goulson, 2013). During foraging, bees often collect pesticide contaminated pollen and nectar, which is finally brought to the hive (Bonmatin et al., 2005; Kievits, 2007), leading to bee deaths (Van Engelsdorp et al., 2008), and thus a serious hazard (OECD, 1998; EFSA, 2014). Neonicotenoids are considered to be the main reasons behind the decline of pollinators worldwide (Goulson, 2013; Van der Sluijs et al., 2013). These are the neurotoxins which act against nicotinic acetylcholine receptors in insects (Matsuda et al., 2001; Elbert et al., 2008). However, thiamethoxam is a poor agonist of nAChRs in insects (Nauen et al., 2003; Tan et al., 2007) and is a full agonist at cercal afferent/ giant interneuron synapses (Thany, 2011). The LD_{50} for thiamethoxam against bees is 4-5 ng/ bee (Iwasa et al., 2004; Decourtye and Devillers, 2010; Laurino et al., 2011).

The synthetic pyrethroids are generally known to interfere with sodium gate in nerve membrane (Narahashi, 1962). Honey bees show variation in tolerance to different pyrethroid insecticides (Johnson et al., 2006). Fenvalerate is extremely toxic to honey bees with its LD_{50} of 0.0063 µg/ bee (Abrol and Andotra, 2003) and λ-cyhalothrin on the other hand is considered to be highly toxic to honey bees with its LD_{50} of 83 ng/ bee (Johnson et al., 2006). Organophosphates (OPs) are poisonous to insects because of their capability to inactivate enzyme, acetyl cholin estrase (Fukuto, 1990). Quinalphos is regarded to be moderately toxic to honey bees with its LD_{50} of 0.0292 µg/bee (Abrol and Andotra, 2003). Since less data is available regarding toxicity of insecticides to larvae of *A. mellifera*, this study focused on the larval stages as success of larval period is considered to be critical for maintenance honey bee colony (Godfray et al., 2014).

MATERIALS AND METHODS

The present study was carried out at the apiary situated in Khalsa College, Amritsar during 2018-2019. Three strong colonies of *A. mellifera* comprising 8-10 frames were chosen, with three replications having queens of the same age along with homogeneous circumstances (brood composition, capped larvae, nectar, pollen, free from diseases and pests etc.). For treatment, *A. mellifera* queen was first separated using queen excluder and restricted to two or three vacant frames to obtain larvae of same age group. Frames

containing eggs were separated on the same day when eggs were placed in sufficient number by the queen by frequent surveillance of these frames. To achieve more eggs, these frames were substituted with other chosen frames and the process continued until the specified age group requirement was met. Ten larvae constituted a replication to accomplish requirement of larvae for control and for all the five concentrations from or close to the middle region of single frame with proper space for cage installation prior to emergence to record the rate of emergence.

Four insecticides viz., thiamethoxam, λ-cyhalothrin, fenvalerate and quinalphos were evaluated, with the concentrations decided on the basis of residue reported in pollen and nectar (Johnson et al., 2010). However, approach towards higher concentrations was also made to compare toxicity. Five concentrations *viz*. 0.02, 0.1, 0.5, 2.5 and 12.5 ppm were included, and done using micropipette (10µl) through which 1 µl of the insecticide solution was applied in each cell in the marked region containing larva. Two controls were used viz. negative control (without solvent) and positive control (with solvent) for comparison. Insecticides were applied as single and multiple doses, in the latter case, applied more than once with a waiting period of 24 hr after each; thus applied four times in case of 1-2 days old larva and 2 times with 3-4 days old larva. The survival of worker brood was recorded after 24 hr of application of insecticides. The number of larvae capped among survived were also recorded. The data obtained was statistically analysed in randomized block design (RBD) through SPSS software (version 21).

RESULTS AND DISCUSSION

The results revealed a dose dependent reduction in survival of larvae of different age groups with application of insecticides; and mortality can occur at any stage of development after exposure; and 1-2 days old larvae were more susceptible compared to 3-4- and 5-6-days old ones. One time exposure of insecticides on survival of *A. mellifera* larva revealed high susceptibility towards fenvalerate. At highest concentration tested i.e.

Table 1. Effect of single exposure of insecticides on survival of larvae of *A. mellifera*

Chemical and Conc. used (in ppm)		1-2 days old larvae			3-4 days old larvae			5-6 days old larvae		
		Survived brood (1 DAT)	Capped brood	Emerged bees	Survived brood (1 DAT)	Capped brood	Emerged bees	Survived brood (1 DAT)	Capped brood	Emerged bees
Fenvalerate	NC	10.00^{a}	9.33^{a}± 0.58	8.67^{a}± 0.58	10.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}
	PC	9.33^{a}± 0.58	9.33^{a}± 0.58	9.00^{a}± 0.00	10.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}
	0.02	10.00^{a}	9.67^{a}± 0.58	8.67^{a}± 0.58	10.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}
	0.1	9.67^{a}± 0.58	9.00^{a}± 0.00	8.67^{a}± 0.58	10.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}	10.00^{a}
	0.5	9.33^{a}± 0.58	9.00^{a}± 0.00	8.33^{a}± 0.58	10.00^{a}	9.33^{b} ± 0.58	9.00^{b}± 0.00	10.00^{a}	10.00^{a}	9.33^{a}± 0.58
	2.5	9.33^{a}± 0.58	9.00^{a}± 0.00	7.67^{a}± 1.15	10.00^{a}	9.00^{b}± 0.00	8.67^{b}± 0.58	9.33^{a}± 0.58	9.33^{a}± 0.58	9.33^{a}± 0.58
	12.5	4.67^{b}± 1.15	1.67^{b}± 1.53	1.00^{b}± 1.00	8.67^{b}± 0.58	8.00^{c}± 0.00	6. 67^{c}± 0.58	8.67^{a}± 1.15	8.67^{a}± 1.15	6.67^{b}± 0.58
λ-cyhalothrin	NC	10.00^{a}	9.67^{a}± 0.58	9.33^{a}± 0.58	10.00^{a}	10.00^{a}	9.67^{a}± 0.58	10.00^{a}	10.00^{a}	10.00^{a}
	PC	10.00^{a}	9.00^{a}± 0.00	9.00^{ab}± 0.00	10.00^{a}	9.67^{ab}± 0.58	9.67^{a}± 0.58	10.00^{a}	10.00^{a}	10.00^{a}
	0.02	10.00^{a}	10.00^{a}	9.33^{a}± 0.58	10.00^{a}	10.00^{a}	9.67^{a}± 0.58	10.00^{a}	10.00^{a}	10.00^{a}
	0.1	10.00^{a}	10.00^{a}	9.00^{ab}± 0.00	10.00^{a}	10.00^{a}	9.33^{a}± 0.58	10.00^{a}	10.00^{a}	10.00^{a}
	0.5	10.00^{a}	9.33^{a}± 0.58	8.67^{ab}± 0.58	10.00^{a}	9.33^{ab}± 0.58	9.00^{a}± 0.00	10.00^{a}	10.00^{a}	9.67^{ab}± 0.58
	2.5	9.33^{ab} ± 0.58	9.00^{a}± 0.00	7.67^{b}± 0.58	9.67^{a}± 0.58	8.67^{b}± 0.58	8.33^{a}± 0.58	10.00^{a}	10.00^{a}	9.00^{b}± 0.00
	12.5	8.67^{b} ± 0.58	3.67^{b}± 0.58	3.33^{c}± 0.58	9.00^{b}± 0.00	7.33^{c}± 0.58	6.67^{b}± 0.58	9.33^{b}± 0.58	9.33^{b}± 0.58	7.33^{c}± 0.58
Quinalphos	NC	10.00^{a}	9.67^{a}± 0.58	9.33^{a}± 0.58	9.67± 0.58	9.00^{a}± 0.00	9.00^{a}± 0.00	10.00^{a}	10.00^{a}	9.67^{a}± 0.58
	PC	10.00^{a}	9.33^{ab}± 0.58	9.00^{ab}± 0.00	9.33± 0.58	9.33^{a}± 0.58	9.33^{a}± 0.58	10.00^{a}	10.00^{a}	9.67^{a}± 0.58
	0.02	10.00^{a}	9.67^{a}± 0.58	9.33^{a}± 0.58	9.67± 0.58	9.67^{a}± 0.58	9.00^{a}± 0.00	10.00^{a}	10.00^{a}	9.67^{a}± 0.58
	0.1	8.67^{ab}± 0.58	8.67^{ab}± 0.58	8.67^{ab}± 0.58	9.67± 0.58	9.33^{a}± 0.58	9.00^{a}± 0.00	10.00^{a}	10.00^{a}	9.67^{a}± 0.58
	0.5	9.33^{ab}± 0.58	8.67^{ab}± 0.58	8.67^{ab}± 0.58	9.67± 0.58	9.00^{a}± 0.00	8. 67^{a}± 0.58	10.00^{a}	10.00^{a}	9.33^{a}± 0.58
	2.5	9.33^{ab}± 0.58	8.00^{b}± 0.00	7.33^{b}± 0.58	9.00± 1.00	8.67^{a}± 0.58	8.33^{a}± 0.58	10.00^{a}	10.00^{a}	9.00^{ab}± 0.00
	12.5	8.00^{b}± 1.00	6.33^{c}± 0.58	4.00^{c}± 1.00	8.33± 0.58	7.00^{b}± 1.00	6.67^{b}± 0.58	9.33^{b}± 0.58	9.33^{b}± 0.58	7.33^{b}± 1.15
Thiamethoxam	NC	9.67± 0.58	9.67^{a}± 0.58	9.67^{a}± 0.58	10.00	10.00^{a}	9.67± 0.58	10.00	10.00	9.67± 0.58
	PC	10.00	10.00^{a}	9.67^{a}± 0.58	10.00	10.00^{a}	9.67± 0.58	10.00	10.00	9.67± 0.58
	0.02	10.00	10.00^{a}	9.67^{a}± 0.58	10.00	10.00^{a}	9.67± 0.58	10.00	10.00	9.67± 0.58
	0.1	10.00	9.67^{a}± 0.58	9.33^{a}± 0.58	10.00	10.00^{a}	9.67± 0.58	10.00	10.00	9.67± 0.58
	0.5	10.00	10.00^{a}	9.33^{a}± 0.58	10.00	10.00^{a}	9.33± 0.58	10.00	10.00	9.67± 0.58
	2.5	10.00	9.33^{a}± 0.58	8.67^{ab}± 0.58	9.67± 0.58	9.67^{a}± 0.58	9.33± 0.58	10.00	10.00	9.67± 0.58
	12.5	9.67± 0.58	9.00^{b}± 0.00	7.33^{b}± 0.58	9.67± 0.58	9.00^{b}± 0.00	8.33± 0.58	10.00	10.00	9.00± 0.00

All values Mean± SD; NC- Negative control; PC- Positive control; DAT- Days after treatment; Values significant at p=0.05; Variables ($^{a, b, c,}$) significantly differ from each other (p=0.05)

Table 2. Effect of multiple exposures of insecticides on larvae of *A. mellifera*

Chemical and Conc. used (in ppm)		1-2 days old larvae			3-4 days old larvae		
		Survived brood (1 DAT)	Capped brood	Emerged bees	Survived brood (1 DAT)	Capped brood	Emerged bees
Fenvalerate	NC	9.33^{a}± 0.58	9.33^{a}± 0.58	9.33^{a}± 0.58	10.00^{a}	10.00^{a}	10.00^{a}
	PC	9.33^{a}± 0.58	9.33^{a}± 0.58	9.33^{a}± 0.58	10.00^{a}	10.00^{a}	10.00^{a}
	0.02	9.67^{a}± 0.58	9.33^{a}± 0.58	9.33^{a}± 0.58	10.00^{a}	10.00^{a}	10.00^{a}
	0.1	9.33^{a}± 0.58	9.33^{a}± 0.58	9.00^{ab}± 1.00	10.00^{a}	10.00^{a}	10.00^{a}
	0.5	9.00^{a}± 1.00	8.67^{a}± 1.15	8.67^{ab}± 1.15	9.33^{a}± 0.58	9.00^{a}± 0.00	8.67^{b}± 0.58
	2.5	8.33^{a}± 0.58	8.00^{a}± 0.00	7.00^{b}± 1.00	9.33^{a}± 0.58	9.00^{a}± 0.00	8.00^{b}± 0.00
	12.5	0.00^{b}	0.00^{b}	0.00^{c}	7.00^{b}± 1.00	6.00^{b}± 1.00	5.00^{c}± 1.00
λ-cyhalothrin	NC	10.00^{a}	10.00^{a}	9.33^{a}± 0.58	10.00^{a}	10.00^{a}	9.33^{a}± 0.58
	PC	9.67^{a}± 0.58	9.67^{ab}± 0.58	9.33^{a}± 0.58	10.00^{a}	9.67^{a}± 0.58	9.33^{a}± 0.58
	0.02	10.00^{a}	10.00^{a}	9.33^{a}± 0.58	10.00^{a}	10.00^{a}	9.33^{a}± 0.58
	0.1	10.00^{a}	10.00^{b}	9.00^{a}± 0.00	10.00^{a}	10.00^{a}	9.33^{a}± 0.58
	0.5	9.33^{a}± 0.58	9.00^{ab}± 0.00	8.33^{ab}± 0.58	10.00^{a}	9.33^{a}± 0.58	9.00^{a}± 0.00
	2.5	9.00^{a}± 1.00	8.67^{b}± 0.58	7.33^{b}± 0.58	9.33^{a}± 0.58	9.33^{a}± 0.58	8.33^{a}± 0.58
	12.5	1.67^{b}± 1.53	0.67^{c}± 0.58	0.00^{c}	6.67^{b}± 0.58	5.67^{b}± 0.58	4.33^{b}± 1.53
Quinalphos	NC	9.33^{a}± 0.58	9.00^{a}± 0.00	9.00^{a}± 0.00	10.00^{a}	9.67^{a}± 0.58	9.00^{ab}± 0.00
	PC	9.33^{a}± 0.58	9.33^{a}± 0.58	9.33^{a}± 0.58	9.33^{ab}± 0.58	9.33^{ab}± 0.58	9.33^{a}± 0.58
	0.02	9.33^{a}± 0.58	9.33^{a}± 0.58	9.00^{a}± 0.00	10.00^{a}	9.00^{abc}± 0.00	9.00^{ab}± 0.00
	0.1	9.00^{a}± 0.00	8.67^{a}± 0.58	8.33^{ab}± 0.58	9.33^{ab}± 0.58	8.67^{abc}± 0.58	9.00^{ab}± 0.00
	0.5	9.00^{a}± 0.00	8.33^{a}± 0.58	8.00^{ab}± 1.00	8.67^{ab}± 0.58	8.33^{abc}± 0.58	8.33^{ab}± 0.58
	2.5	7.67^{a}± 0.58	7.33^{a}± 0.58	7. 33^{b}± 0.58	8.33^{b}± 0.58	8.00^{bc}± 0.00	8.00^{b}± 0.00
	12.5	3.67^{b}± 2.31	2.67^{b}± 1.53	1.33^{c}± 0.58	8.33^{b}± 0.58	7.67^{c}± 0.58	4.67^{c}± 0.58
Thiamethoxam	NC	9.33^{a}± 0.58	9.33^{a}± 0.58	9.33^{a}± 0.58	10.00	10.00	9.33^{a}± 0.58
	PC	10.00^{a}	9.67^{a}± 0.58	9.67^{a}± 0.58	9.67± 0.58	9.67± 0.58	9.33^{a}± 0.58
	0.02	9.67^{a}± 0.58	9.67^{a}± 0.58	9.00^{a}± 0.00	10.00	10.00	9.33^{a}± 0.58
	0.1	9.33^{a}± 0.58	9.00^{ab}± 0.00	9.00^{a}± 0.00	10.00	9.67± 0.58	9.33^{a}± 0.58
	0.5	9.00^{ab}± 0.00	9.00^{ab}± 0.00	8.67^{a}± 0.58	10.00	9.33± 0.58	9.00^{ab}± 0.00
	2.5	9.00^{ab}± 0.00	8.67^{ab}± 0.58	8.33^{a}± 0.58	9.67± 0.58	9.33± 0.58	8.67^{ab}± 0.58
	12.5	8.00^{b}± 0.00	7.33^{b}± 1.15	6.67^{b}± 0.58	9.33± 0.58	9.00± 1.00	7.67^{b}± 0.58

Values Mean± S; NC- Negative control; PC- Positive control; DAT- Days after treatment
Values are significant at 5% level of significance, Variables ($^{a, b, c,}$) significantly differ from each other at 5% level of significance

12.5 ppm, survival reduced significantly ($p \leq 0.05$) to 10 and 66.67% in 1-2 days old and 3-4 and 5-6 days old larvae, respectively. The other insecticide observed to be highly toxic was λ-cyhalothrin- in 1-2 days old larvae survival reduced significantly ($p \leq 0.05$) to 33.33% at the time of emergence at highest concentration i.e. 12.5 ppm; in 3-4 and 5-6 days old larvae, survival observed at emergence was 66.67 and 73.33% at 12.5 ppm. With quinalphos, at highest concentration (12.5 ppm), the survival in 1-2, 3-4, and 5-6 days old larvae significantly reduced ($p \leq 0.05$) to 40, 66.67 and 73.33% at the time of emergence. In case of thiamethoxam, 1-2 days old larvae showed 73.33% survival at emergence stage at 12.5 ppm; in 3-4 days old larvae, 83.33% survival was observed; and survival rate was extremely high in 5-6 days old larvae; however, at emergence, survival at highest concentration reduced non-significantly to 90% (Table 1).

Multiple exposure of insecticides to *A. mellifera* larvae lead to higher mortality in comparison to single exposure; 24 hr after application of last dose (4th exposure) of fenvalerate (12.5 ppm), all the treated larvae died; and same trend was observed in 3-4 days old larvae when exposed twice; at emergence, survival was 50% at highest concentration i.e. 12.5 ppm. Against λ-cyhalothrin, 6.67% survival in 1-2 days old larvae was observed at capping stage; and none survived till emergence; and in 3-4 days old ones, survival reduced significantly ($p \leq 0.05$) to 43.33% at emergence at 12.5 ppm. For quinalphos, 13.33% larval survival was observed in 1-2 days old larvae; and 46.67% survival was observed in 3-4 days old ones at 12.5 ppm. After multiple exposures of thiamethoxam, survival of larvae significantly reduced ($p \leq 0.05$) to 66.67% in 1-2 days old larvae and to 76.67% in 3-4 days old ones 12.5 ppm (Table 2). Comparison of toxicity with data obtained after single as well as multiple exposure, revealed reduction in survival at highest concentration as follows: Fenvalerate> λ-cyhalothrin> Quinalphos> Thiamethoxam. Abrol and Andotra (2003) reported that toxicity of fenvalerate to *A. mellifera* was greater than

that of quinalphos and Marletto et al. (2003) revealed that after 72 hr of exposure, λ-cyhalothrin was slightly more toxic to bumble bees than quinalphos.

The present study also showed that among the two pyrethroids, fenvalerate was more toxic to *A. mellifera* larvae; 24 hr after multiple exposures, all the larvae died at highest concentration (12.5 ppm); and with λ-cyhalothrin, also highly toxic, after multiple exposures, only 6.67% survival was observed at capping stage, whereas none survived till emergence. Lesser toxicity of λ-cyhalothrin as compared to fenvalerate might be due to difference in honey bee tolerance. Johnson et al. (2006) observed that honey bees showed variation in tolerance to pyrethroids and cytochrome P450 monooxygenases (P450s) plays an important role in detoxification. Among the insecticides evaluated, thiamethoxam was observed to be least toxic to larvae of *A. mellifera*. Earlier, however, thiamethoxam had been reported to be highly toxic to adult bees both via ingestion as well as through indirect contact (Iwasa et al., 2004; Laurino et al., 2011; Shah et al., 2020). It shows that the larval stage of honey bee is more tolerant to thiamethoxam. Lesser toxicity of some of the neonicotinoids to honey bee larvae is known (Yang et al., 2012; Tavares et al., 2015; Tavares et al., 2017). Although the reduction of survival was observed at higher concentrations tested, the survival was high at lower concentrations (residue level). Hence these insecticides can be considered as safe in case honey bee larvae, when exposed through residue in pollen or nectar.

REFERENCES

Abrol D P, Andotra R S. 2003. Relative toxicity of some insecticides to *Apis mellifera* L. Journal of Asia-Pacific Entomology 6(2): 235-237.

Bonmatin J M, Marchand P A, Charvet R, Moineau I, Bengsch E R, Colin M E. 2005. Quantification of imidacloprid uptake in maize crops. Journal of Agricultural and Food Chemistry 53(13): 5336-5341.

Decourtye A, Devillers J. 2010. Ecotoxicity of neonicotinoid insecticides to bees. Thany S H (ed.) Insect nicotinic acetylcholine receptors. Springer, New York, NY. 85-95 pp.

Elbert A, Haas M, Springer B, Thielert W, Nauen R. 2008. Applied aspects of neonicotinoid uses in crop protection. Pest Management Science 64(11): 1099-1105.

EFSA. 2014. Towards an integrated environmental risk assessment of multiple stressors on bees: Review of research projects in Europe, knowledge gaps and recommendations. EFSA Journal 12(3): 3594.

Fukuto T R. 1990. Mechanism of action of organophosphorus and carbamate insecticides. Environmental Health Perspectives 87: 245-254.

Godfray H C J, Blacquiere T, Field L M, Hails R S, Petrokofsky G, Potts S G, Raine N E, Vanbergen A J, McLean A R. 2014. A restatement of the natural science evidence base concerning neonicotinoid insecticides and insect pollinators. Proceedings of the Royal Society B: Biological Sciences 281(1786): 20140558.

González-Varo J P, Biesmeijer J C, Bommarco R, Potts S G, Schweiger O, Smith H G, Steffan-Dewenter I, Szentgyörgyi H, Woyciechowski M, Vilà M. 2013. Combined effects of global change pressures on animal-mediated pollination. Trends Ecology and Evolution 28: 524-530.

Goulson D. 2013. An overview of the environmental risks posed by neonicotinoid insecticides. Journal of Applied Ecology 50: 977-987.

Iwasa T, Motoyama N, Ambrose J T, Roe R M. 2004. Mechanism for the differential toxicity of neonicotinoid insecticides in the honey bee, *Apis mellifera*. Crop Protection 23(5): 371-378.

Johnson R M, Ellis M D, Mullin C A, Frazier M. 2010. Pesticides and honey bee toxicity- USA. Apidologie 41: 312-331.

Johnson R M, Wen Z, Schuler M A, Berenbaum M R. 2006. Mediation of pyrethroid insecticide toxicity to honey bees (Hymenoptera: Apidae) by cytochrome P450 monooxygenases. Journal of Economic Entomology 99(4): 1046-1050.

Kievits J. 2007. Bee gone: colony collapse disorder. Pesticides News 76(6): 3-5.

Klein A M, Vaissiere B E, Cane J H, Steffan-Dewenter I, Cunningham S A, Kremen C, Tscharntke T. 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B: Biological Sciences 274(1608): 303-313.

Laurino D, Porporato M, Patetta A, Manino A. 2011. Toxicity of neonicotinoid insecticides to honey bees laboratory tests. Bulletin of Insectology 64: 107-113.

Marletto F, Patetta A, Manino A. 2003. Laboratory assessment of pesticide toxicity to bumblebees. Bulletin of Insectology 56(1): 155-158.

Matsuda K, Buckingham S D, Kleier D, Rauh J J, Grauso M, Sattelle D B. 2001. Neonicotinoids: insecticides acting on insect nicotinic acetylcholine receptors. Trends in Pharmacological Sciences 22(11): 573-580.

McGregor S E. 1976. Insect pollination of cultivated crop plants. Agriculture handbook No. 496. Agricultural Research Service, US Department of Agriculture Washington, DC.

Narahashi T. 1962. Effect of the insecticide allethrin on membrane potentials of cockroach giant axons. Journal of Cellular and Comparative Physiology 59(1): 61-65.

Nauen R, Ebbinghaus-Kintscher U, Salgado V L, Kaussmann M. 2003. Thiamethoxam is a neonicotinoid precursor converted to clothianidin in insects and plants. Pesticide Biochemistry and Physiology 76(2): 55-69.

Neumann P, Carreck N L. 2010. Honey bee colony losses. Journal of Apicultural Research 49: 1-6.

OECD. 1998. Test No. 213: Honeybees, Acute Oral Toxicity Test. OECD Guidelines for the testing of chemicals, Section 2. OECD Publishing, Paris.

Ollerton J, Winfree R, Tarrant S. 2011. How many flowering plants are pollinated by animals? Oikos 120: 321-326.

Potts S G, Biesmeijer J C, Kremen C, Neumann P, Schweiger O, Kunin W E. 2010. Global pollinator declines: Trends, impacts and drivers. Trends in Ecology and Evolution 25(6): 345-353.

Shah R, Al Maawali A S A, Al Raeesi A. 2020. Comparative toxicity of two neonicotinoids and a pyrethroid to forager honeybees (*Apis mellifera* L., 1758) (Hymenoptera: Apidae) by different exposure methods. Türkiye Entomoloji Dergisi (Turkish Journal of Entomology) 44(1): 111-121.

Tan J, Galligan J J, Hollingworth R M. 2007. Agonist actions of neonicotinoids on nicotinic acetylcholine receptors expressed by cockroach neurons. Neurotoxicology 28(4): 829-842.

Tautz J. 2008. The buzz about bees: Biology of a superorganism. Springer-Verlag Berlin Heidelberg. pp 284.

Tavares D A, Dussaubat C, Kretzschmar A, Carvalho S M, Silva-Zacarin E C, Malaspina O, Berail G, Brunet J, Belzunces L P. 2017. Exposure of larvae to thiamethoxam affects the survival and physiology of the honey bee at post-embryonic stages. Environmental Pollution 229: 386-393.

Tavares D A, Roat T C, Carvalho S M, Silva-Zacarin E C M, Malaspina O. 2015. In vitro effects of thiamethoxam on larvae of Africanized honey bee *Apis mellifera* (Hymenoptera: Apidae). Chemosphere 135: 370-378.

Thany S H. 2011. Thiamethoxam, a poor agonist of nicotinic acetylcholine receptors expressed on isolated cell bodies, acts as a full agonist at cockroach cercal afferent/giant interneuron synapses. Neuropharmacology 60(4): 587-592.

Van der Sluijs J P, Simon-Delso N, Goulson D, Maxim L, Bonmatin J M, Belzunces L P. 2013. Neonicotinoids, bee disorders and the sustainability of pollinator services. Current Opinion in Environmental Sustainability 5: 293-305.

VanEngelsdorp D, Hayes Jr J, Underwood R M, Pettis J. 2008. A survey of honey bee colony losses in the US, fall 2007 to spring 2008. PloS One 3(12): e4071.

Yang E C, Chang H C, Wu W Y, Chen Y W. 2012. Impaired olfactory associative behavior of honey bee workers due to contamination of imidacloprid in the larval stage. PloS One 7(11): e49472.

(Manuscript Received: September, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20352

Indian Journal of Entomology 84(1): 54-58 (2022) DoI.: 10.55446/IJE.2021.297

GELATIN CAPSULES TO ENHANCE THE EFFICACY OF *LECANICILLIUM LECANII* AGAINST *MYZUS PERSICAE*

Sharada Boodal, Ramanagouda S H*, Venkateshalu and Jamunarani G S

Department of Entomology, College of Horticulture, Bagalkot 587104, Karnataka, India
*Email: goudaento@gmail.com (corresponding author)

ABSTRACT

Evaluation of gelatin capsule-based formulations of indigenous isolate of *Lecanicillium lecanii* (Zimm.) Zare and Games was carried out at the College of Horticulture, Bagalkot during 2018-19. The gelatine capsules filled with different ratios of spore and talc powder (1:0, 1:1, 1:2 and 1:3) were evaluated in the laboratory for their efficacy against aphid *Myzus persicae*. The results indicate that equal quantity of spore and talc powder showed better efficacy than other two combinations and next best to spore alone. The gelatine capsules containing the spore powder alone though proved better with maximum mortality when it was used fresh and immediately after their formulation; the efficacy decreased drastically after 30 days after storage. Evaluation of their storability, under varying storage conditions revealed that refrigerated condition is the best in maintaining the virulence of the spore after four months of storage period. The pot culture experiment revealed that significantly more mortality of aphid was obtained with gelatine capsules formulations of local isolate of *L. lecanii* as compared to commercial formulation.

Key words: *Lecanicillium lecanii*, capsule formulations, gelatin, virulence, spore, talc powder, *Myzus persicae*, mortality, storage, period, refrigeration, pot culture

The development of insecticide resistance and their effects on the human kind have forced the scientists for the development of biological based IPM strategies. Biological control is receiving a new thrust and it has become an integral component of IPM in several crops. Due to its host specificity, protect natural enemies, ease in production, farmers and producer's friendly, ecofriendly and better compatibility with other methods, it can be a sustainable option in IPM. Among the entomopathogens, the entomopathogenic fungi (EPF) are currently used in large scale for the management of crop pests. These are having diverse advantages like wider host range, ease of mass production and relatively good environmental tolerance over other entomopathogens. In addition, these occur in frequent epizootics in nature both on chewing and sucking insect pests. Unlike, other entomopathogens such as bacteria and viruses which require ingestion of contaminated food, mere contact of the host is sufficient for the EPF to cause disease. A huge number of myco-insecticides have reached the market and millions of hectares are being treated annually with EPF globally. Though, the efficiency of most of the formulations developed have proved good under laboratory conditions and but are proved ineffective in field trials. The inefficiency in field condition is mainly attributed to loosing virulence by ultraviolet (UV) rays, short shelf life and harsh environmental conditions. Hence, keeping this in view, improving the efficacy is attempted in this study with capsule-based formulations and their evaluation under laboratory and pot culture experiments.

MATERIALS AND METHODS

The study was conducted at the College of Horticulture, Bagalkot during 2018-19 to evaluate the capsule-based formulations of indigenous isolate of *L. lecanii* against *M. persicae* under both laboratory and pot culture experiments. The pure slant cultures of identified virulent local isolate of *L. lecanii* (LL-2) was maintained by subculturing on Sauboured Maltose Agar (SMA) medium and their virulence was retained by inoculation and reisolating on their natural hosts. The spore powder of *L. lecanii* was prepared by growing it on broken grains of rice. About 50 g of broken grains was taken in 250 ml flask containing 50 ml of distilled water and autoclaved at 121˚C for 30 min. After sterilization, broken grains were cooled under room temperature. The cooled flasks containing the broken grains were inoculated with pure culture of *L. lecanii* under aseptic condition in laminar air flow chamber. The inoculated flasks were incubated at room temperature for 15 days under dark condition to harvest the spores. Later, spores were dried and ground for 30 sec to make it as fine powder. Powder formulations were developed by mixing spore powder of *L. lecanii* obtained from rice

grains with talc powder in different ratios (1:1, 1:2 and 1:3) and made into fine dust by grinding for 30 sec to facilitate for easy packing into empty gelatine capsules (2.0x 0.5 cm dia) to hold 2 g powder, obtained from M/s. Amazon Pvt Ltd. Wild population of the test insect, cabbage aphid was collected from vegetable fields of COH, Bagalkot. Its culture was maintained on cabbage seedlings grown under nethouse condition. When plants were 15-20 days old, the field collected aphids were released and the culture of aphids was maintained till completion of the experiment.

The efficacy of gelatine capsules of *L. lecanii* against *M. persicae* was evaluated with leaf dip bioassay. Cabbage leaf disc of 9 cm dia was dipped in gelatine capsule dissolved solution of *L. lecanii* for two min and then air dried and placed onto petridish (10cm dia.). About twenty apterous *M. persicae* were released on to petridish and allowed to feed. The experiment was conducted with five treatments - spore + talc powder (1:1), spore + talc powder (1:2), spore + talc powder (1:3), spore powder alone and control) with $2x10^8$cfu/ ml dosage and three replications at room temperature. Observations on number of moribund and dead aphids recorded at three, five, seven and ten days after treatment (DAT) were made and % mortality of aphid was computed. The spore viability was studied for best gelatine capsule formulations containing spore + talc powder (1:1) and spore powder alone of *L. lecanii* at monthly intervals up to four months. The formulations were stored at different storage conditions- refrigerated condition (4 °C), mud pot filled with wet sand (10- 15 °C) and ambient condition (28 °C). The bioefficacy study was conducted at monthly intervals up to four months against *M. persicae* with seven replications. The experiment to evaluate the efficacy of capsule formulations of *L. lecanii* against *M. persicae* was conducted on potted cabbage plants with five treatments and four replications under CRD design. The treatments were imposed after uniform natural infestation of *M. persicae* using the hand operated sprayer. Pretreatment observations one day earlier and subsequent observations on one, three, five, seven, ten and fifteen days after treatment were made on number of *M. persicae*/ cm^2 leaf. Data on aphid counts were subjected to square root transformation for reliable analysis and treatments means were compared by Duncan's Multiple Range Test (DMRT, p=0.05%).

RESULTS AND DISCUSSION

The results reveal that the mortality of *M. persicae* increased with advancement of 10 days exposure period. Gelatin capsule formulation of *L. lecanii* spore alone recorded significantly high mortality (90.00%) which was followed by spores mixed with talc powder in the ratio of 1:1 (82.50%). No mortality of aphid was recorded in untreated control (Table 1). The mortality of nymphs of *M. persicae* was noticed after three days of treatment, and this reached 100% after five to seven days after treatments. Similarly, Ei-Sinary and Quesada-Moraga (2006) observed that the efficacy of the EPF began clearly after 48 hr after inoculation and during which hyphae penetrated the integument, epithelial and epidermal cells. After 72 hr, fungi damage the fat tissues and finally, mortality reached 100% after 96 hr.

Table 1. Efficacy of gelatine capsule formulations of *L. lecanii* against *M. persicae* under laboratory conditions

Treatments	Formulations	Cumulative mortality (%)				
		3 DAT	5 DAT	7 DAT	10 DAS	Mean
T_1	Spore + talc powder (1:1)	65.00 (53.73)^b	77.50 (61.68)^b	87.50 (69.30)^b	100 (90.00)^a	82.50 (65.27)^b
T_2	Spore + talc powder (1:2)	47.50 (43.57)^c	52.50 (46.43)^c	67.50 (55.24)^c	75.00 (60.00)^b	60.62 (51.13)^c
T_3	Spore + talc powder (1:3)	32.50 (34.76)^d	37.50 (37.76)^d	47.50 (43.57)^d	57.50 (49.31)^c	43.75 (41.40)^d
T_4	Spore powder alone	75.00 (60.00)^a	85.00 (67.21)^a	100.00 (90.00)^a	100.00 (90.00)^a	90.00 (71.56)^a
T_5	Control	0.00 (0.29)^e	0.00 (0.29)^e	0.00 (0.29)^e	0.00 (0.29)^d	0.00 (0.29)^e
S. Em.±		0.26	0.24	0.59	0.32	0.36
CD (p=0.05)		0.81	0.74	0.19	0.12	0.47
CV (%)		3.12	2.73	2.05	2.5	2.6

DAT-Days After Treatment; Figures in the parentheses arcsine transformed values; In a column, means followed by same alphabet (s) do not differ significantly by DMRT (p=0.05); Dosage $2x10^8$ cfu/ ml

Among the eight wettable powder (WP) formulations evaluated, the crude WP registered the least LC_{50} value of 80.09 x 10^3 conidia ml^{-1} followed by talc-based WP and rice flour. Among the WP formulations crude formulation recorded 82% mortality followed by talc and rice flour. Similarly, Mallikarjuna et al. (2010) formulated *M. rileyi* as WP using different carrier materials viz., bentonite + glucose (7:1), bentonite + sucrose (7:1), talc + glucose (7:1) and talc + sucrose (7:1); these were evaluated against *Spodoptera litura* and *Helicoverpa armigera* resulting in mortalities of 72-87% in the former and 66- 88% in the latter. Hence, the present study indicated that efficacy increases with incorporating the spores in the gelatine capsules with equal proportion of talc. This can be attributed to the retention of moisture inside the capsule.

The pot culture experiment revealed reduction in counts of *M. persicae* with capusule formulation over commercial formulations of *L. lecanii*; maximum reduction being with standard check, chlorantraniliprole 18.5 SC followed by NSKE 5%. Six isolates of *L. lecanii* screened against *A. craccivora* revealed that, *L. lecanii*-3 as most virulent EPF isolate $1x10^8$ cfu/ ml (Table 2). Naik and Shekharappa (2009) evaluated fungal formulations against sucking pests of okra, and oil based formulations were observed to be superior in reducing the pests giving increased fruit yield. The study conducted by Gulsar and Gopalakrishnan (2012) on management of *Paracoccous marginatus* in potted papaya plant revealed that the oil-based formulations of local isolate of *L. lecanii* was more efficient compared to talc-based formulations. The efficacy of *B. bassiana* and *L. lecanii* against whitefly under polyhouse condition showed 69.64 to 85.65% mortality. Rashmi (2018) conducted the semi-field experiment to evaluate the effectiveness of oil formulations of *M. rileyi* against *S. litura* damaging cabbage. Among the tested formulations of *M. rileyi*, the groundnut oil formulation was efficient (31.73%) as compared to the rest of the formulations. Similarly, Varun (2018) evaluated the effectiveness of *L. lecanii* oil formulations against *M. persicae*. Among the formulations, sesamum oil was superior. The effectiveness of formulated products depends mainly on external factors. Thus, there was a significant difference in suppressing the *M. persicae* in tested gelatine capsules over commercial formulation available in the market.

The gelatine capsule formulations stored under refrigerator condition recorded the significantly more mortality with >30% in all the formulations even at

Table 2. Evaluation of selected capsule formulations of *L. lecanii* against *M. persicae* under pot culture experiment

Tr. No.	Treatments	Dosage	I Spray						II Spray					
			Number of aphids / 5 cm^2 leaf area						Number of aphids / 5 cm^2 leaf area					
			DBS	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS	Mean	DBS	3 DAS	5 DAS	7 DAS	10 DAS	15 DAS	Mean
T_1	Gelatine capsule formulation	2 capsules/1	22.21 (4.71)	16.85 (4.16)^e	15.85 (4.04)^e	16.42 (4.05)^b	19.57 (4.36)^b	22.28 (4.71)^a	18.19	15.74 (3.96)	12.14 (3.55)^e	11.42 (3.45)^e	12.14 (3.55)^b	12.71 (3.63)^e	13.78 (3.77)^a	12.43
T_2	Chlorantraniliprole 18.5 SC	0.2ml/1	23.42 (4.83)	6.28 (2.60)^e	3.85 (2.08)^e	0.28 (0.52)^d	2.28 (1.66)^e	4.14 (4.09)^d	3.36	15.57 (3.94)	4.53 (3.28)^d	2.71 (1.79)^e	0.85 (1.16)^d	2.64 (1.77)^e	4.14 (2.15)^b	2.97
T_3	NSKE	5%	22.85 (4.78)	14.42 (3.86)^d	14.00 (3.80)^d	13.28 (3.64)^e	14.57 (3.86)^d	16.28 (3.36)^e	14.51	15.64 (3.95)	10.28 (2.24)^e	9.42 (3.14)^d	8.85 (3.05)^e	9.56 (3.17)^d	14.67 (3.86)^a	10.55
T_4	Commercial formulation of *L. lecanii* @ 2 X 10^8 cfu/ ml	2 g/ 1	20.81 (4.56)	17.57 (4.25)^b	16.42 (4.11)^b	15.85 (3.98)^b	17.28 (4.21)^c	18.42 (4.34)^e	17.10	15.57 (3.94)	13.28 (3.71)^b	12.53 (3.60)^b	11.85 (3.51)^b	13.42 (3.73)^b	14.56 (3.88)^a	13.13
T_5	Control	-	22.22 (4.71)	21.22 (4.66)^a	22.65 (4.81)^a	22.5 (4.74)^a	21.50 (4.69)^a	21.60 (4.70)^b	21.89	15.64 (3.95)	15.71 (4.01)^a	15.03 (3.94)^a	14.42 (3.86)^a	14.99 (3.93)^a	15.24 (3.96)^a	15.08
S. Em.±				0.022	0.022	0.038	0.022	0.015	-		0.038	0.031	0.038	0.027	0.122	-
C.D.(5%)			NS	0.024	0.023	0.076	0.028	0.016	-	NS	0.039	0.038	0.066	0.029	0.374	-
C.V. (%)				0.386	0.394	1.527	0.435	0.275	-		0.766	0.682	1.340	0.544	7.059	-

DBS- Days before spray; DAS- Days After Spraying; Figures in parentheses square root transformed value. In a column, means followed by same alphabet (s) do not differ significantly by DMRT (p=0.05)

120 days of storage. Similarly, the formulations stored under mud pot filled with wet sand also recorded the desirable mortality of *M. persicae*. The formulation stored under room temperature gave less mortality. The reason for the higher mortality of *M. persicae* in above storage condition might be due to low temperature which retained the viability of fungal spore and lead to maximum mortality. Among the capsule formulations of *L. lecanii*, the ones filled with spore and talc resulted in maximum mortality of *M. persicae* for a prolonged period of storage. It might be attributed to the talc which served a good carbon source (35-100 %) and mineral composition. While spore powder alone maintained the superiority only short storage period (<30 days). The least mortality was observed in the formulations stored under room temperature during storage period. These results are in confirmation with the studies conducted by Simkova (2009) that conidial germination of *B. bassiana* was maximum (97.33 %) at 4˚C after 90 days of treatment compared to 22˚C. Viability of *M. anisopliae* was found better at 10˚C than 27˚C for all tested oil-based formulations when stored for 40 weeks. Viability of *M. rileyi* conidia was about 50% even after six months of storage as reported by Swetha (2011) and Ramegowda (2005) had reported 82.47% conidial viability of *M. rileyi* formulations stored for 180 days in refrigerated condition compared to only 63.23% per cent under room temperature with talc. The present studies revealed that, carrier material, temperature and storage duration had significant effect on *M. persicae* mortality. Virulence decreased over storage time in all the formulations across different storage conditions.

ACKNOWLEDGEMENTS

The authors thank the Department of Science & Technology (DST), Science for Equity, Empowerment and Development Division (SEED Division), New Delhi for financial assistance.

REFERENCES

Alves R T, Bateman R P, Gunn J, Prior C, Leather S R. 2002. Effects of different formulations on viability and medium-term storage of *Metarhizium anisopliae* Conidia. Netropical Entomology 31: 91-99.

Banu J G. 2013. Effect of different storage conditions on spore viability of *Lecanicillium lecanii* formulations and infectivity to mealy bug, *Paracoccus marginatus*. International Journal of Plant Protection 6(2): 334-337.

Brar S K, Verma M, Tyagi R D, Valero J R. 2006. Recent advances in downstream processing and formulations of *Bacillus thuringiensis* based bio pesticides. Process Biochemistry 41(2): 323-342.

El-Sinary G H. 2006. Influence of the entomopathogenic fungus, *Beauveria bassiana* (Balsamo) on the mature larvae of the potato tuber moth, *Phthorimaea operculella* (Zeller) under different degrees of temperature and relatively humidity. Journal of Agricultural Sciences 27: 4151-4161.

Faria M R, Wraight S P. 2007. Mycoinsecticides and mycoacaricides: a comprehensive list with worldwide coverage and international classification of formulation types. Journal of Biological Control 43(3): 237-256.

Fleming R A, Retnakaran A. 1985. Evaluating single treatment data using Abbott's formula with reference to insecticides. Journal of Economic Entomology 78(6): 1179-1181.

Gangwar R K. 2017. Role of biological control agents in integrated pest management approaches. Acta Scientific Agriculture 1(2): 365-2581.

Gokak R, Ramanagouda S H, Jayappa J. 2017. Collection, isolation and bioassay studies of indigenous isolates of *Lecanicillium lecanii* (Zimm.) Zare and Games against *Myzus persicae* (Sulzer). Journal of Entomology and Zoology studies 5(2): 686-691.

Gulsar B J, Gopalakrishnan N. 2012. Development of formulations of a native entomopathogenic fungus, *Lecanicillium lecanii* and testing virulence against mealy bug, *Paracoccus marginatus* infesting cotton. Indian Journal of Plant Protection 40(3): 182-186.

Hossain M M, Khalequzzaman K M, Mondal M T R, Alam J, Islam M S. 2016. Development of Management Approach against Thrips-Mite Complex of Chilli. International Journal of Scientific Research in Agricultural Sciences 3(1): 18-24.

Karthikeyan A, Selvanarayanan V. 2013. *In vitro* efficacy of *Beauveria bassiana* (Bals.) Vuill. and *Verticillium lecanii* (Zimm.) viegas against selected insect pests of cotton. Recent Research in Science and Technology 3(2): 142-143.

Kaur G, Padmaja V, Sasikala V. 1999. Control of insect pests on cotton through mycopesticide formulations. Indian Journal of Microbiology 39 (2): 169-173.

Mallikarjuna D R, Patil R K, Sujay Y H, Ramegowda G K. 2010. Development and evaluation of wettable powder and oil based formulations of *Nomuraea rileyi* (Farlow) Samson against *Helicoverpa armigera* (Hubner) and *Spodoptera litura* (Fabricius). Journal of Biological Control 24 (3): 231-237.

Manjula K, Krishna Murthy K V M. 2005. Efficacy of *Nomuraea rileyi* against different instars of *Spodoptera litura* and *Helicoverpa armigera*. Annals of Plant Protection Sciences 13 (2): 347–350.

Naik P R H, Shekharappa. 2009. Field evaluation of different entomopathogenic fungal formulations against sucking pests of okra. Karnataka Journal of Agricultural Sciences 22 (3): 575-578.

Pandey A K, Kanaujia K R. 2005. Effect of different grains as solid substrates on sporulation, viability and pathogenecity of *Metarhizium anisopliae* (Metschnikoff) Sorokin. Journal of Biological Control 22(2): 369-374.

Pillai K G, Visalakshy P N G. 2017. Entomopathogenic fungi for the management of whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae) on gerbera (*Gerbera jamesonii*) in polyhouses. Pest Management in Horticulture Ecosystem 23: 31-36.

Quesada-Moraga E J, Carrasco-Diaz A, Santiago-Alvarez C. 2006. Insecticidal and antifeedant activities of proteins secreted by entomopathogenic fungi against *Spodoptera littoralis* (Lepidoptera: Noctuidae). Journal of Applied Entomology 130 (8): 442-452.

Ramegowda G K. 2005. *Aerobiology, epizootiology and utilization of Nomuraea rileyi* (Farlow) Samson, PhD thesis, University of Agricultural Sciences, Dharwad.

Rashmi S H. 2018. Development and evaluation of formulations of *Nomuraea rileyi* (Farlow) Samson against *Spodoptera litura (*Fabricius*)* on cabbage, M Sc thesis. University of Horticultural Sciences, Bagalkot.

Shah P A, Pell J K. 2003. Entomopathogenic fungi as biological control agents. Applied Microbiology and Biotechnology 61(4): 413-423.

Sharmila T, Manjula K, Murali Krishna T. 2015. Evaluation of oil formulations of *Nomuraea rileyi* (Farlow) Samson against *Spodoptera litura* under laboratory conditions. International Journal of Plant Sciences 10(7): 29-32.

Simkova J. 2009. Influence of different storage conditions on vitality and virulence of *Beauveria bassiana* spores. Journal of Agrobiology 26(2): 75-81.

Sowmya G, Ramanagouda S H, Jayappa J. 2017. Lethal and sublethal effect of indigenous isolates of *Metarhizium anisopliae* (Metchnikoff) Sorokin against *Spodoptera litura* (Fabricius). Journal of Entomology and Zoology studies 5(4): 1154-1160.

Suresh B C, Khan H K, Prasanna P M. 2012. Efficacy of different entomopathogenic fungi against cowpea aphid, *Aphis craccivora* Koch under laboratory conditions. International Journal of Plant Protection 5(1): 68-71.

Swetha K. 2011. Evaluation of dry formulations of *Nomuraea rileyi (Farlow) Samson* and molecular characterization of its isolates, M Sc thesis, Acharya N G Ranga Agricultural University, Hyderabad.

Varun Y B. 2018. Development and evaluation of formulations of *Lecanicillium lecanii* (Zimm.) Zare and Games against *Myzus persicae* (Sulzer) on cabbage, M Sc thesis, University of Horticultural Sciences, Bagalkot.

(Manuscript Received: September, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20342

Indian Journal of Entomology 84(1): 59-63 (2022) DoI.: 10.55446/IJE.2021.292

DIVERSITY OF ENCYRTID PARASITOIDS FROM THREE ECOSYSTEMS

M S Abhishek*, Prashanth Mohanraj[1], A Rameshkumar[2] and K Veenakumari[1]

Department of Agricultural Entomology, University of Agricultural Sciences, Bengaluru 560045, Karnataka, India
[1]ICAR- National Bureau of Agricultural Insect Resources, Bengaluru 560045, Karnataka, India
[2]Zoological Survey of India, M-Block, New Alipore, Kolkata 700053, West Bengal, India
*Email: abhigowda02@gmail.com (corresponding author)

ABSTRACT

Encyrtid parasitoids play an important role in the biological control of many agricultural as well as horticultural pests. The present study determines and compares the faunal and temporal diversities of Encyrtidae in finger millet, rice and sugarcane ecosystems at the College of Agriculture, V C Farm, Mandya, Karnataka. The study was conducted at fortnightly intervals over a period of 12 months from March, 2016 to February, 2017 at the G and C-blocks of the farm. As a result, 2647 encyrtids were collected- 1019 specimens (20 genera) were from finger millet; 604 (22 genera) and 1024 (29 genera) were from rice and sugarcane ecosystems, respectively. The abundance, Shannon-Wiener index, Simpson index and richness (Margalef's index) were computed and it was concluded that maximum diversity occurred in sugarcane and rice ecosystems (H′=3.00) and the least was with the finger millet ecosystem (H′=.2.78). Bray-Curtis cluster analysis and Metric Multidimensional scaling analysis were made to study the similarity and encyrtid diversity in different seasons.

Key words: Encyrtidae, Mandya, abundance, rice, finger millet, sugarcane, Shannon-Wiener index, Simpson index, richness (Margalef's index), Bray-Curtis analysis

Encyrtidae is one of the largest families of superfamily Chalcidoidea of parasitic Hymenoptera group and they are highly diverse micro-hymenopterans with 3710 described species under 455 genera (Noyes and Valentine, 1989). At present, 742 species of Encyrtidae are known from India (Noyes, 2020). Hymenopterans act as useful biodiversity indicators as their abundance and richness reflect the diversity of other arthropods (Anderson et al., 2011). Encyrtids play an important role in communities, as they are endoparasitoids or hyperparasitoids of other arthropod pests and have the greatest impact on maintaining the diversity. These can be used as efficient biological control agents against key insect pests, and are important primary parasitoids of mealybug, scales, aphids and also other insects like Lepidoptera, Neuroptera and the eggs of ticks and spiders (Hayat, 2006). Three important crops viz., finger millet, rice and sugarcane of Karnataka were selected for the present study. Their cultivation practices differ significantly with finger millet being a rainfed crop, sugarcane an irrigated crop and rice, a crop that is submerged in water throughout its growth period. In addition, sugarcane is an annual crop; rice and finger millet are seasonal in nature. Plant architecture too varies between these crops. The interplay of these factors can be expected to impact the diversity as well as faunal composition of encyrtid parasitoids.

MATERIALS AND METHOD

This study was conducted to determine and compare the faunal and temporal diversities of encyrtids in finger millet, rice and sugarcane ecosystems at the College of Agriculture, V C Farm, Mandya, Karnataka under southern dry zone of Karnataka (12°34.3'N, 76°49.8'E, 697 masl). The study was conducted over a period of 12 months from March, 2016 to February, 2017 at the G and C-blocks of the farm. Rice was cultivated in C block of an area of 2 ha and G block where the finger millet and sugarcane crops were grown in an area of 1 and 4 ha, respectively. A distance between the finger millet and sugarcane crops in G block is half a km. The varieties of finger millet grown in the first cropping season were MR-1 and MR-6 and in the 2nd season were INDOF-9 and INDOF-7. Hybrid lines of rice were grown in both cropping seasons, while VCF-0517 variety of sugarcane was grown in both seasons of study period. Yellow pan traps (YPT) work on the principle of yellow colour being attractive to insects (Hollingworth et al., 1970). Twenty yellow pan traps (21cm dia., 2cm deep) were laid on the ground, randomly at fortnightly

intervals from March (79th Julian day), 2016 to February (49th Julian days), 2017 in each of the three ecosystems of experiment site to collect encyrtid parasitoids. Twenty-four hours after the installation of the traps, the contents (water plus the trapped insects) were sieved and collected in 70% ethanol for further sorting. The samples collected contained Hymenoptera, Diptera, Coleoptera, Lepidoptera, Collembolans, Diplurans, etc., Encyrtidae were sorted under a stereozoom microscope, and were identified up to generic level through the keys provided by Hayat (2006) and Noyes and Hayat (1994).

Generic abundance data were tabulated and analysed across time to ascertain the temporal changes in the diversity of Encyrtidae in finger millet, rice and sugarcane ecosystems. Generic richness (Margalef's diversity index D_{mg} = S-1 / ln N, Where, S is the number of genera recorded and N is the number of individuals combined of all S genera), Shannon-Wiener index (H' = - ∑ Pi ln Pi …… Eq. 1, Where, Pi = Proportion of individuals of genera i) and Simpson index (D = 1-∑ Pi^2 …… Eq. 2, Pi = Proportion of individuals of genera i) were estimated. Multivariate analyses such as Bray Curtis Cluster analysis and Metric Multidimensional scaling (M-MDS) analysis were done using PRIMER version 7.0.5 (Clarke and Gorley, 2015). Abbreviations used: ACE – *Acerophagus*; ADE – *Adelencyrtus*; AGA – *Agarwalencyrtus*; ALO – *Aloencyrtus*; ALA – *Alamella*; ANA – *Anagyrus*; ANI – *Anicetus*; ANO – *Anomalicornia*; APO – *Apoleptomastix*; BLE – *Blepyrus*; CAL – *Callipteroma*; CHE - *Cheiloneurus*; COP - *Copidosoma*; DIV - *Diversinervus*; ENC - *Encyrtus*; GEN - *Gentakola*; HOM - *Homalotylus*; LEP - *Leptomastix*; MET - *Metaphaenodiscus*; MEP - *Metaphycus*; MIC - *Microterys*; NEO - *Neodusmetia*; OOE - *Ooencyrtus*; PEN - *Pentelicus*; PRO - *Prochiloneurus*; PRT - *Protyndarichoides*; RHO - *Rhopus*; SAK - *Sakencyrtus*; TAS- *Tassonia*; ZAP - *Zaplatycerus*.

RESULTS AND DISCUSSION

Abundance: A total of 2647 encyrtids were collected from finger millet, rice and sugarcane ecosystem. Among these, 1019 individuals belonging to 20 genera were from finger millet ecosystem, 604 individuals of 22 genera and 1024 individuals of 29 genera in rice and sugarcane ecosystems, respectively. Crop architecture too is similar in all these crops. Increasing complexity in canopy density is also noticed with abundance increasing progressively from finger millet to rice to sugarcane. Waschke et al. (2014) stated that the increasing parasitoid diversity and abundance is direct proportional to the plant diversity and foliage. As results of one year survey, 30 genera of Encyrtidae were collected from finger millet, rice and sugarcane ecosystems. *Encyrtus, Homalotylus* and *Sakencyrtus* were only collected from finger millet and sugarcane ecosystems. *Anicetus, Protyndarichoides, Metaphaenodiscus* and *Procheiloneurus* were only recorded in the rice and sugarcane ecosystems. *Zaplatycerus* were found exclusively in the rice ecosystem. *Microterys, Gentakola, Pentelicus, Agarwalencyrtus* and *Alamella* were collected from the sugarcane ecosystem (Table 1). These findings are supported by Randhawa et al. (2006) where, *Copidosoma* sp. and *Copidosomopsis nacoleiae* on rice leaf folder *Cnaphalocrocis medinalis* from India was reported and Dung (2006) reported *Copidosomopsis coni* from Vietnam. Similarly, Sallam (2006) reviewed and listed the major parasitoid families viz., Encyrtidae, Bethylidae, Braconidae,

Table 1. Richness and abundance of encyrtid parasitoids (March-2016 to February-2017)

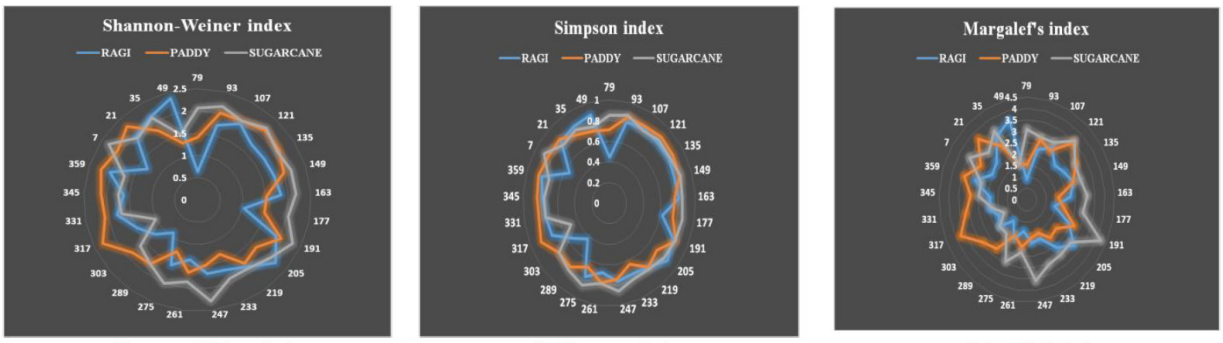
Sl. No.	Generic richness	Abundance		
		Finger millet	Rice	Sugarcane
1	*Acerophagus*	46	13	101
2	*Adelencyrtus*	9	12	11
3	*Agarwalencyrtus*	0	0	10
4	*Alamella*	0	0	8
5	*Aloencyrtus*	56	6	14
6	*Anagyrus*	32	22	44
7	*Anicetus*	0	14	13
8	*Anomalicornia*	73	12	9
9	*Apoleptomastix*	13	8	35
10	*Blepyrus*	4	6	4
11	*Callipteroma*	10	14	18
12	*Cheiloneurus*	53	32	17
13	*Copidosoma*	438	113	277
14	*Diversinervus*	3	18	11
15	*Encyrtus*	1	0	8
16	*Gentakola*	0	0	9
17	*Homalotylus*	15	0	24
18	*Leptomastix*	6	7	21
19	*Metaphaenodiscus*	0	14	17
20	*Metaphycus*	119	47	92
21	*Microterys*	0	0	6
22	*Neodusmetia*	42	164	107
23	*Ooencyrtus*	26	19	103
24	*Pentelicus*	0	0	5
25	*Procheiloneurus*	0	9	10
26	*Protyndarichoides*	0	12	9
27	*Rhopus*	48	35	25
28	*Sakencyrtus*	4	0	5
29	*Tassonia*	21	14	11
30	*Zaplatycerus*	0	13	0
	Total	1019	604	1024

Chalcididae, Elasmidae, Eucoilidae, Eulophidae, Ichneumonidae, Eupelmidae, Pteromalidae, Scelionidae and Trichogrammatidae on sugarcane pests. The genus *Copidosoma* (438 individuals), *Neodusmetia* (164 individuals), *Copidosoma* (277 individuals) were the most abundant in finger millet, rice and sugarcane ecosystems, respectively, whereas, the least abundant genus was *Encyrtus* (1 individual) in finger millet; *Blepyrus* and *Aloencyrtus* (6 individuals) in rice and *Blepyrus* (4 individuals) in sugarcane ecosystem (Table 1). *Copidosoma* is most abundant in three ecosystems because these individuals are major egg larval parasitoids of many lepidopteran pests. *Cheiloneurus* sp. had been recorded as a hyperparasitoid of dryinids on *N. lugens* in Vietnam (Lam, 2002).

Diversity: The Shannon-Wiener index diversity values for the three ecosystems revealed that it was more or less similar, with maximum diversity accounted for the sugarcane and rice ecosystems (H′=3.00) and the least diversity in the finger millet ecosystem (H′=.2.78). The Simpson's index values were near to one for all the three ecosystems, even though there was a difference in the assemblages of the parasitoids. The sugarcane (0.94) and rice (0.94) ecosystems showed maximum Simpson's index, followed by finger millet (0.92) ecosystem. From the values of the Margalef index (α), it was observed that the sugarcane ecosystem was very rich in genera with a richness value of 3.53, followed by finger millet (3.35) and rice (3.25) with closely similar values. Thus, it is clear that species diversity and richness did not vary greatly between the ecosystems. Crop architecture too is similar in all these crops. Increasing complexity in canopy density can however be noticed with diversity increasing progressively from finger millet to rice to sugarcane. The majority of the studies reviewed by Waschke et al. (2014) revealed an increasing parasitoid diversity and abundance as a result of increased plant diversity and foliage.

Temporal variation and generic richness: The highest Shannon-Wiener index, Simpson index and Margalef's index, 2.36, 0.88, 3.60, respectively were observed during monsoon whereas the least of Shannon-Wiener (0.63), Simpson (0.44) and Margalef's indices (0.91) were observed during early summer (Fig. 1a-c). Encyrtid parasitoids were the most abundant during the monsoon, because of the lush growth of the crops as well as weeds and also a large number of plants resources. The availability of hosts and plentiness of nectar enabled the increase in parasitoids. Though the number of individuals varied significantly, very little variation was noticed in the number and composition of the families of parasitoids. Daniel et al. (2020) also compared the diversity of parasitic Aculeata in high rainfall zone and dry zone (Cauvery delta zone) and results revealed that, the high rainfall zone was the most diverse and the dry zone (Cauvery delta zone) become the least diverse. The population of encyrtid parasitoids were the least during summer and post monsoon months due to high temperature, less rainfall and availability of host as well as plant resources. Similarly, Anbalagan et al. (2015) stated that the parasitoid abundance and diversity were maximum during the monsoon and winter seasons. In Mandya, the diversity and abundance of parasitoids was more in monsoon followed by summer.

Bray Curtis cluster Analysis and M-MDS analysis: In rice, the data showed that there were three clusters formed between the seasons- 1. post monsoon (75% similarity); 2. a mixed cluster between post monsoon and winter (December-16 and February 17); 3. again, a mixed cluster between summer and monsoon season (April 16 and July 16) (Fig. 2a). The collected raw data from rice ecosystem are highly validated through M-MDS. The analysis revealed the high diversity status of Encyrtidae parasitoids observed between the seasons of post monsoon and winter (December 16- February 17). The contribution of CHE,



a. Shannon-Weiner index b. Simpson index c. Margale index

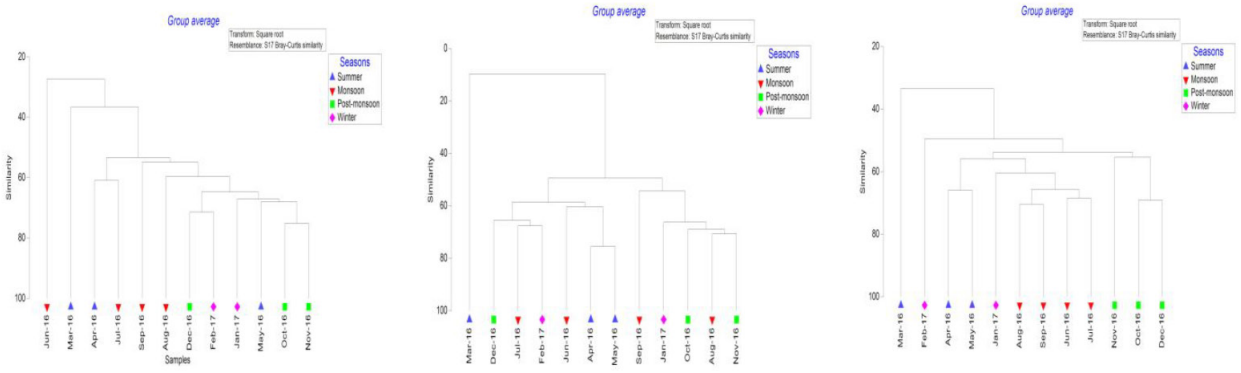
Fig. 1. Temporal variation in diversity of Encyrtidae in finger millet, rice and sugarcane ecosystems

TAS, PRT, ADE, ANO and OOE were observed more towards the seasons between summer and monsoon (April 16- July 16) (Fig. 3a). In finger millet, there were three clusters- 1. that formed between summer and early monsoon period (April 16- June 16); 2. that formed between 3 different seasons (July 16, December 16 and February 17); and the third also between 3 seasons (August 16- November 16 and January 17) (Fig. 2b). The collected raw data from finger millet ecosystem are highly validated through M-MDS. The analysis showed that there was maximum diversity of encyrtid parasitoids observed in two seasons such as monsoon (August 16) and winter (January 17- February 17). The contribution of DIV, ADE, CHE, CAL, MEP, ALO, COP, HOM, ANO, NEO and ACE were observed to be more towards the seasons such as monsoon (August 16), post monsoon (October- November 16) and winter (January 17) (Fig. 3b). About sugarcane, again there were 3 clusters formed with post monsoon, monsoon and summer (Fig. 2c); the raw data are highly validated through M-MDS. The analysis showed that there was maximum diversity of Encyrtidae parasitoids observed between the seasons summer and monsoon (April-September 16). The most influencing variable during the seasons were ALO, ANO, NEO, LEP, CAL, COP, OOE, PRT, APO, SAK, and ALA (Fig. 3c).

Univariate as well as multivariate analyses shows that the diversity of encyrtid parasitoids were rich in sugarcane followed by rice and finger millet ecosystems. The genus *Copidosoma* is the most abundant in finger millet and sugarcane ecosystems because of it is polyembryony and on of larvae of moths in the subfamily Plusiinae (Noctuidae). The lepidopteran (Noctuidae) pest incidence is usually more in finger millet and sugarcane as compared to rice ecosystem, hence the abundance of *Copidosoma* was more. The genus *Neodusmetia* is more abundant in rice ecosystem because these are parasitoids of Rhodes grass scale, *Antonina graminis* (Green). These scales feed on grasses like *Cynodon dactylon*, *Rhodes* grass, *Eragrastes ciliaris* (Dean et al., 1979). In general, the growth of the above listed grasses more in rice ecosystem as compared to other two ecosystems. The diversity and generic richness of Encyrtidae were more in monsoon season compare to winter and summer. In the entire crop ecosystems, March 16 got outliered due to the less diversity of encyrtid parasitoids.

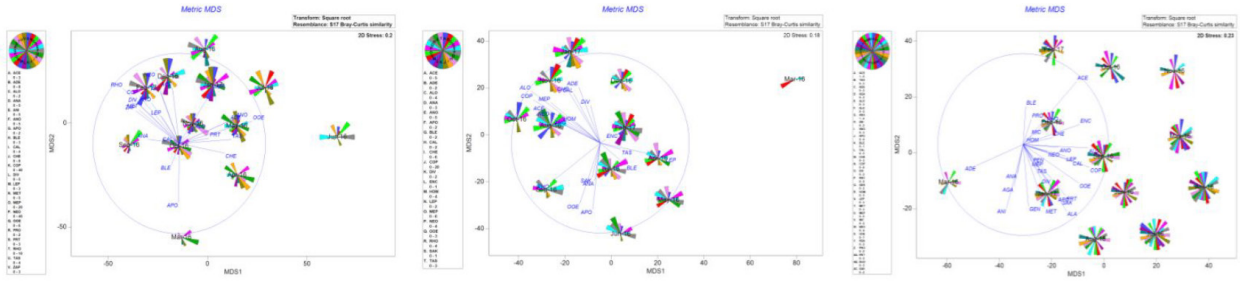
ACKNOWLEDGEMENTS

Authors thank the Director, ICAR-National Bureau of Agricultural Insect Resources, Bengaluru, Dean,



a. Rice ecosystem b. Finger millet ecosystem c. Sugarcane ecosystem

Fig. 2. Brays-Curtis cluster analysis- formation of cluster between the seasons



a. Rice ecosystem b. Finger millet c. Sugarcane

Fig. 3. M-MDS analysis- diversity status of encyrtid parasitoids among seasons

Faculty of Agriculture, UAS, Bengaluru and Dean, College of Agriculture, V C Farm, Mandya, Karnataka for provided necessary permission and facilities. AR grateful to the Director, Zoological Survey of India, Kolkata, for providing facilities.

REFERENCES

Anbalagan V, Paulraj M G, Ignacimuthu S. 2015. Diversity and abundance of Hymenoptera families in vegetable crops in north-eastern District of Tamil Nadu, India. International Journal of Fauna and Biological Studies 2(3): 100-104.

Anderson A, Mccormack S, Helden A, Sheridan H, Kinsella A, Purvis G. 2011. The potential of parasitoid Hymenoptera as bioindicators of arthropod diversity in agricultural grasslands. Journal of Applied Ecology 48: 382-390.

Chiu S C. 1979. Biological control of the brown plant hopper. In Brown Plant hopper: Threat to Rice Production in Asia, International Rice Research Institute, Manila, Philippines 91: 335-355.

Clarke K R, Gorley R N. 2015. PRIMER V. PRIMER-E, Plymouth. 296 pp.

Daniel J A, Ramaraju K. 2020. Collecting parasitic Aculeata (Hymenoptera) from rice ecosystems of Tamil Nadu, India. Journal of Threatened Taxa 12: 15828-15834.

Dean H A, Schuster M F, Boling J C, Riherd P T. 1979. Complete biological control of *Antonina graminis* in Texas with *Neodusmetia sangwani* (A classic example). ESA Bulletin 25(4): 262-267.

Hayat M. 2006. Indian Encyrtidae (Hymenoptera: Chalcidoidea). Department of Zoology, Aligarh Muslim University, India. 198 pp.

Hollingsworth J P, Hartstack A W T, Lingren P D. 1970. The spectral response of *Campoletis perdistinctus*. Journal of Economic Entomology 63: 1758-1761.

Lam P V. 2002. Findings on collecting and identifying natural enemies of key pests on economic crops in Vietnam. Natural Enemy-resources of Pests: Studies and Implementation 1: 7-57.

Noyes J S, Valentine E W. 1989. Chalcidoidea (Insecta: Hymenoptera) — introduction, and review of genera in smaller families. Fauna of New Zealand 18: 96.

Noyes J S. 2020. Universal Chalcidoidea Database. World Wide Web electronic publication. At: http://www.nhm.ac.uk/entomology/chalcidoids (accessed on 18th August 2020)

Sallam M N S. 2006. A review of sugarcane stem borers and their natural enemiesin Asia and Indian Ocean Islands: an Australian perspective. Annales de la Societe Entomologique de France 42 (3-4): 263-283

Waschke N, Hardge K, Hancock C, Hilker M, Obermaier E, Meiners T. 2014. Habitats as complex odour environments: how does plant diversity affect herbivore and parasitoid orientation. PLoS ONE 9: 21-26.

(Manuscript Received: September, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20338

Indian Journal of Entomology 84(1): 64-70 (2022) DoI.: 10.55446/IJE.2021.289

OCCURRENCE OF LAC INSECT AND ITS HOST PLANTS IN MADHYA PRADESH

Pratibha Bhatnagar*, Balram Lodhi, Sunil Prajapati and Bharat Aarmo

Division of Social Economics, Marketing and Mensuration,
State Forest Research Institute, Jabalpur, Madhya Pradesh 482008, India
*Email: pratibhasfri1@gmail.com (corresponding author)

ABSTRACT

Lac insect occurrence was observed in 302 locations, and samples of 267 populations belonging to Rangeeni and 35 from Kusmi strains were collected. A total of 17 host plants belonging to 7 genera were observed with live lac encrustation. Maximum frequency of occurrence was seen on Palas in 133 sites (44.03%) followed by Pipal in 97 sites (32.11%), Kusum- 35 sites (11.60%), Ber- 15 sites (4.97%) and other 13 lac hosts in 22 sites. Maximum lac insect occurrence in terms of sites were reported from Seoni (49- 16.2%), followed by Mandla (42- 13.9%), Balaghat (39- 12.9%), Hoshangabad (13- 4.3%), Chhindwara (10- 3.31%) and other 41 districts of Madhya Pradesh (149 sites). During the study, 2 colour variants were observed- these are crimson (236 sites) and yellow (62 sites0 and crimson-yellow (mixed- 4 sites). The study listed 167 lac cultivation sites, of which the maximum cultivated sites were from Seoni district (49 sites- 29.30%) followed by Balaghat (39 sites- 23.40%), Mandla (30 sites-18.00%), Hoshangabad (9- 5.39%) and other ten districts (40 sites). In natural condition total 135 lac insect occurrence sites were observed and of these maximums were observed in Rajgarh, Morena, Shivpuri (each in 8 sites- 5.93%) followed by Sagar, Indore, Mandsaur, Agar Malwa each (6 sites- 4.44%) and other 87 sites in 32 other districts.

Key words: Lac insect, rangeeni, kusmi, palas, pipal, colour, crimson, yellow, mixed, diversity, relative abundance, Mandla, Balaghat, Hoshangabad, Chhindwara, natural occurrence

Lac is a resinous secretion of lac insect *Kerria lacca* Kerr. (Tachardiidae: Hemiptera). Lac insects are plant sap feeders (Sharma et al., 2006) and thrive well only on certain plant species known as lac host (Kapur, 1962 and Varshney, 1985). Lac insect's nymph settle and feed phloem sap of host plants by piercing its proboscis into phloem region of succulent shoot. There are >400 lac hosts reported throughout the world (Kapur, 1962; Varshney, 1968 and Sharma et al, 1997). Palas, Ber and Kusum are the most common and major hosts for commercial lac production in India (Roonwal, 1962; Pal, 2009) which are found in states of Jharkhand, Chhattisgarh, Madhya Pradesh, West Bengal, Maharashtra and its adjoining states (Sharma et al, 2006 and Pal et al, 2011). Lac production is confined to South, Southeast and East Asian countries in the tropical forest region (Ramani et al., 2007) with India as the leading lac producing country contributing about 80% (Ramani, 2002) with an annual production of 20,000 mt (Pal et al., 2011). Lac insects are the crowning glory of India's rich insect fauna. Of the nine genera and 99 species reported from all over the world, two genera and 26 species are from India, representing 26.3% of the known lac-insect species diversity. Mainly *K. lacca* is exploited for commercial production of lac. *Kerria chinensis* in the north eastern states and *K. sharda* in coastal regions of Orissa and West Bengal are also cultivated to a certain extent (Sharma et al., 2006). In India, Jharkhand state shares 50.83% of total lac production followed by Chhatisgarh (14.58%), Madhya Pradesh (14.41%), Maharashtra (8.98%), Orissa (4.21%), West Bengal (2.66%), Assam (1.68%) (Yogi et al., 2018). Total export of lac and its value-added products in 2012-2013 was 543620.51 mt. The major lac producing districts in Madhya Pradesh are Balaghat, Seoni, Mandla, Chhindwara, Dindori, Narsinghpur and Hoshangabad and they contribute about 80% of the lac produced in the state (Thomas, 2010) Among these districts, Seoni is leading district, which produced 900 mt annually followed by Balaghat (882 mt) (Yogi et al., 2018).

Potential of other lac insect species reported from the country remains to be exploited. Wild populations of lac insects are principally distributed in the forest and subforest regions. Fast depleting forest cover of the country is a serious threat to their biodiversity as well as their host plants. It was reported that cultivation of lac insect is restricted in eastern parts and some pockets of central parts of Madhya Pradesh on major

host plants like Palas, Ber and Kusum trees. However, natural lac insect occurrence is reported thought out the state with number of specific host plants. In the state presence of lac insect on different host plants are sign of favourable climatic condition for the natural occurrence of lac insect/ host plants. There is lack of awareness among local people about the existence of lac insect genetic resources on these host trees and ignorantly, the natural habitat of lac insects of the region is destroyed host plants/ lac insects recorded from this region will help to promote lac culture in other areas as well as biodiversity of lac insect species will remain conserved and maintained. There are plenty of host plants available in this region which provides greater scope for commercial lac culture. The present field study was carried out with the intent to record the lac insect occurrence and also to record the new or potential host plants.

MATERIALS AND METHODS

The field survey was conducted in 319 blocks of 51 districts in Madhya Pradesh during 2015-2019 to document occurrence of lac insect under the ICAR-Network Project on Conservation of Lac Insect Genetic Resources. All districts were surveyed to identify cultivated and natural occurrence sites, with documentation of district wise occurrence, colour variation and lac encrustation on host plants. Prior to undertaking the survey, contact was made with the concerned Forest Department DFO in all surveyed districts. The districts which have information about lac insect/ host plant occurrence and cultivation status were recorded. Thereafter, each forest range office in each block was visited in various districts. Information was also taken from traders and farmers at block level. With this pre-information and cultivation status a number of surveys were undertaken at block level. The live lac insect was traced through binocular or visually. Randomly different lac host plants were also observed for identifying lac species. The observations of different parameters of host plants, their intensity and location were made. The lac insect and host plants were surveyed and observed for the presence of lac insects, their strain, growth, stage, intensity and colour variation, and these documented in prescribed passport datasheet, photographs along with GPS coordinates (Montana Garmin). In the field survey if lac insect samples were found, then the branches having the lac insect were collected using secateurs and tree pruner and kept in the 60 mesh net for proper aeration during travelling period and labelled. The relative abundance was calculated as follows:

$$\text{Relative abundance (RD \%)} = \frac{\text{No. of host plant of one species}}{\text{Total no. host plant of all species}} \times 100$$

RESULTS AND DISCUSSION

Fifty one districts covering 319 blocks of Madhya Pradesh were surveyed. During study visual survey was made in the fringe areas of forests and farmers field and numbers of host plants were observed (Table 1, 2). The cultivated populations of lac insect was observed on major host plants Palas *(Butea monosperma),* Kusum *(Schleichera oleosa),* Ber *(Ziziphus mauritiana)* and Ghont *(Ziziphus xylopyra)* only. However, natural population of lac insect was reported on Pipal *(Ficus religiosa),* Bargad *(Ficus benghalensis),* Rain tree *(Albizia saman),* Kala siris *(Albizia lebbek),* Gular *(Ficus racemosa),* Pakud *(Ficus rumphii),* Akashmoni *(Acacia auriculiformis),* Khair *(Acacia catechu),* Jangli Jalebi *(Pithocibium dulce),* Jangli Bargad *(Ficus citrifolia),* Sitaphal *(Annona squamosa),* Babul *(Acacia nilotica)* and Tendu *(Diospyros melanoxylon)*. A total 302 lac occurrence sites were recorded, and the occurrences of lac insect/ host plants as depicted in Table 1 and Fig. 1.

Occurrence

Cultivation sites: During the study, total 167 lac cultivated sites were reported from different districts of Madhya Pradesh. Maximum lac cultivated sites were reported from Seoni district, 49 sites (29.30%) followed by Balaghat in 39 sites (23.40%), Mandla 30 sites (18.00%), Hoshangabad 9 (5.39%), Narsinghpur 05 sites (2.99%), Dindori, Shahdol each 5 sites (2.99%), Anuppur, Betul, Katni 04 sites (2.40%), Jabalpur,

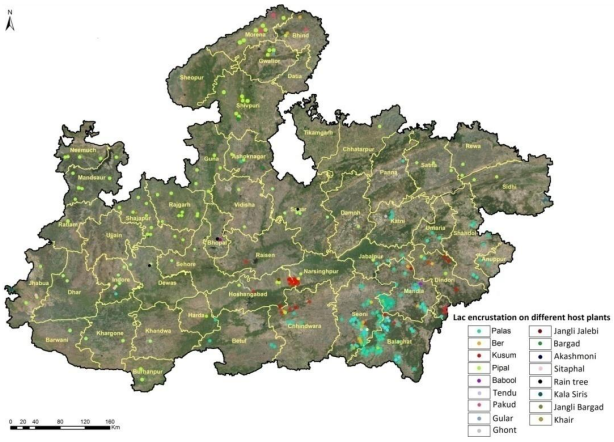


Fig. 1. Live lac insect occurrence in Madhya Pradesh

Table 1. Occurrence of lac insect in cultivated sites

District	Block with lac insect occurrence sites	Host plants found with lac encrustation	Survey period
Mandla	Nayanganj (1), Nainpur (19), Bichhiya (5), Mohgaon (3) Ghughri (1), Mavai (1)	*Butea monosperma, Schleichera oleosa, Ziziphus mauritiana*	May, June, Nov. 2015, Nov. 2016, May 2019
Seoni	Barghat (22), Kurai (7), Seoni (7), Keolari (6), Lakanadon (2), Dhanora (5)	*Butea monosperma, Ziziphus mauritiana, Schleichera oleosa, Diospyros melanoxylon, Acacia auriculiformis*	July, Nov., Aug. 2015, Sep., Nov. 2016, Nov. 2019
Balaghat	Lalbarra (6), Waraseoni (10), Katangi (6), Paraswara (07), Balaghat (3), Lanji (1), Kirnapur (4), Baihar (2)	*Butea monosperma, Schleichera oleosa, Ziziphus mauritiana, Diospyros melanoxylon*	Aug., Nov. and July 2015, Nov. 2019
Anuppur	Jaithari (3), Anuppur (1)	*Butea monosperma, Ziziphus mauritiana*	July 2015
Shahdol	Budhar (2), Gohparu (1) Jaisinghnagar (1), Pali (1)	*Butea monosperma*	June 2015 and Oct. 2017
Dindori	Bajag (1), Dindori(2), Shahpur (2)	*Schleichera oleosa, Butea monosperma*	Aug. 2015, Feb. 2020
Narsinghpur	Chichli (4), Gadarwara (1)	*Schleichera oleosa*	Aug., Dec. 2015, Jan. 2017
Hoshangabad	Bankhedi (7), Babai (1), Piparia (1)	*Schleichera oleosa*	Sep., Oct. and Dec. 2015
Betul	Chicholi (2), Multai (2)	*Butea monosperma*	Nov. 2015 and Nov. 2016
Chhindwara	Parasia (2), Jamai (3), Tamia (1), Jumnaradeo (3), Damua (1)	*Butea monosperma, Ziziphus mauritiana, Schleichera oleosa,*	Nov. and Dec. 2015, July 16, June 19
Jabalpur	Kundam (1)	*Butea monosperma*	June 2016
Panna	Devendra Nagar (1)	*Butea monosperma*	June 2016
Raisen	Dehgaon (1)	*Schleichera oleosa*	Nov. 2016
Katni	Rethi (3), Bahoriband (1)	*Butea monosperma, Ziziphus xylopyra*	Sep. 2019

Panna, Raisen in one site (0.60%). Seoni, Balaghat and Mandla are the major lac producers of the state which contributes 81% of total lac production (Yogi et al., 2018). In the state traditionally lac insect is cultivated on *B. monosperma* and *S. oleosa* host plants. In Seoni district farmers mostly utilize *B. monosperma* host plants for brood lac production in Katki crop (rainy season) while in Baisakhi crop (winter season) they utilize *Z. mauritiana* for stick lac production. In case of Kusmi strain Bankhedi (Hoshanagabad), Chichli (Narsinghpur), Mavai (Mandla) and Dindori have potential for producing good amount of Kusmi lac on *S. oleosa,* which is the abundant host plant. In cultivated condition all 167 sites reported crimson colour variants. District wise cultivated sites in Madhya Pradesh are given in Table 1 and 3.

Natural occurrence: Total 135 natural lac insect occurrence sites were found. In natural condition, about 70% lac insect occurrences were observed on *F. religiosa* in 35 districts of Madhya Pradesh. Maximum occurrence of lac insect was reported from Rajgarh, Morena and Shivpuri districts in 8 sites (5.93%) followed by Sagar, Indore, Mandsaur, Agar Malwa in 6 sites (4.44%), 5 sites, (3.70%) Guna, Shajapur, 4 sites (2.96%) in Ashoknagar, Neemuch, Alirajpur and 3 sites (each 2.20%) in Umaria, Satna, Dewas etc. In Eastern part of Madhya Pradesh cultivated lac sites were found on major host *B. monosperma, S. oleosa, Z. mauritiana* while in western parts of Madhya Pradesh lac is mostly found scattered on few species only viz., *F. religiosa, F. rumphii, F. benghalensis and A. saman.* Some host plants dominant in specific region are *Zizyphus xylopyra* in Damoh and Katki, *F. rumphi* in Morena and Bhind, *A. saman* in Bhopal, Sagar and Sehore etc. In the natural condition, 69 sites reported with crimson colour lac insect, 62 sites with yellow and 4 sites reported with crimson-yellow mixed. The district wise natural sites of lac insect occurrence are given in Table 2 and 3.

Colour variations: Lac insect showing diverse body colour have been observed. Quantitative variations with regard to body colour had been reported varying from crimson, yellow and cream (Sharma et al., 2006) Colour

Table 2. Natural occurrence of lac insect in Madhya Pradesh

District	Block with lac insect occurrence sites	Host plants with lac encrustation	Survey period
Mandla	Bijadandi (1), Niwas (5), Mohgaon (3), Mavai (3)	*B.monosperma, Schleichera oleosa, Ziziphus mauritiana, F. racemosa, A. nilotica*	June 2015, May 2019
Harda	Timarni (1)	*Ficus religiosa*	Nov. 2015
Dindori	Shahpura (2), Dindori (1)	*F. religiosa, Z. mauritiana, Schleichera oleosa*	July 2016, Nov. 2019
Shahdol	Gohparu (1)	*Butea monosperma*	June 2015
Alirajpur	Alirajpur (1), Jobat (2), Kathewara (1)	*Ficus religiosa, Annona squamosa, A. lebbek*	Feb. 2016
Neemuch	Rampura (1), Neemuch (2), Manasa (1)	*Ficus religiosa*	Feb. 2016, Nov. 2019
Mandsaur	Mandsaur (2), Shamgarh (1), Dalonda (1), Bhanpura (1), Malhargarh (1)	*Ficus religiosa*	Feb. 2016 and Nov. 2019
Indore	Sanwer (1), Indore (1), Mhow (4)	*F. religiosa, Annona squamosa, B. monosperma*	Feb. 2016
Jhabua	Jhabua (1)	*Ficus religiosa*	Feb. 2016
Khandwa	Khandwa (1)	*Ficus religiosa*	July 2016
Khargone	Segaon (1), Bhikangaon (1)	*Ficus religiosa*	July 2016
Badwani	Rajpur (1)	*Ficus religiosa*	Nov. 2016
Dhar	Rajgarh (1), Sardarpur (1)	*Ficus religiosa*	July, Nov. 2016
Jabalpur	Jabalpur (3)	*B. monosperma, F. religiosa*	July 2016, June 2019
Sehore	Sehore (1), Asta (1)	*Ficus religiosa*	Nov. 2016
Dewas	Sonkakch (2), Shipra (1)	*Ficus religiosa. A. saman*	Nov., Feb. 2016
Ratlam	Jaora (1)	*Ficus religiosa*	Feb. 2016
Narsinghpur	Chichli (1), Gadarwada (1)	*Ficus religiosa*	Jan. and Dec. 2017
Hoshanagabad	Hoshanagabad (1), Piparia (3)	*Ficus religiosa, Pithocobium dulce*	Dec. 2017, July 2018
Satna	Satna (1), Bela (1), Nagod (1)	*Ficus religiosa*	Oct., June 2017
Ashoknagar	Ashoknagar (2), Mungwani (1), Sadora (1)	*F. benghalensis, F. religiosa, Butea monosperma*	Jan. 2017
Rajgarh	Narsinghgarh (1), Pachore (2), Jirapur (3), Khailchipur (1), Sarangpur (1)	*Ficus religiosa*	Feb. 2017, May 2019
Guna	Binaganj (1), Maksudanganj (1), Kumbhraj (1), Guna (1), Rathihai (1)	*Ficus religiosa*	Jan., Feb. 2017
Chhatarpur	Lavkushnagar (1)	*Ficus religiosa*	Jan. 2017
Vidisha	Sironj(1), Vidisha (1)	*Ficus religiosa*	Feb. 2017
Burhanpur	Burhanpur (1), Ikchapur (1)	*Ficus religiosa*	July 2017
Rewa	Govindgarh (1), Rewa (1)	*Ficus religiosa*	Oct. 2017
Sidhi	Rampur (1), Sidhi (1)	*Ficus religiosa*	Oct. 2017
Sagar	Sagar (3), Rahatgarh (1), Garhakota (1), Bina (1)	*Ficus religiosa, A. saman*	June 2016 and Feb. 2017, May, Nov. 2019
Bhopal	Phanda (2)	*A. saman, Acacia nilotica*	June, July 2018
Anuppur	Anuppur (1)	*Ficus religiosa*	Oct. 2018
Umaria	Umaria (1), Nowrojabad (1)	*Butea monosperma*	Sep. 2019
Shivpuri	Shivpuri (4), Kolaras (3), Pohri (1)	*F. religiosa, F. amphissimma, F. benghalensis*	April and Nov. 2019
Morena	Morena (4), Jaora (2), Porsa (1), Ambah (1)	*Ficus religiosa, F. rumphi*	April 2019
Bhind	Bhind (1), Ater (1), Gohad (2)	*Ficus religiosa, F. rumphi, Ziziphus mauritiana*	April 2019
Gwalior	Gwalior (4)	*F. religiosa, F. racemosa*	April 2019
Agar Malwa	Agar (3), Nalkheda (1), Susner (1), Badod (1)	*F. religiosa, Acacia catechu*	May 2019
Shajapur	Shajapur (2), Kalapipal (1), Mohan Barodiya (1), Shujalpur (1)	*Ficus religiosa*	May 2019
Damoh	Jaora (1)	*Ficus religiosa*	May 2019

Table 3. District wise data of occurrence of lac insect in Madhya Pradesh

S.No.	District	Lac insect occurrence sites (Nos.)	Relative abundance (%)	Cultivated sites (Nos.)	Natural sites (Nos.)	Frequency of occurrence Cultivated sites (%)	Natural sites (%)
1	Seoni	49	16.2	49	-	29.3	-
2	Balaghat	39	12.9	39	-	23.40	-
3	Mandla	42	13.9	30	12	18.00	8.89
4	Dindori	08	2.65	05	03	2.99	2.22
5	Shahdol	06	1.99	05	1	2.99	0.74
6	Anuppur	05	1.66	04	1	2.40	0.74
7	Umaria	03	0.99	-	03	-	2.22
8	Katni	04	1.32	04	-	2.40	-
9	Jabalpur	04	1.32	01	03	0.60	2.22
10	Rewa	2	0.66	-	2	-	1.48
11	Panna	1	0.33	1	-	0.60	-
12	Sidhi	2	0.66	-	2	-	1.48
13	Satna	3	0.99	-	3	-	2.22
14	Sagar	6	1.99	-	6	-	4.44
15	Damoh	1	0.33	-	1	-	0.74
16	Bhopal	1	0.33	-	1	-	0.74
17	Raisen	1	0.33	1	-	0.60	-
18	Sehore	2	0.66	-	2	-	1.48
19	Vidisha	2	0.66	-	2	-	1.48
20	Hoshanagabad	13	4.30	9	4	5.39	2.96
21	Narsinghpur	7	2.32	5	2	2.99	1.48
22	Herda	1	0.33	-	1	-	0.74
23	Gwalior	4	1.32	-	4	-	2.96
24	Shivpuri	8	2.65	-	8	-	5.93
25	Bhind	4	1.32	-	4	-	2.96
26	Morena	8	2.65	-	8	-	5.93
27	Guna	5	1.66	-	5	-	3.7
28	Ashoknagar	04	1.32	-	4	-	2.96
29	Chatarpur	1	0.33	-	1	-	0.74
30	Indore	6	1.99	-	6	-	4.44
31	Mandsaur	6	1.99	-	6	-	4.44
32	Dhar	2	0.66	-	2	-	1.48
33	Neemuch	4	1.32	-	4	-	2.96
34	Dewas	3	0.99	-	3	-	2.22
35	Ratlam	1	0.33	-	1	-	0.74
36	Rajgarh	8	2.65	-	8	-	5.93
37	Agar Malwa	6	1.99	-	6	-	4.44
38	Shajapur	5	1.66	-	5		3.7
39	Chhindwara	10	3.31	10	-	5.99	-
40	Betul	4	1.32	4	-	2.40	-
41	Khargone	2	0.66	-	2	-	1.48
42	Khandwa	1	0.33	-	1	-	0.74
43	Badwani	1	0.33	-	1	-	0.74
44	Burhanpur	2	0.66	-	2	-	1.48
45	Jhabua	1	0.33	-	1	-	0.74
46	Alirajpur	04	1.32	-	4	-	2.96
	Total	302	100.00	167.00	135.00	100.00	100.00

differences in lac insect are inherited as a unit character and crimson is dominant to yellow (Sharma et al., 2011). Colour variation were observed in 302 lac insect occurrence sites, and two colours crimson and yellow are common. Crimson lac insect was reported from 236 sites, yellow from 62 sites and crimson-yellow mixed from 4 sites. Crimson lac insect reported on Palas, Ber, Kusum, Pipal, Bargad, Jangli Jalebi jangli Bargad, Babul, Gular, Rain tree, Black Siris, Tendu and Ghont host plants whereas yellow lac insect were observed from Pipal, Sitaphal, Pakud, Bargad, Khair and Ber trees. Details of colour variations are given in Fig. 2.

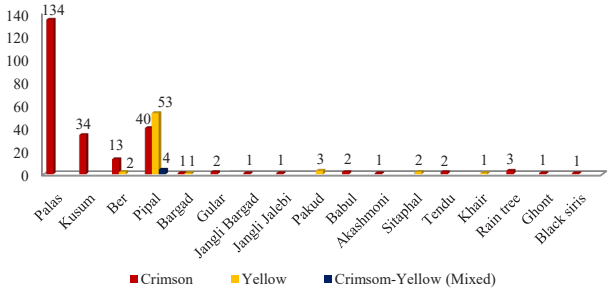


Fig. 2. Colour variation of lac insect on host plants in Madhya Pradesh

District wise analysis: On the basis of data given in Table 1 and 2, 302 sites from different districts of Madhya Pradesh revealed occurrence of lac insect, with maximum occurrence being from Seoni, 49 sites (16.2%) followed by Mandla, 42 sites (13.9%), Balaghat, 39 sites (12.9%), Hoshanagabad, 13 sites (4.3%), Chhindwara, 10 sites (3.31%), Dindori, Rajgarh, Morena, Shivpuri each 08 sites (2.65%), Narsinghpur, 7 sites (2.32%), Shahdol, Sagar, Indore, Mandsaur, Agar Malwa each 6 sites (1.99%), Anuppur, Guna, Shajapur each 5 sites (1.66%), Jabalpur, Katni, Gwalior, Bhind, Ashoknagar, Neemuch, Betul, Alirajpur each 4 sites (1.32%), Umaria, Satna, Dewas each 3 sites (0.99%), Rewa, Sidhi, Sehore, Vidisha,Dhar, Khargone, Burhanpur each 2 sites (0.66%) and minimum occurrence sites reported from Panna, Damoh, Bhopal, Raisen, Harda, Chhatarpur, Ratlam, Khandwa, Badwani, Jhabua each 1 sites (0.33%).

Host plants

The present study revealed that out of 302 locations of lac insect occurrence 267 belong to Rangeeni strain and 35 from Kusmi strain on 17 host plants. This work is in conformity with the findings of Meena et al. (2020) who reported lac occurrence on 14 host plants in western plains of India. Maximum frequency of occurrence was reported on *B. monosperma*- 133 sites (43.70%) followed by *F. religiosa*- 97 sites (32.5%), *S. oleosa*- 35 sites (11.60%), *Z. mauritiana*- 15 sites (4.97%), Rain tree and Pakud in 3 sites (both 0.99), Tendu, Babul, Bargad and Gular 2 sites (each 0.66%) and least frequency was reported with, Khair, Ghont, Black siris, Jangli Jalebi, Jangli Bargad and Akashmoni (0.33%) each with only 1 site. Of these *B. monosperma, S. oleosa*, *Z. mauritiana*, *F. religiosa* are the major host plants which account for about 92.72% lac insect occurrence sites of Madhya Pradesh. Similar findings of Singh and Chatterjee (1994) reported *Z. mauritiana*, *B. monosperma and F. religiosa* as the major lac hosts.

The study reveals that the occurrence of lac insect in different districts of Madhya Pradesh is of significant importance as these are habitats of important lac host plant on which lac insect thrives cultivated and found naturally. During the study lac encrustation was found on 17 host plants, and in view of abundant availability of host plants in farmer's field and forest areas, lac cultivation has great scope in the region and this biodiversity could be better utilized for the its conservation. In the present study good lac encrustations were found on Kusum, Palas, Ber, Pipal, Jangli Jalebi, Rain tree, Kala siris, Ghont, Pakud in different parts of Madhya Pradesh. Occurrence of both Kusmi and Rangeeni lac insect indicated the climate suitability of lac cultivation in surveyed areas. The study aims for in-situ conservation, multiplication and cultivation of lac insect and host plants in the local area, through on farm trials and demonstration. District wise collection and maintenance need to be continued for conserving valuable lac associated faunal and floral diversity of Madhya Pradesh. Effort should be made for the conservation of local hosts and strains of lac insect and popularizing the lac cultivation in non lac growing areas of Madhya Pradesh.

ACKNOWLEDGEMENTS

Authors thank Dr K K Sharma, Director and Project Coordinator ICAR-Indian Institute of Natural Resins and Gums, Ranchi for providing financial support under the ICAR Network Project on Conservation of Lac Insect Genetic Resources. Authors also thank the Director SFRI Jabalpur for providing help and logistic support.

REFERENCES

Kapur A P. 1962. The lac insect. In: Mukhopadhyay B, Muthana M S, editors. A Monograph on lac. Indian Lac Research Institute, Ranchi. 59-89 pp.

Meena S C, Sharma K K, Swami H, Rana, Lekha B S, Lahot V D 2020. Survey record of lac insect *Kerria lacca* and its host plants

in western plains of India. India Journal of Agriculture Science 90(1): 220-5.

Pal G, Bhagat M L, Bhattacharya A. 2009. Economics and resource use efficiency of Lac cultivation in Jharkhand. Indian Journal of Forestry 32:95-98.

Pal G, Jaiswal A K, Bhattacharya A. 2011. Lac statics at a glance 2010 (Technical bulletin No. 01/2011) Indian Institute of Natural Resins and Gums, Ranchi. 1-24 pp.

Ramani R, Baboo B, Goswami D N. 2007. Lac –An Introduction. India Lac Research Institute, Ranchi.12 pp.

Ramani R. 2002. Present status of lac at national and international level. In Recent advances in lac culture (eds Kumar K K, Ramani R, Sharma K K), Indian Lac Research Institute, Ranchi. 254-262 pp.

Ramani R. 2005. Genetics of lac insects. Gleanings in entomology, Ramamurthy V V, Singh V S, Gupta G P, Paul A V N (eds) Indian Agriculture Research Institute, New Delhi. 266-280 pp.

Roonwal M L. 1962. A monograph on lac. In: Mukhopadhayay B, Muthana M S (eds). India Lac Research Institute, Ranchi. 53-207 pp.

Sharma K K, Jaiswal A K, Kumar K K. 2006. Role of lac culture in biodiversity Conservation: Issue at stake and conservation strategy. Current Science 91 (7): 894-898.

Sharma K K, Ramani R, Mishra Y D. 1997. An additional list of the host plant of lac insects, *Kerria spp*. (Tachardiidae:Homoptera). Journal of Non-Timber Forest Products 4(3/4): 151-155.

Sharma K K, Ramani R. 2011. Recent advance in lac culture. India Institute of Natural Resins and Gums, Namkum, Ranchi. 1-319 pp.

Singh B P, Chatterji R. 1994. Potential for increasing lac production in West Bengal. Van Vigyan 32 (1/2): 44-47.

Thomas M. 2020. Madhya Pradesh: Current status of Lac production, issues, remedial measures and support system for development. Current issues related to lac production. 35-37 pp.

Varshney R K. 1968. Further data on host plants of lac insect (Homoptera: Tachardiidae). Journal of Bombay Natural History Society 65: 249-251.

Varshney R K. 1985. A Review of India Coccids (Homoptera, Coccoidae) Oriental Insects 19:1-101.

Yogi R K, Kumar Alok, Singh A K. 2018. Lac plant Resins and Gums statistics 2016: At a Glance. ICAR-Indian Institute of Natural Resins and Gums Ranchi (Jharkhand), India. Bulletin (Technical) No. 19/2018. 80 pp.

(Manuscript Received: September, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20334

Indian Journal of Entomology 84(1): 71-76 (2022) DoI No.: 10.55446/IJE.2021.247

RESISTANCE MONITORING OF *HELICOVERPA ARMIGERA* TO INSECTICIDES ACROSS LOCATIONS OF KARNATAKA

Bheemanna M, Hanchinal S G*, Rajesh Chowdary L[1], Akshatha G, Kariyanna B and Patil B V

University of Agricultural Sciences, College of Agriculture, Raichur 584104, Karnataka, India
[1]Agriculture Research Station, Acharya NG Ranga Agricultural University,
Darsi 523247, Andhra Pradesh, India
*Email: shanchinal@gmail.com (corresponding author)

ABSTRACT

This study evaluates the toxicity of eight insecticides against *Helicoverpa armigera* (Hubn.). These include conventional and newer molecules which are being used on a large scale in six districts (Raichur, Kalaburagi, Bidar, Dharwad, Ballari, Bengaluru and Gangavathi) of north eastern Karnataka. The results revealed that the least LC_{50} value was observed in chlorantraniliprole 18.5%SC (0.17- 0.39 ppm- 2014-15; 0.19-0.43 ppm- 2015-16; and 0.70-0.94 ppm- 2016-17. Maximum LC_{50} value was observed with chlorpyriphos 20%EC (35.16-41.08; 37.35-43.27; and 36.02- 41.94 ppm). The order of toxicity was chlorantraniliprole > emamectin benzoate > flubendiamide > spinosad > thiodicarb > methomyl > profenophos > chlorpyriphos. These results reveal that rotation of conventional insecticides along with the new insecticides might be more effective.

Key words: *Helicoverpa armigera*, insecticide toxicity, N-E Karnataka, topical bioassay LC_{50} values, chlorantraniliprole, chlorpyriphos, resistance management

The pest *Helicoverpa armigera* (Hubn.), also known as the cotton bollworm is classified as one of the top 100 world invasive species (Kontsedalov et al., 2012). This is a cosmopolitan insect and has gained importance as a major destructive pest (Dinsdale et al., 2010), and its control up to desired level has become difficult (McCaffery et al., 1998). Crops such as cotton, chickpea, tomato, sunflower, okra, pea, tobacco, potato, egg plant are particularly affected by *H. armigera*. Due to its tremendous damage to crops, the use of insecticides constitutes the main control strategy. However, the indiscriminate use of insecticides has resulted in the development of resistance (Ferre and Vann, 2012). Resistance to a wide range of insecticides in *H. armigera* had been reported (McCaffery et al., 1998). Moderate to high level of resistance to conventional insecticides (chlorinated hydrocarbons, organophosphates, carbamates and pyrethroids) as well as to neonicotinoids and insect growth regulator (IGR) had been reported in field populations (Nauen and Bretschneider, 2002). Indiscriminate use of broad spectrum insecticides has resulted in secondary pest outbreaks and development of resistance (Kranthi et al., 2002; Ahmad et al., 2007). Hence, the insecticide resistance must be continuously monitored and must form an integral part of chemical control. The use of the new chemistry insecticides has increased now. These were found highly effective in controlling *H. armigera* as compared to conventional ones (Razaq et al., 2005), but a low level of resistance to these in *H. armigera* is known (Ahmad et al., 2007). In the present study, the degree of resistance in *H. armigera* against both conventional and new chemistry insecticides has been evaluated using topical bioassay.

MATERIALS AND METHODS

The 5th and 6th instar larvae of *H. armigera* were collected from fields of seven districts (Raichur, Kalaburagi, Bidar, Dharwad, Bellary, Bangalore and Gangavathi) during 2014-15, 2015-16 and 2016-17. The distance between locations are approximately 200-250 kms. From Bangalore, the larva was collected during 2014-15 and 2015-16. About 400-500 larvae were collected by walking through a plot randomly of selected host crop from each location and larvae were reared in the insecticide resistance laboratory at the UAS, Raichur during cropping season from 2014 to 2017. Rearing was done on semisynthetic wheat germ based diet (25± 2°C, 65± 5%RH, 14:10 hrs light: dark photoperiod). Diet was replaced after 24 hr, and pupae were collected on sequential days. The adults that emerged from larvae were kept in perspex oviposition cages (45x 25x 30 cm) with two sides covered with muslin cloth to maintain ventilation. These were

fed on a solution containing sucrose (10%), vitamin solution (20 ml) and methyl 4- hydroxybenzoate in soaked cotton wool hanging in the oviposition cages. Commercial formulations of profenophos 50%EC, emamectin benzoate 5%SG, spinosad 45%SC, methomyl 40%SP, chlorpyriphos 20%EC, thiodicarb 70%SP, flubendiamide 37.9%SC and chlorantraniliprole 18.5%SC were used. Newly moulted third instar larvae (30-40 mg) from F_1 laboratory cultures were exposed to these insecticides using topical bioassay method (IRAC; http://www.irac-online.org/ resources/methods. asp). Serial dilutions as ppm the active ingredient of these insecticides were prepared in distilled water. Number of larvae used for each location varied from 75-120, larvae after the treatments were reared in the semisynthetic diet and observation on the mortality vs. dose response was observed after 48hr exposure. Larvae were regarded as dead when they were not able to move when probed with a blunt probe or brush. Mortality data were corrected by Abbott's formula where necessary and analyzed by probit analysis. Estimation of LC_{50} values and their 95% fiducial limits (FL) was done by probit analysis using the SPSS.

RESULTS AND DISCUSSION

The data on the LC_{50} values of profenophos to the populations of *H. armigera* given in Table 1 reveal that the values varied from 26.41 to 33.28 ppm; least LC_{50} value was observed in Dharwad population (26.41 ppm) and maximum with that of Bangalore (33.28 ppm) (2014-15); in 2015-16, these values varied from 28.20 to 34.7 ppm; least being with Dharwad population (28.20 ppm) and maximum with Raichur one (34.77 ppm). Similarly, the least value was observed in Dharwad population (26.71 ppm) and maximum with Raichur one (33.28 ppm) in 2016-17. As regards chlorpyriphos, the values ranged from 37.28 to 41.08 ppm; least with Gangavathi (35.16 ppm- 2014-15); and in 2015-16, with the larvae from Dharwad (37.35 ppm); LC_{50} did not vary between Dharwad and Ballari populations during 2016-17. Maximum LC_{50} values and slopes was obtained with profenophos followed by chlorpyriphos and these were least effective. For emamectin benzoate, LC_{50} values across locations did not vary much, with overlapping fiducial limits (0.28 to 0.39 ppm), least value being with Bellary population (0.28 ppm) followed by Dharwad (0.29 ppm), and Bangalore (0.39 ppm) during 2014-15; in 2015-16, it varied from 0.26 to 0.47 ppm, and the least LC_{50} value was observed in Gangavathi population (0.26 ppm). More or less similar results were obtained in 2016-17. Brevault et al. (2009) observed maximum mortality with emamectin-benzoate (33.33 mg a.i L-1) of a high level (99.3± 0.8%) in 2nd instar.Hirooka et al. (2007) obtained a much lower LC_{50} value (0.049 mg a.i. L-1) for emamectin in a laboratory reared susceptible strain. Gupta et al. (2005) concluded that emamectin benzoate was more toxic than indoxacarb and spinosad.

As regards spinosad, in 2014-15 LC_{50} values varied from 0.41 to 0.58 ppm; with the least being observed in Kalaburagi population (0.41 ppm) and maximum with that of Bangalore (0.58 ppm). In 2015-16, these varied from 0.38 to 0.53 ppm, least with Bidar population

Table 1. Toxicity to insecticides in field collected populations of *H. armigera*

Insecticides	Location	Year	n	LC_{50} (ppm)	95% (FL) LL	95% (FL) UL	Slope± S.E	χ2	P
Profenophos 50%EC	Raichur	2014-15	90	29.25	18.2	37.75	1.72± 0.38	1.63	0.86
		2015-16	120	34.77	28.43	43.49	2.25± 0.74	2.05	1.00
		2016-17	90	33.28	25.66	40.61	1.75± 0.54	1.15	0.96
	Kalaburagi	2014-15	105	31.42	20.41	40.82	1.56± 0.43	2.14	0.93
		2015-16	120	32.25	22.5	44.59	1.85± 0.31	1.80	0.85
		2016-17	75	30.76	19.73	41.71	2.05± 0.25	1.93	1.00
	Bidar	2014-15	75	30.28	19.86	42.25	1.29± 0.79	1.85	0.56
		2015-16	75	32.07	21.95	46.02	1.55± 0.50	2.13	0.93
		2016-17	75	30.58	19.18	43.14	1.55± 0.40	2.05	1.00
	Dharwad	2014-15	75	26.41	17.78	32.54	2.04± 0.22	1.76	0.88
		2015-16	90	28.20	19.87	36.31	1.93± 0.40	2.05	1.05
		2016-17	90	26.71	17.10	33.43	1.03± 0.13	2.41	0.95
	Bellary	2014-15	75	27.60	20.23	34.79	1.86± 0.22	1.52	0.55
		2015-16	90	29.39	22.32	38.56	2.05± 0.20	1.79	1.10
		2016-17	105	27.90	19.55	35.68	1.85± 0.25	1.25	1.05
	Bangalore	2014-15	90	33.28	26.34	39.72	1.73± 0.56	1.95	1.02
		2015-16	120	31.04	20.29	41.52	2.15± 0.29	1.55	1.01
		2016-17	--	--	--	--	--	--	--
	Gangavathi	2014-15	90	27.39	20.76	38.22	2.04± 0.29	1.98	1.04
		2015-16	75	28.45	22.85	41.99	2.49± 0.15	2.00	1.09
		2016-17	75	26.96	20.08	39.11	2.29± 0.10	1.34	1.00

(contd.)

(Table 1 contd.)

	Raichur	2014-15	75	0.35	0.16	1.26	1.09± 0.85	3.74	0.54
		2015-16	105	0.44	0.21	1.37	1.44± 1.05	2.15	0.65
		2016-17	75	0.39	0.16	1.30	1.50± 0.50	1.95	0.75
	Kalaburagi	2014-15	90	0.38	0.18	1.59	1.18± 0.46	2.96	0.77
		2015-16	105	0.47	0.23	1.55	1.35± 0.58	2.74	0.49
		2016-17	75	0.43	0.18	1.48	1.26± 0.28	2.05	1.00
	Bidar	2014-15	75	0.32	0.15	0.93	1.66± 0.21	1.78	0.91
		2015-16	90	0.35	0.17	1.01	1.08± 0.76	1.98	0.57
		2016-17	90	0.31	0.12	0.94	1.00± 0.34	2.14	1.05
	Dharwad	2014-15	90	0.29	0.13	3.04	1.55± 0.31	2.04	0.59
Emamectin benzoate 5%SG		2015-16	75	0.34	0.16	0.88	2.05± 0.20	2.05	0.74
		2016-17	90	0.30	0.11	0.81	1.92± 0.11	1.96	0.78
	Bellary	2014-15	75	0.28	0.21	1.02	1.19± 0.52	2.55	0.72
		2015-16	90	0.31	0.15	0.97	2.11± 0.44	1.75	1.05
		2016-17	75	0.28	0.10	0.91	2.01± 0.25	1.55	1.00
	Bangalore	2014-15	105	0.39	0.24	1.22	2.04± 0.73	2.08	0.56
		2015-16	105	0.35	0.14	1.08	1.89± 0.51	2.41	0.83
		2016-17	--	--	--	--	--	--	--
	Gangavathi	2014-15	75	0.38	0.19	0.83	1.35± 1.02	2.16	1.00
		2015-16	75	0.26	0.18	1.05	1.68± 0.73	1.59	1.10
		2016-17	75	0.22	0.13	1.00	1.36± 0.16	1.31	1.00
	Raichur	2014-15	90	0.48	0.35	0.71	1.96± 0.11	2.18	0.76
		2015-16	90	0.52	0.39	0.79	2.05± 0.08	2.24	0.55
		2016-17	75	0.48	0.34	0.72	2.05± 0.08	1.75	0.75
	Kalaburagi	2014-15	75	0.41	0.33	0.65	1.81± 0.09	1.95	0.54
		2015-16	75	0.44	0.35	0.62	1.93± 0.15	2.00	0.93
		2016-17	75	0.40	0.30	0.55	1.93± 0.15	2.25	0.56
	Bidar	2014-15	75	0.46	0.29	0.81	1.59± 0.47	1.88	0.48
		2015-16	102	0.38	0.19	0.91	1.75± 0.30	1.75	0.81
		2016-17	90	0.33	0.15	0.82	1.75± 0.30	1.54	1.03
	Dharwad	2014-15	75	0.49	0.38	0.56	2.17± 0.17	2.41	0.91
Spinosad 45%SC		2015-16	90	0.43	0.21	0.55	2.05± 0.15	2.09	1.02
		2016-17	90	0.39	0.16	0.46	2.05± 0.15	1.76	0.82
	Bellary	2014-15	75	0.58	0.43	1.39	1.55± 0.15	1.95	0.85
		2015-16	75	0.51	0.38	1.12	2.15± 0.22	1.93	0.79
		2016-17	75	0.47	0.33	1.03	2.15± 0.22	2.58	1.16
	Bangalore	2014-15	105	0.51	0.38	0.70	1.66± 0.12	2.13	0.73
		2015-16	75	0.53	0.37	0.98	1.93± 0.10	1.82	0.88
		2016-17	--	--	--	--	--	--	--
	Gangavathi	2014-15	75	0.45	0.31	1.02	1.56± 0.18	2.03	0.71
		2015-16	105	0.47	0.30	1.05	1.95± 0.05	2.05	1.10
		2016-17	90	0.43	0.25	0.96	1.95± 0.05	3.05	0.68
	Raichur	2014-15	90	14.13	10.17	15.88	2.55± 0.15	2.09	0.93
		2015-16	105	15.62	11.14	18.79	1.85± 0.10	1.98	1.05
		2016-17	75	18.34	13.96	21.15	1.85± 0.10	1.11	0.93
	Kalaburagi	2014-15	90	15.27	12.09	18.26	1.75± 0.23	2.26	0.79
		2015-16	105	16.76	13.06	21.17	2.45± 0.31	2.05	1.00
		2016-17	75	17.05	13.72	22.04	2.45± 0.31	2.05	0.59
	Bidar	2014-15	90	16.29	11.86	20.43	1.89± 0.28	1.77	1.01
		2015-16	90	17.78	12.77	22.45	2.04± 0.10	2.14	0.95
		2016-17	45	18.07	13.43	23.32	2.04± 0.10	2.61	0.69
	Dharwad	2014-15	75	14.65	11.96	20.42	1.58± 0.34	1.89	0.84
Methomyl 40%SP		2015-16	75	16.14	12.59	22.13	2.15± 0.20	2.52	1.14
		2016-17	60	16.43	13.25	23.00	2.15± 0.20	1.85	0.77
	Bellary	2014-15	90	16.56	12.33	17.37	1.73± 0.28	3.05	0.70
		2015-16	75	18.05	13.3	20.28	1.88± 0.37	2.79	0.83
		2016-17	90	15.91	11.80	19.66	1.88± 0.37	1.77	1.15
	Bangalore	2014-15	90	17.10	13.56	19.08	2.11± 0.18	1.79	0.58
		2015-16	90	18.59	14.41	20.99	1.95± 0.25	2.00	1.09
		2016-17	--	--	--	--	--	--	--
	Gangavathi	2014-15	75	13.10	11.86	17.30	1.66± 0.35	1.78	0.66
		2015-16	105	14.59	12.23	19.21	2.05± 0.22	1.93	0.78
		2016-17	75	14.88	12.89	20.08	2.05± 0.22	2.06	1.04

(contd.)

(Table 1 contd.)

	Raichur	2014-15	90	39.74	28.25	47.22	1.85± 0.34	3.46	0.55
		2015-16	105	41.93	29.73	48.41	2.14± 0.22	2.24	1.05
		2016-17	75	40.60	27.74	47.44	2.14± 0.22	2.75	0.76
	Kalaburagi	2014-15	75	41.08	34.78	54.78	2.36± 0.72	2.77	0.94
		2015-16	105	43.27	36.26	55.97	2.05± 0.51	1.86	0.89
		2016-17	60	41.94	34.27	54.81	2.05± 0.51	2.25	0.83
	Bidar	2014-15	90	40.44	32.70	51.78	1.73± 0.51	1.82	0.86
		2015-16	90	42.63	34.18	52.88	2.00± 0.35	2.54	1.10
		2016-17	60	41.30	32.19	51.91	2.00± 0.35	1.96	1.00
	Dharwad	2014-15	90	37.47	32.51	45.82.	2.00± 0.55	1.91	0.57
Chlorpyriphos 20%EC		2015-16	90	37.35	31.00	45.31	1.85± 0.29	1.95	0.75
		2016-17	75	36.02	29.01	44.34	1.85± 0.29	1.74	1.00
	Bellary	2014-15	90	37.28	26.12	43.18	2.25± 0.57	2.73	1.01
		2015-16	75	39.47	27.60	44.35	2.53± 0.25	2.74	1.24
		2016-17	75	38.14	25.61	43.38	2.53± 0.25	1.58	1.01
	Bangalore	2014-15	75	39.82	33.48	49.73	1.96± 0.76	2.08	0.51
		2015-16	105	42.01	34.96	50.92	1.82± 0.14	2.39	1.00
		2016-17	--	--	--	--	--	--	--
	Gangavathi	2014-15	90	35.16	29.52	44.18	1.98± 0.46	2.19	0.89
		2015-16	90	39.66	33.99	47.01	2.08± 0.25	2.10	0.68
		2016-17	75	38.33	32.00	46.04	2.08± 0.25	2.02	0.85
	Raichur	2014-15	75	11.71	10.16	14.55	2.74± 0.45	0.57	0.79
		2015-16	105	12.54	10.74	15.14	1.94± 0.74	1.25	0.55
		2016-17	75	15.15	11.24	18.07	1.32± 0.15	1.02	0.70
	Kalaburagi	2014-15	90	13.49	11.85	17.76	1.86± 0.51	1.89	0.88
		2015-16	105	14.32	12.43	18.45	2.00± 0.49	2.84	0.69
		2016-17	75	13.37	9.55	14.76	1.70± 0.26	1.88	1.00
	Bidar	2014-15	75	12.81	10.73	17.29	1.95± 0.15	1.57	1.08
		2015-16	75	13.74	11.31	17.88	2.25± 0.33	1.56	1.02
		2016-17	90	14.57	10.12	17.50	2.05± 0.35	2.34	1.05
	Dharwad	2014-15	75	12.49	10.21	16.46	1.93± 0.35	2.14	1.01
Thiodicarb 70%SP		2015-16	105	13.44	10.79	14.25	3.16± 0.61	1.08	0.73
		2016-17	105	12.44	7.55	13.63	2.24± 0.10	2.10	0.85
	Bellary	2014-15	90	12.93	10.35	15.91	2.19± 0.73	1.02	0.80
		2015-16	90	13.89	10.93	16.6	2.97± 0.48	0.79	0.62
		2016-17	90	14.72	9.74	16.22	3.07± 0.21	1.25	0.56
	Bangalore	2014-15	75	15.15	12.18	17.44	1.81± 0.18	2.15	0.73
		2015-16	75	16.02	12.76	18.03	2.43± 0.29	1.15	1.09
		2016-17	--	--	--	--	--	--	--
	Gangavathi	2014-15	105	10.73	8.16	13.25	2.05± 0.57	1.67	0.55
		2015-16	75	11.61	8.74	14.01	1.99± 0.42	0.83	1.15
		2016-17	75	14.27	9.60	13.87	2.09± 0.37	0.92	1.00
	Raichur	2014-15	75	0.21	0.16	0.32	1.68± 0.19	1.65	0.75
		2015-16	75	0.47	0.30	0.53	1.59± 0.28	1.25	0.59
		2016-17	75	0.99	0.66	1.23	1.66± 0.31	1.30	0.51
	Kalaburagi	2014-15	105	0.29	0.19	0.51	2.04± 0.24	2.49	0.59
		2015-16	75	0.43	0.32	0.58	1.96± 0.10	1.64	0.72
		2016-17	75	1.07	0.73	1.39	1.54± 0.20	2.34	0.63
	Bidar	2014-15	90	0.25	0.17	0.62	1.14± 0.82	1.77	0.68
Flubendiamide 37.9%SC		2015-16	75	0.42	0.31	0.51	1.51± 0.41	1.88	0.91
		2016-17	75	1.00	0.70	1.24	1.75± 0.28	2.08	1.00
	Dharwad	2014-15	105	0.19	0.11	0.38	1.75± 0.12	1.83	0.99
		2015-16	90	0.41	0.27	0.50	1.49± 0.74	2.05	0.84
		2016-17	75	1.10	0.67	1.39	2.29± 0.67	1.95	0.83
	Bellary	2014-15	60	0.29	0.12	0.41	2.08± 0.08	1.15	0.63
		2015-16	90	0.52	0.28	0.66	1.76± 0.55	1.70	1.01
		2016-17	60	1.05	0.69	1.26	2.36± 0.15	3.20	1.00
	Bangalore	2014-15	90	0.27	0.17	0.49	1.72± 0.38	1.92	1.00
		2015-16	105	0.45	0.32	0.60	2.14± 0.41	1.59	0.96
		2016-17	--	--	--	--	--	--	--
	Gangavathi	2014-15	90	0.18	0.06	0.39	1.84± 0.27	1.93	0.66
		2015-16	90	0.43	0.23	0.55	2.29± 0.12	2.00	0.59
		2016-17	75	1.01	0.62	1.28	2.54± 0.10	2.14	0.94

(contd.)

(Table 1 contd.)

Chlorantriniliprole 18.5%SC	Raichur	2014-15	90	0.18	0.11	0.38	2.73± 0.24	3.52	0.87
		2015-16	105	0.23	0.12	0.41	2.34± 0.43	2.59	0.59
		2016-17	75	0.70	0.59	1.17	1.76± 0.25	1.74	0.95
	Kalaburagi	2014-15	90	0.25	0.17	0.45	1.86± 0.12	2.61	0.76
		2015-16	105	0.43	0.23	0.63	2.19± 0.10	3.04	0.90
		2016-17	75	0.94	0.71	1.52	2.25± 0.15	2.95	0.88
	Bidar	2014-15	75	0.19	0.13	0.43	1.54± 0.59	3.16	1.00
		2015-16	75	0.20	0.13	0.45	1.86± 0.21	2.76	1.05
		2016-17	75	0.76	0.56	1.28	3.05± 0.20	1.86	1.00
	Dharwad	2014-15	75	0.17	0.10	0.29	2.19± 0.26	1.72	0.68
		2015-16	105	0.24	0.10	0.51	2.00± 0.10	1.95	1.11
		2016-17	90	0.71	0.61	1.34	2.10± 0.36	3.90	0.92
	Bellary	2014-15	75	0.22	0.09	0.36	1.85± 0.32	2.58	1.05
		2015-16	90	0.25	0.08	0.39	1.58± 0.26	2.44	0.74
		2016-17	90	0.75	0.58	1.40	2.11± 0.22	3.20	1.05
	Bangalore	2014-15	90	0.39	0.22	0.55	2.05± 0.25	1.86	0.58
		2015-16	90	0.27	0.17	0.49	2.22± 0.13	3.15	0.64
		2016-17	--	--	--	--	--	--	--
	Gangavathi	2014-15	75	0.20	0.11	0.64	2.13± 0.51	2.29	1.06
		2015-16	75	0.19	0.11	0.28	2.09± 0.38	2.83	0.85
		2016-17	75	0.74	0.60	1.30	2.00± 0.31	1.99	1.13

(0.38 ppm) and maximum with that of Bengaluru. The observations from 2015-16, revealed the least value in Dharwad population (0.33 ppm) and maximum with Raichur (0.48 ppm). Ahmad et al. (2005) found spinosad (1 ppm) toxic to 2nd instar larvae. Kranthi et al. (2000) observed that the toxicity of spinosad was relatively less variable falling within LD_{50} range of 0.023 to 0.24 µg/larvae and LD_{90} of 0.27 to 4.33 µg/ larvae. With methomyl LC_{50} varied from 13.10 to 17.10 ppm, least observed in Gangavathi population (13.10 ppm) and maximum in Bangalore (17.10 ppm) during 2014-15. In 2015-16, similar results were obtained. Ahmed et al. (1990) reported that the egg mortalities were more with methomyl @ 1%. LC_{50} values of thiodicarb varied from 10.73 to 15.15 ppm (2014-15) with least values being in Gangavathi population (10.73 ppm); in 2015-16 these varied from 11.61 to 16.02 ppm, with least being again with Gangavathi population (11.61 ppm). Lowest LC_{50} value was observed in Dharwad population (12.44 ppm) in 2016-17 (Table 1). Prasad Rao and Grace (2008) reported that LC_{50} value of thiodicarb was 1.86 µg/ larvae, much higher than that of spinosad, emamectin benzoate and methomyl. The lower level of toxicity and higher level of resistance was also observed earlier by Gunning et al. (1996). The effect of thiodicarb on the larval population of *H. armigera* was found to be moderate (Ramasubramanian and Regupathy, 2003).

LC_{50} values of flubendiamide ranged from 0.18 to 0.29 ppm, with the least value being with Gangavathi population (0.18 ppm) and maximum with that of Bellary (0.29 ppm) in 2014-15; least value during 2015-16 was observed in Dharwad population (0.41 ppm); while in 2016-17, it was the least in Dharwad population (0.99 ppm). Naresh Kanwar et al. (2012) found in their studies, flubendiamide 480 SC was relatively more toxic (relative toxicity was calculated over novaluron); and flubendiamide was 6.41x and lufenuron was 2.73x more toxic (Nikam et al., 2015). LC_{50} values of chlorantraniliprole in 2014-15 varied from 0.17 to 0.38 ppm and with the least value being with Dharwad population (0.17 ppm) and maximum with that of Bangalore (0.39 ppm). The least value was observed with Gangavathi population (0.19 ppm) and maximum with Kalaburagi population (0.43 ppm) during 2015-16; while the least value was observed in Dharwad population (0.71 ppm), and maximum with Kalaburagi population (0.94 ppm) (2016-17) (Table 1). In laboratory studies, LC_{50} for rynaxypyr (0.1 ppm) were significantly lower compared to indoxacarb and cypermethrin in tobacco budworm (Anonymous, 2007); in third instar larvae of *H. armigera* in okra, susceptibility increased after five generations. Joshua et al. (2008) in bioassay against bollworm obtained LC_{50} values ranging from 0.038 to 0.089 µg/ ml of diet. Thus, bioassay results showed varying degrees of toxicity to insecticides in the populations of *H. armigera* and the order of toxicity of insecticides chlorantraniliprole > emamectin benzoate > flubendiamide > spinosad > thiodicarb > methomyl > profenophos > chlorpyriphos. If used in rotation with the new insecticides, insecticide resistance management can be better.

REFERENCES

Ahmad Arif M I, Ahmad Z. 2005. Susceptibility of *Helicoverpa armigera* (Lepidoptera: Noctuidae) to new chemistries in Pakistan. Crop Protection 22: 539-544.

Ahmad M, Sayyed A H, Crickmore N Saleem S A. 2007. Genetics and mechanism of resistance to deltamethrin in a field population of *Spodoptera litura* (Lepidoptera: Noctuidae). Pest Management Science 63: 1002-1010.

Ahmed K, Rao N H P, Reddy A S. 1990. Ovicidal action of insecticides on eggs of gram pod borer (*Helicoverpa armigera*). Indian Journal of Agricultural Science 60: 154-156.

Anonymous. 2007. DuPont Rynaxypyr® insect control technical bulletin. (Online). Available at http://www2.dupont. com/Production Agriculture/en_US/assets /downloads/ pdfs/ Rynaxypyr®_tech. Bulletin. pdf

Brevault T, Oumarou Y, Achaleke J, Vaissayre M, Nibouche S. 2009, Initial activity and persistence of insecticides for the control of bollworms (Lepidoptera: Noctuidae) in cotton crops. Crop Protection 28: 401- 406.

Dinsdale A B, Cook L, Riginos C, Buckley Y M, Barro P D. 2010. Refined global analysis of *Helicoverpa armigera*, mitochondrial cytochrome oxidase I to identify species level genetic boundaries. Annals of the Entomological Society of America 103: 196-208.

Ferre J, Van R J. 2012. Biochemistry and genetics of insect resistance to *Bacillus thuringien* sis. Annnual Review of Entomology 47: 501-533.

Gunning R V, Moores G D, Devonshire A L. 1996. Insensitive acetylcholinesterase and resistance to thiodicarb in Australian *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae). Pesticide Biochemistry and Physiology 55: 21-28

Gupta G P, Birah A, Rani S, Raguraman M. 2005. Relative toxicity of novel insecticides to American bollworm (*Helicoverpa armigera*). Indian Journal of Agricultural Sciences 75(4): 235-237.

Hirooka T, Nishimatsu T, Kodama H, Reckmann U, Nauen R. 2007. The biological profile of flubendiamide, a new benzenedicarboxamide insecticide. Pflanzenschutz- Nachrichten Bayer 60(2): 183-202.

Joshua H, Temple Bommireddy, P L Paul Marcon, Tephen Micinski, Enfinger K D, Ieonard B R. 2008. Rynaxypyr (DPX-E2Y45) and Cypermethrin: susceptibility Of Selected Lepidopteran Insect Pests. Beltwide Cotton Conf, Nashville, Tennessee, January 8-11-2008.

Kontsedalov S, Abu-Moch F, Lebedev G, Czosnek H, Horowitz R, Ghanim M. 2012. *Helicoverpa armigera* biotype dynamics and resistance to insecticides in Israel during the years 2008-2010. Journal of Integrative Agriculture 11: 312-320.

Kranthi K R, Ali S S, Banerjee S K. 2000. Baseline toxicity to spinosad on cotton bollworm: *H. armigera* (Hubner) in India. Resistant Pest Management 11: 9-12

Kranthi K R, Jadhav D R, Kranthi S, Wanjari R R, Ali S S, Russell D A. 2002. Insecticide resistance in five major insect pests of cotton in India. Crop Protection 21: 449- 460.

McCaffery A R, Head D J, Jianguo T, Dubbeldam A A, Subramaniam V R, Callaghan. 1998. Nerve insensitivity resistance to pyrethroids in *Heliothine* Lepidoptera. Journal of Pesticide Science 51: 315-320.

Naresh Kanwar O P, Ameta and Abhishek Pareek. 2012. Relative toxicity of insecticides against *Helicoverpa armigera*. Indian Journal of Entomology 74: 233-235.

Nauen R, Bretschneider T. 2002. New modes of action of insecticides. Pesticide Outlook. 13:241-245.

Nikam A G, Chandele, Nikit, Awasthi. 2015. Relative toxicity of some newer insecticides to Diamondback moth, *Plutella xylostella* Linnaeus. The Ecoscan 22: 105-108.

Prasada Rao G M V, Grace A D G. 2008. Status of new insecticides vis-a-vis conventional insecticides against the American bollworm, *Helicoverpa armigera* (Hub.) Resistance Pest Management Newslettter 18(1): 26-28.

Ramasubramanian T, Regupathy A. 2003. Laboratory Measured Resistance and Field Control of *Helicoverpa armigera* Hub. by thiodicarb. Asian Journal of Plant Sciences 2: 1175-1178.

Razaq M, Suhail M, Aslam M J, Arif M A, Saleem M H A. 2005. Evaluation of new chemistry and conventional insecticides against *Helicoverpa armigera* (Hubner) on cotton at Multan (Pakistan). Pakistan Entomology 27: 71-73.

(Manuscript Received: November, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: April, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20257

Indian Journal of Entomology 84(1): 77-81 (2022) DoI No.: 10.55446/IJE.2021.254

DIVERSITY AND ABUNDANCE OF FLOWER VISITING INSECTS ASSOCIATED WITH SESAME

K Sankara Rao*, Yogesh Kumar, Sunita Yadav and Roomi Rawal

Department of Entomology, CCS Haryana Agricultural University, Hisar 125004, Haryana, India
*Email: ksankararao0987@gmail.com (corresponding author)

ABSTRACT

A field experiment was conducted at the Research farm of Department of Entomology, CCS Haryana Agricultural University (CCSHAU) Hisar, Haryana to determine the diversity and abundance of insect pollinators on two varieties of sesame HT-1 and HT-2 during 2017 and 2018. A total of 34 insect species belonging to 18 families from four orders were observed. Of these *Apis dorsata* (4.76 bees/ m²/ 5 min; 26.92% of total flower visitors) followed by *A. mellifera* (2.34 bees/ m²/ 5 min), *M. lanata* (2.23 bees/ m²/ 5 min) and *A. florea* (1.32 bees/ m²/ 5 min) were predominant. Peak activity of the insect visitors was observed at 1000-1200 hr of the day.

Key words: Sesame, pollination, insect visitors, diversity, hymenopterans, coleopterans, lepidopterans, honey bees, solitory bees, relative abundance, peak activity

Pollination is one of the most prized provisioning services chiefly valued for its contribution in sexual reproduction in many angiosperms (Kearns et al., 1998). In India, out of 211 crops, 108 (51.2%) crops are dependent on animal pollination where it was essential for 14 crops, great for 34, moderate for 29 and little for 31 crops. Among them, oilseeds followed by fruits are found to be more dependent. Decline in pollinator contribution in these crops could significantly decrease output (Chaudhary and Chand, 2017). Sesame, ancient oil seed crop, is being cultivated in 78 countries belonging to many tropical countries where 73% of global production come from China, Ethiopia, India, Myanmar, Nigeria, Sudan and Tanzania (FAO, 2017). In India the productivity is only 448 kg ha-1 (CCSHAU, 2017). The crop has observed to show high variance in pollination dependence as its outcrossing rates vary from 10 to 68%, evidencing that it has mixed mating system and produces capsules through self and cross-pollination (Free, 1993; Sarker, 2004). Recent study had also reported it as one of the pollinator dependent crops where the loss of bee pollinators would result in yield gaps between 50 and 87% (Stein et al., 2017). Hence, as a part of good crop production initiatives, conserving and utilizing the available pollinator fauna is of paramount importance. This necessitates the continued research to monitor the pollinator fauna in the sesame crop ecosystem. Information on insect pollinators of sesame in Haryana is also scarce. Hence, the present study with objective of determining the diversity and relative abundance of flower visiting insects/ pollinators in sesame at Hisar, Haryana.

MATERIALS AND METHODS

The present study was conducted at the Research farm (29º10'N,75º 46'E) of Department of Entomology, CCS Haryana Agricultural University (CCSHAU), Hisar, Haryana. All observations on the flower visiting insects were made on the selected varieties, HT-1and HT-2 during kharif season 2017 and 2018. The crop was raised as per the recommended practices of CCSHAU excluding protection measures (Anonymous, 2017). Both the varieties were sown on 12th July (2017) and 16th June (2018) and harvested on 10th October (2017) and 4th October (2018). The flowering period of 34 days (20th August- 22nd September, 2017) and 38 days (1st August- 7th September, 2018) was observed. Plants were observed to collect the flower visiting insects from 0600 to 1800 hr, every two hourly intervals. Cone type hand net measuring 38 cm dia was used and the collected insects were processed as per standard procedures. These specimens were got identified from the Insect Identification Service, Division of Entomology, Indian Agricultural Research Institute, New Delhi. The insects collecting nectar and/ or pollen through were characterized as pollinators, whereas the insects which enter otherwise simply as flower visitors. In addition, individuals working from the top side of flower were considered as top worker, whereas individuals visiting through side route were referred as side worker. For recording the diurnal abundance, 17 frequently visiting insect visitors/ pollinators were considered. The number of insects. m^2 area of crop/ 5 min was counted from four randomly selected areas.

These observations were taken at two hourly intervals, starting from 0600 to 1800 hr and repeated at weekly intervals starting from 10% of the flowering to the end of flowering. The diurnal abundance data was further used to calculate the % relative abundance of an individual species using the following formula-

$$\text{Relative abundance of 'X' spp.} = \frac{\text{No. of visits 'X' spp.}}{\text{Total visits}} \times 100$$

The data for 2017 and 2018 and the pooled data were subjected to statistical analysis following factorial randomized block design using OPSTAT software (Sheoran et al.1998) and the results were compared using LSD (p=0.05).

RESULTS AND DISCUSSION

A total of 34 species under 18 families of four orders viz., Hymenoptera, Diptera, Lepidoptera and Coleoptera were observed to visit the sesame flowers (Table 1). Thus, the species collected did not vary with variety. Hymenoptera constituted a dominant share (62%) followed by Lepidoptera (17%), Diptera (12%) and Coleoptera (9%). Hymenoptera consisted of 21 species under 8 families, while other orders had less numbers. The maximum number of species observed were from the family Apidae (6), followed by Megachilide (5) and Vespidae (3). Of the insects observed, 16 were observed to be pollinators. These visitors were taking the nectar from extrafloral nectaries present at the base of flower, and

Table 1. Flower visiting insects of *S. indicum* (var. HT-1 and HT-2, kharif 2017, 2018)

S.No.	Scientific name	Family	Order	Insect pollinator/ Insect visitor	Working behaviour
1	*Apis mellifera* L.	Apidae	Hymenoptera	IP*	T*
2	*Apis cerana indica* F.	Apidae	Hymenoptera	IP	T
3	*Apis dorsata* F.	Apidae	Hymenoptera	IP	T
4	*Apis florea* F.	Apidae	Hymenoptera	IP	T and S
5	*Ceratina smaragdula* F.	Apidae	Hymenoptera	IP	T
6	*Xylocopa iridipennis* Lepeletier	Apidae	Hymenoptera	IP	T and S
7	*Megachile lanata* F.	Megachilidae	Hymenoptera	IP	T
8	*Megachile cephalotes* Smith	Megachilidae	Hymenoptera	IP	T
9	*Megachile bicolor* F.	Megachilidae	Hymenoptera	IP	T
10	*Coelioxys* sp.	Megachilidae	Hymenoptera	IP	T
11	*Anthidium* sp.	Megachilidae	Hymenoptera	IP	T
12	*Nomia curvipes* F.	Halictidae	Hymenoptera	IP	T
13	*Halictus* sp.	Halictidae	Hymenoptera	IP	T
14	*Anthophora cingulata* F.	Anthophoridae	Hymenoptera	IP	T
15	*Sceliphron madrasapatnam* F.	Vespidae	Hymenoptera	IV	S*
16	*Polistes hebraceus* F.	Vespidae	Hymenoptera	IV	S
17	*Vespa orientalis* L.	Vespidae	Hymenoptera	IV	S
18	*Compsomeriella* sp.	Scolidae	Hymenoptera	IV	S
19	*Delta dimidiatipenne* Saussure	Eumenidae	Hymenoptera	IV	S
20	*Odynerus ovalis* Saussure	Eumenidae	Hymenoptera	IV	S
21	*Camponotus* sp.	Formicidae	Hymenoptera	IV	T and S
22	*Episyrphus* sp.	Syrphidae	Diptera	IP	T and S
23	*Ersitalinus* sp.	Syrphidae	Diptera	IP	T and S
24	*Musca* sp.	Muscidae	Diptera	IV	T and S
25	*Calliphora* sp.	Calliphoridae	Diptera	IV	T and S
26	*Danus chrysippus* L.	Nymphalidae	Lepidoptera	IV	T and S
27	*Julonia almana* L.	Nymphalidae	Lepidoptera	IV	T and S
28	*Papilio demoleus* L.	Papillionidae	Lepidoptera	IV	T and S
29	*Pelopidas mathias* F.	Hesperiidae	Lepidoptera	IV	T and S
30	*Antigastra catalaunalis* (Duponchel)	Crambidae	Lepidoptera	IV	T and S
31	*Earias insulana* Boisduval	Nolidae	Lepidoptera	IV	T and S
32	*Oxycetonia versicolor* (F.)	Scarabaeidae	Coleoptera	IV	T
33	*Chiloloba acuta* Wiedemann	Scarabaeidae	Coleoptera	IV	T
34	*Mylabris pustulata* (Thunberg)	Meloidae	Coleoptera	IV	T

*IP –Insect Pollinator and IV – Insect Visitor; T – Top Worker and S – Side Worker

Table 2. Diurnal abundance of insect visitors/ pollinators on flowers of *S. indicum* (Cv. HT-1 and HT-2, kharif 2017, 2018)

S. No.	Insect visitor/ pollinator	Mean no. of insects / m^2 / 5min															% Relative abundance
		HT-1							HT-2								
		0600-0800 hr	0800-1000 hr	1000-1200 hr	1200-1400 hr	1400-1600 hr	1600-1800 hr	Mean	0600-0800 hr	0800-1000 hr	1000-1200 hr	1200-1400 hr	1400-1600 hr	1600-1800 hr	Mean	Pooled mean	
1.	*A. mellifera*	1.94 (1.71)	2.63 (1.91)	3.94 (2.22)	2.82 (1.95)	1.54 (1.59)	0.75 (1.32)	2.27 (1.81)	1.97 (1.72)	2.78 (1.94)	3.84 (2.20)	2.91 (1.98)	1.88 (1.70)	1.03 (1.42)	2.40 (1.84)	2.34 (1.83)	13.24
2.	*A. cerana*	0.51 (1.23)	1.10 (1.45)	1.66 (1.63)	0.53 (1.24)	0.53 (1.24)	0.07 (1.03)	0.73 (1.32)	0.47 (1.21)	0.81 (1.35)	1.53 (1.59)	0.75 (1.32)	0.38 (1.17)	0.16 (1.08)	0.68 (1.30)	0.71 (1.31)	4.02
3.	*A. dorsata*	3.60 (2.14)	5.35 (2.52)	9.37 (3.22)	4.75 (2.40)	3.07 (2.02)	1.82 (1.68)	4.66 (2.38)	3.41 (2.10)	5.63 (2.57)	9.63 (3.26)	4.81 (2.41)	3.66 (2.16)	2.03 (1.74)	4.86 (2.42)	4.76 (2.40)	26.92
4..	*A. florea*	0.10 (1.05)	1.16 (1.47)	2.76 (1.94)	2.54 (1.88)	1.03 (1.42)	0.44 (1.20)	1.34 (1.53)	0.03 (1.01)	1.44 (1.56)	2.41 (1.85)	2.34 (1.83)	1.16 (1.47)	0.38 (1.17)	1.29 (1.51)	1.32 (1.52)	7.47
5.	*C. smaragdula*	0.00 (1.00)	1.82 (1.68)	1.97 (1.72)	2.00 (1.73)	0.69 (1.30)	0.16 (1.08)	1.11 (1.45)	0.06 (1.03)	1.22 (1.49)	1.66 (1.63)	2.19 (1.79)	0.66 (1.29)	0.16 (1.08)	0.99 (1.41)	1.05 (1.43)	5.94
6.	*X. iridipennis*	0.35 (1.16)	0.16 (1.08)	0.25 (1.12)	0.32 (1.15)	0.00 (1.00)	0.00 (1.00)	0.18 (1.09)	0.13 (1.06)	0.41 (1.55)	0.09 (1.04)	0.47 (1.21)	0.03 (1.01)	0.00 (1.00)	0.19 (1.09)	0.19 (1.09)	1.07
7.	*M. lanata*	0.13 (1.06)	2.38 (1.84)	3.29 (2.07)	4.00 (2.24)	1.78 (1.67)	1.03 (1.42)	2.10 (1.76)	0.00 (1.00)	2.66 (1.91)	3.56 (2.14)	4.16 (2.27)	2.06 (1.75)	1.47 (1.57)	2.35 (1.83)	2.23 (1.80)	12.61
8.	*M. cephalotes*	0.00 (1.00)	1.38 (1.54)	1.82 (1.68)	2.22 (1.79)	1.19 (1.48)	0.69 (1.30)	1.22 (1.49)	0.00 (1.00)	1.41 (1.55)	1.91 (1.71)	2.34 (1.83)	1.38 (1.54)	0.81 (1.35)	1.31 (1.52)	1.27 (1.51)	7.18
9.	*M. bicolor*	0.00 (1.00)	0.19 (1.09)	0.57 (1.25)	1.60 (1.61)	0.10 (1.05)	0.10 (1.05)	0.42 (1.19)	0.00 (1.00)	1.00 (1.41)	1.19 (1.48)	0.63 (1.28)	0.19 (1.09)	0.13 (1.06)	0.52 (1.23)	0.47 (1.21)	2.66
10.	*Coelioxys* sp.	0.00 (1.00)	0.07 (1.03)	0.13 (1.06)	0.22 (1.10)	0.03 (1.01)	0.00 (1.00)	0.07 (1.03)	0.00 (1.00)	0.06 (1.03)	0.34 (1.16)	0.41 (1.19)	0.03 (1.01)	0.00 (1.00)	0.14 (1.07)	0.11 (1.05)	0.62
11.	*N. curvipes*	0.00 (1.00)	1.03 (1.42)	1.82 (1.68)	1.85 (1.69)	0.50 (1.22)	0.16 (1.08)	0.89 (1.37)	0.00 (1.00)	0.66 (1.29)	1.63 (1.62)	1.91 (1.71)	0.94 (1.39)	0.31 (1.14)	0.91 (1.38)	0.90 (1.38)	5.09
12.	*Halictus* sp.	0.00 (1.00)	0.60 (1.26)	0.75 (1.32)	0.85 (1.36)	0.10 (1.05)	0.00 (1.00)	0.38 (1.17)	0.00 (1.00)	0.50 (1.22)	1.16 (1.47)	0.91 (1.38)	0.06 (1.03)	0.00 (1.00)	0.44 (1.20)	0.41 (1.19)	2.32
13.	*A. cingulata*	0.07 (1.03)	0.32 (1.15)	0.38 (1.17)	0.41 (1.19)	0.00 (1.00)	0.00 (1.00)	0.20 (1.10)	0.09 (1.04)	0.28 (1.13)	0.34 (1.16)	0.22 (1.10)	0.03 (1.01)	0.00 (1.00)	0.16 (1.08)	0.18 (1.09)	1.02
14.	*Compsomer-iella* sp.	0.16 (1.08)	0.56 (1.25)	0.41 (1.19)	0.13 (1.06)	0.10 (1.05)	0.00 (1.00)	0.23 (1.11)	0.13 (1.06)	0.34 (1.16)	0.25 (1.12)	0.13 (1.06)	0.03 (1.01)	0.00 (1.00)	0.15 (1.07)	0.19 (1.09)	1.07
15.	*M. pustulata*	1.91 (1.71)	1.35 (1.53)	0.63 (1.28)	0.35 (1.16)	0.07 (1.03)	0.53 (1.24)	0.80 (1.34)	1.78 (1.67)	1.16 (1.47)	0.53 (1.24)	0.06 (1.03)	0.16 (1.08)	0.50 (1.22)	0.70 (1.30)	0.75 (1.32)	4.24
16.	*O. versicolor*	0.03 (1.01)	0.85 (1.36)	0.69 (1.30)	0.28 (1.13)	0.16 (1.08)	0.16 (1.08)	0.36 (1.17)	0.19 (1.09)	0.53 (1.24)	0.56 (1.25)	0.22 (1.10)	0.28 (1.13)	0.22 (1.10)	0.33 (1.15)	0.35 (1.16)	1.98
17.	*Eristalinus* sp.	0.63 (1.28)	0.91 (1.38)	0.66 (1.29)	0.57 (1.25)	0.53 (1.24)	0.03 (1.01)	0.55 (1.24)	0.72 (1.31)	0.88 (1.37)	0.75 (1.32)	0.38 (1.17)	0.34 (1.16)	0.03 (1.01)	0.52 (1.23)	0.54 (1.24)	3.05
	Total***	9.38 (1.25)	22.16 (1.52)	31.23 (1.68)	25.54 (1.58)	11.60 (1.30)	6.07 (1.16)	17.46 (1.42)	8.97 (1.24)	21.75 (1.51)	31.38 (1.69)	24.81 (1.57)	13.25 (1.33)	7.22 (1.19)	17.90 (1.43)	17.68 (1.43)	-

(Table 2 contd.)

(Table 2 contd.)

Factors	CD (p≤0.05)		
	2017	2018	Pooled
Variety	NS	NS	-
Year	0.05	0.06	0.06
Insect Visitor	0.02	0.03	0.03
Time	0.03	0.03	0.03
Insect Visitor × Time	0.12	0.06	0.14
Variety × Year	-	-	NS
variety × Time	-	-	NS
Variety × Year × Time	-	-	NS
Insect Visitor × Time × Year	-	-	0.20

*Each value represents a mean of four weekly observations; **Data subjected to √n+1 transformation; ***Transformation on the basis of respective mean

there were 15 top and 6 side workers, and 13 worked as both top and side workers. These observations revealed that the number of insects of collected were significantly higher in comparison to earlier reports on sesame- only 12 insect visitors in Hisar, Haryana (Sachdeva et al., 2003), 13 species in Dharwad, Karnataka (Patil, 1999), 22 species in Bengaluru, Karnataka (Pashte and Shylesha, 2013a) and eight species in Bhubaneswar, Orissa (Mohapatra and Sontakke, 2012). The observation that hymenopterans were the most dominant visitors of sesame corroborates with earlier results- Patil (1999) at Dharwad, Karnataka reported 13 species with 8 of Hymenoptera. Mahfouz et al. (2012) observed Hymenoptera (86%) as the predominant flower visitors. Sajjanar and Eswarappa (2015) at Raichur, Karnataka and Kamel et al. (2013) at Ismailia, Egypt are also in agreement with present results.

The data on diurnal abundance of the 17 pollinators revealed moderate to low abundance (Table 2); with no significant variation in relation to variety. Mishra (1994) also observed such insignificance in abundance of honey bees in varieties, as observed by Chandran (2009) with honey bees at Dharwad, Karnataka. In general, the diurnal abundance was more in 2018 than 2017. This small but measurable variation might be due to differential foraging rate of flower visitors/ pollinators which was in turn depended on weather factors (Reddy et al. 2015). Among the 17 flower visitors/pollinators, *Apis dorsata* was found to be the most abundant followed by others, with the four species forming a share of 60.24 % of the total abundance. Significant number of *M. cephalotes* (1.27), *C. smaragdula* (1.07) and *N. curvipes* (0.90) were also noted. *Coelioxys* sp., *A. cingulata, Compsomeriella* sp., and *X. iridipennis* visited the crop rarely and of a very low abundance values of < 0.20 insects/ m²/ 5 min. Sachdeva et al. (2003) also made similar observations while recording the abundance of flower visitors on *S. indicum* cv. HT- 1 at Hisar, Haryana. The honey bees *viz*., *A. dorsata* (7.53 bees/ m² / 5 min), *A. mellifera* (4.73 bees/ m² / 5 min) and *A. florea* (4.20 bees/ m² / 5 min) were observed as predominant. Similarly, in Hisar, Nagpal (2016) on flowers of Indian mustard *B. juncea* also reported the dominance of the honey bees. in southern and eastern parts of India higher abundance of *A. cerana* over *A. dorsata*, *A. mellifera* and *A. florea* in *S. indicum* was observed (Mohapatra and Sontakke, 2012; Sajjanar and Eswarappa, 2015). In Egypt, Kamel et al. (2013) recorded *A. mellifera*, *Ceratina tarsata*, *Xylocopa pubescens* and *Osmia* sp. as dominant species in sesame, while wasps, syrphid flies and butterflies as least abundant species.

The observations on visits of flower visitors/ pollinators at different time intervals of the day indicate a unimodal diurnal activity of the all the species as there was single visiting peak at 1000-1200 hr, irrespective of variety. The number of flower visiting insects increased from early morning to mid day (0600 to 1400 hr) and then there existed a declining trend with least activity from 1600 to 1800 hr. These observations are in agreement with results of Mohapatra and Sontakke (2012). Pashte and Shylesha (2013b) also observed the peak activity of nectar as well as pollen foragers at 1000 and 1100 hr of the day. Said et al. (2013) observed peak activity of pollinators between 1100 -1300 hr nd 1300-1500 hr. Thus, the results of the study indicate that the true attractiveness of sesame crop towards myriad of flower visitors/ pollinators is for 34 species of four orders viz., Hymenoptera, Diptera, Lepidoptera and Coleoptera. Among these, 17 were frequent visitors with a peak activity at 1000-1200 hr of the day; and *A. dorsata* was most abundant.

ACKNOWLEDGEMENTS

Authors thank Dr. Debjani Dey, Division of Entomology, Indian Agricultural Research Institute, New Delhi for identifying the insect specimens. Indian Council of Agricultural Research is acknowledged for providing the financial support in terms of Senior Research fellowship.

REFERENCES

Anonymous. 2017. Agricultural statistics at a glance 2017. Controller of publications, Government of India, Ministry of Agriculture & Farmers Welfare, Department of Agriculture, Cooperation & Farmers Welfare, Directorate of Economics and Statistics. 544 pp.

CCSHAU. 2017. Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana. Sesame. Package of practices of kharif crops, Astral Publication. 139-144 pp.

Chandran N. 2009. Evaluation of indigenous bee attractants in enhancing the yield of sesame and niger. M Sc Thesis, University of Agricultural Sciences, Dharwad, India. 67 pp.

Chaudhary O P, Chand R. 2017. Economic Benefits of Animal Pollination to Indian Agriculture. Indian Journal of Agricultural Sciences 87: 1117-1138.

FAO. 2017. Food and Agriculture Organization of the United Nations. FAOSTAT Statistical Database, http://www.fao.org/faostat/en, accessed on 13 March 2019.

Free J B.1993. Insect Pollination of Crops. Academic Press, London. 684 pp.

Kamel S M, Blal A H, Mahfouz H M, Said M. 2013.The Most common insect pollinator species on sesame crop (*Sesamum indicum* L.) in Ismailia Governorate, Egypt. Arthropods 2: 66-74.

Kearns C A, Inouye D W, Waser N M. 1998. Endangered mutualisms: The conservation of plant-pollinator interactions. Annual Review of Ecology and Systematics 29: 83-112.

Klein A M, Vaissiere B E, Cane J H, Steffan-Dewenter I, Cunnigham S A, Kremen C Tscharntke T. 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society 274: 303-313.

Mahfouz H M, Kamel S M, Belal A H, Said M. 2012. Pollinators visiting sesame (*Sesamum indicum* L.) Seed crop with reference to foraging activity of some bee species. Cercetari Agronomice in Moldova 45: 49-55.

Mishra R M. 1994. Effect of honey bee (*Apis mellifera* L.) pollination on the yield of sesamum and its oil Content. M Sc Thesis, Orissa University of Agriculture and Technology, Bhubaneswar.

Mohapatra L N, Sontakke B K. 2012. Behavioural studies on pollinators in sesamum. Indian Journal of Entomology 74: 189-192.

Nagpal K. 2016. Role of *Apis* spp. Pollination in quality seed production of Indian mustard. M Sc Thesis, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India. 74 pp.

Pashte V V, Shylesha A N. 2013a. Pollinators diversity and their abundance on sesamum. Indian Journal of Entomology 75: 260-262.

Pashte V V, Shylesha A N. 2013b. Pollen and nectar foraging activity of honey bees in sesamum. Indian Journal of Entomology 75: 124-126.

Patil B. 1999. Role of bee pollinators in enhancing productivity and quality of sesamum. M Sc Thesis, University of Agricultural Sciences, Dharwad.

Reddy P R, Rashmi T, Verghese A. 2015. Foraging activity of Indian honey bee *Apis cerana*, in relation to ambient climate variables under tropical conditions. Journal of Environmental Biology 36: 577-581.

SachdevaY, Bhatnagar P, Gulati R. 2003. Relative abundance and foraging behaviour of *Apis* spp. on sesamum (*Sesamum indicum*) flowers. Annals of Plant Protection Sciences 11: 281-284.

Said M, Kamel S M, Mahfouz A B H. 2013. Impacts of insect pollination on sesame production. Lambert Academic Publishing, Germany. 92 pp.

Sajjanar M S, Eshwarappa G. 2015. Bee pollination in crop production of sesame (*Sesamum indicum* L.). Mysore Journal of Agricultural Sciences 49: 703-707.

Sarker A M. 2004. Effect of honey bee pollination on the yield of rapeseed, mustard and sesame. Geobios 31: 49-51.

Sheoran O P, Tonk D S, Kaushik L S, Hasija R C, Pannu R S. 1998. Statistical Software Package for Agricultural Research Workers. Hooda D S, Hasija R C (eds). Recent Advances in Information Theory, Statistics and Computer Applications. 139-143 pp.

Stein K, Coulibaly D, Stenchly K, Goetze D, Porembski S, Lindner A, Konaté S, Linsenmair E K. 2017. Bee pollination increases yield quantity and quality of cash crops in Burkina Faso, West Africa. Scientific Reports 7: 1-10.

(Manuscript Received: November, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: April, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20267

Indian Journal of Entomology 84(1): 82-87 (2022) DoI No.: 10.55446/IJE.2021.255

DIVERSITY OF SPIDER MITES (TETRANYCHIDAE) ON ORNAMENTAL PLANTS IN CENTRAL KERALA

Jayalakshmi Prakash*, Haseena Bhaskar[1], Deepu Mathew, Vidya C V[1], Chinnamade Gowda[2] and Shylaja M R

Centre for Plant Biotechnology and Molecular Biology; [1]Department of Agricultural Entomology, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur 680656, Kerala, India
[2] Department of Agricultural Entomology, College of Agriculture, University of Agricultural Sciences, GKVK, Bengaluru 560065, Karnataka, India
*Email: jayalakshmiprakashkg@gmail.com (corresponding author)

ABSTRACT

Purposive sampling surveys were conducted in homestead gardens and ornamental nurseries at different localities of Thrissur and Ernakulam districts during 2017-19 to study the diversity of spider mites associated with ornamental plants. Mite samples collected from rose, adenium, gerbera, marigold, chrysanthemum, balsam, cock's comb, orchid, cassia, cairo morning glory, zinnia, bauhinia, crape jasmine and pinto peanut were maintained as isoline cultures in the laboratory. Male and female specimens from isolines were slide mounted for morphological characterisation and identification. The results revealed eight species belonging to three genera viz., *Tetranychus truncatus* Ehara, *T. okinawanus* Ehara, *T. urticae* Koch, *T. fijiensis* Hirst, *T. neocaledonicus* Andre, *T. marianae* McGregor, *Eutetranychus orientalis* Klein and *Oligonychus biharensis* Hirst. The study recorded new hosts for the alien species, *T. okinawanus* and *T. truncatus* which suggests the potential of these species to turn invasive in Kerala's ecosystems. The spider mite fauna on rose was more diverse, indicating the need for imposing strict quarantine regulations. The study observed *T. marianae* as a new record from Kerala.

Key words: Spider mites, diversity, key to species, morphology, ornamental plants, host range, central Kerala, *Tetranychus truncatus*, *T. okinawanus*, *T. marianae,* new record

Spider mites belonging to the family, Tetranychidae comprises of several agricultural and horticultural pests of high economic importance. Spider mites are highly polyphagous in nature and due to its short life cycle, high fecundity and small size, its control is often cumbersome. They are the most diverse group of arthropods encountered in quarantines. Many spider mite species intercepted at the port of entry belonged to the genus *Tetranychus* viz., *T. evansi* Baker & Pritchard *T. fijiensis Hirst and T. kanzawai Kishida,* because of the inter-continental movement of fruits, flowers and ornamental plants (Dhooria, 2016). Trade of commercial ornamentals has been recognized worldwide as an important invasion pathway for non-native pests. In Kerala, Thrissur district is considered as the centre of floriculture nursery business. Majority of nurseries in the area do not maintain their own sources of mother plants. They either purchase plants from other states or import planting materials from other countries which often serve as the potential pathway for pest invasion. Recently, a spider mite species, *Tetranychus okinawanus* Ehara was reported on an ornamental plant, *Adenium obesum* for the first time in India from commercial nurseries in Thrissur district, Kerala (Zeity et al., 2016) which would probably have gained entry into India through imported planting materials. Though spider mite infestation is a serious problem on ornamental plants, no studies have been conducted to document the diversity of mite fauna on ornamental plants in Kerala.

MATERIALS AND METHODS

Purposive sampling surveys were carried out in commercial ornamental nurseries and homestead gardens of Thrissur and Ernakulam districts during November, 2017 to May 2019. During the survey, mite infested leaf samples from the ornamental plants viz., rose, marigold, chrysanthemum, balsam, cock's comb, gerbera, adenium, bauhinia, cairo morning glory, orchid (*Vanda* sp.), zinnia, cassia, crape jasmine and pinto peanut were collected, labelled with locality details and brought to Acarology laboratory. In the laboratory, the leaves were observed under stereomicroscope and single gravid female mite from each sample was collected using camel hair brush and placed on mulberry leaf kept on wet sponge in plastic trays to establish isoline cultures. For morphological characterisation of mites,

permanent slides of male and female specimens from each established isoline culture were prepared separately, using Hoyer's medium. Female specimens were mounted in dorsal orientation, while male specimens were mounted in both dorsal and lateral orientation. The slides were observed under phase contrast microscope (Leica DM 500 phase contrast microscope), which has image analyzer software, to study the taxonomic characters. Characters such as chaetotaxy of hysterosoma and legs and structure of empodium of legs of female were used for genus level identification, while the shape of male genitalia, aedeagus was used for species level identification. Slide mounted specimens were identified based on the available species description and taxonomic keys provided by Gupta (1985), Gupta and Gupta (1994), Ehara (1995), Srinivasa et al. (2012) and Zeity et al. (2016).

RESULTS AND DISCUSSION

The study recorded eight species of spider mites belonging to three genera viz., *Tetranychus* Dufour, *Oligonychus* Berlese and *Eutetranychus* Banks in association with 14 ornamental plants. The genus *Tetranychus* was diverse with six species viz., *Tetranychus truncatus* Ehara, *T. okinawanus* Ehara, *T. urticae* Koch, *T. fijiensis* Hirst, *T. neocaledonicus* Andre and *T. marianae* McGregor. One species each were recorded from the genera, *Oligonychus* and *Eutetranychus* viz., *Oligonychus biharensis* Hirst and *Eutetranychus orientailis* Klein, respectively (Table 1).

Spider mite fauna on rose was found to be more diverse with five species viz., *T. truncatus, T. urticae, T. okinawanus, T. marianae* and *O. biharensis*. Both gerbera and chrysanthemum recorded two mite species viz., *T. okinawanus* and *T. urticae*, while marigold recorded *T. okinawanus* and *T. truncatus*. Adenium and balsam recorded only *T. okinawanus*, while bauhinia and pinto peanut recorded only *O. biharensis*. The ornamental plants zinnia, cock's comb, cassia, cairo morning glory and crape jasmine recorded one species each of spider mite viz., *T. neocaledonicus*, *T. truncatus, T. fijiensis, T. okinawanus* and *Eutetranychus orientalis* respectively.

Taxonomic key to the identification of spider mites

Table 1. Spider mites associated with ornamental plants of Kerala

S. No.	Plant	Location	GPS coordinates		Species
			Latitude (°N)	Longitude (°E)	
1.	Rose	Vellanikkara	10.33	76.17	*Tetranychus okinawanus* Ehara
		Vellanikkara	10.32	76.16	*Tetranychus urticae* Koch
		Madakkathara	10.33	76.15	*Tetranychus urticae* Koch
		Vellanikkara	10.55	76.28	*Tetranychus marianae* McGregor
		Elanadu	10.62	76.39	*Tetranychus truncatus* Ehara
		Aryampadam	10.55	76.28	*Oligonychus biharensis* Hirst
2.	Adenium	Manaloor	10.49	76.10	*Tetranychus okinawanus* Ehara
		Vellanikkara	10.55	76.28	
3.	Gerbera	Paravattani	10.52	76.24	*Tetranychus Okinawanus* Ehara
		Vellanikkara	10.55	76.27	*Tetranychus urticae* Koch
4.	Zinnia	Vellanikkara	10.32	76.16	*Tetranychus neocaledonicus* Andre
5.	Cairo morning glory	Vyttila	9.98	76.32	*Tetranychus okinawanus* Ehara
6.	Marigold	Vellanikkara	10.33	76.17	*Tetranychus truncatus* Ehara
		Odakkali,	10.05	76.33	
7.	Chrysanthemum	Vellanikkara	10.55	76.28	*Tetranychus okinawanus* Ehara
		Madakkathara	10.33	76.15	*Tetranychus urticae* Koch
8.	Cock's comb	Vellanikkara	10.32	76.16	*Tetranychus truncatus* Ehara
		Vellanikkara	10.32	76.16	
9.	Pinto peanut	Vellanikkara	10.32	76.16	*Oligonychus biharensis* Hirst
		Odakkali	10.04	76.37	
10.	Balsam	Vellanikkara	10.54	76.27	*Tetranychus okinawanus* Ehara
		Wadakkanchery	10.63	76.22	
11.	Orchid	Vellanikkara	10.54	76.28	*Tetranychus okinawanus* Ehara
12.	Bauhinia	Vellanikkara	10.32	76.16	*Oligonychus biharensis* Hirst
13.	Cassia	Vellanikkara	10.32	76.16	*Tetranychus fijiensis* Hirst
14.	Crape jasmine	Vellanikkara	10.32	76.16	*Eutetranychus orientalis* Klein

associated with ornamental plants collected during the study is furnished below.

1a. Tarsus I without duplex setae (Fig. 1B); empodium absent (Fig. 1B); with 2 pairs of anal setae (Fig. 1A)……...**Genus *Eutetranychus* Banks**
……..aedeagus hook-like with distal bent longer than dorsal margin of shaft, slightly concave (Fig. 4A) ……..***Eutetranychus orientalis* Klein**

1b. Tarsus I with two sets of duplex setae; empodium well developed: with one pair of anal setae.....2

2a. Tarsus I with two sets of duplex setae distal and adjacent (Fig. 2A); empodium of legs claw like with proximoventral hairs (Fig. 2B)…….....
…….....**Genus *Oligonychus* Berlese**
.....aedeagus long and slender with axis of the knob parallel to the shaft; posterior projection of aedeagal knob acute with tip bending downward; dorsal surface of the knob nearly straight (Fig. 4B)…….....
.....***Oligonychus biharensis* Hirst**

2b. Tarsus I with two sets of duplex setae well separated (Fig. 3A), dividing segment into three more or less equal parts; empodium of legs split distally into three pairs (Fig. 3B)……**Genus *Tetranychus* Dufour**…..…….....3

3a. Aedeagus very long, slender bend upward, tapers distally (Fig. 4C) ……..***Tetranychus fijiensis* Hirst**

3b. Aedeagus not very long, with a knob distally…….....4

4a. Aedeagal knob with anterior projection rounded…….....5

4b. Aedeagal knob with anterior projection not rounded…….....6

5a. Anterior projection of knob broadly rounded; posterior projection of knob very narrow, acute resembling bird's beak (Fig. 4D)…….....
.....……..***Tetranychus okinawanus* Ehara**

5b. Anterior and posterior projection of knob rounded and berry like; anterior projection better developed than posterior projection (Fig. 4E)…….…
.....…***Tetranychus neocaledonicus* Andre**

6a. Dorsum of aedeagal knob convex; anterior and posterior projections of knob acute and similar (Fig. 4F)……..……***Tetranychus urticae* Koch**

6b. Dorsal surface of aedeagal knob not convex; anterior projection of knob not acute, anterior and posterior projections not similar..……..…7

7a. The dorsal margin of aedeagal knob with a medial indentation near the posterior half (Fig. 4G)…….....***Tetranychus truncatus* Ehara**

7b. Aedeagal knob with an acute/angulate posterior projection (Fig. 4H)...***Tetranychus marianae* McGregor**

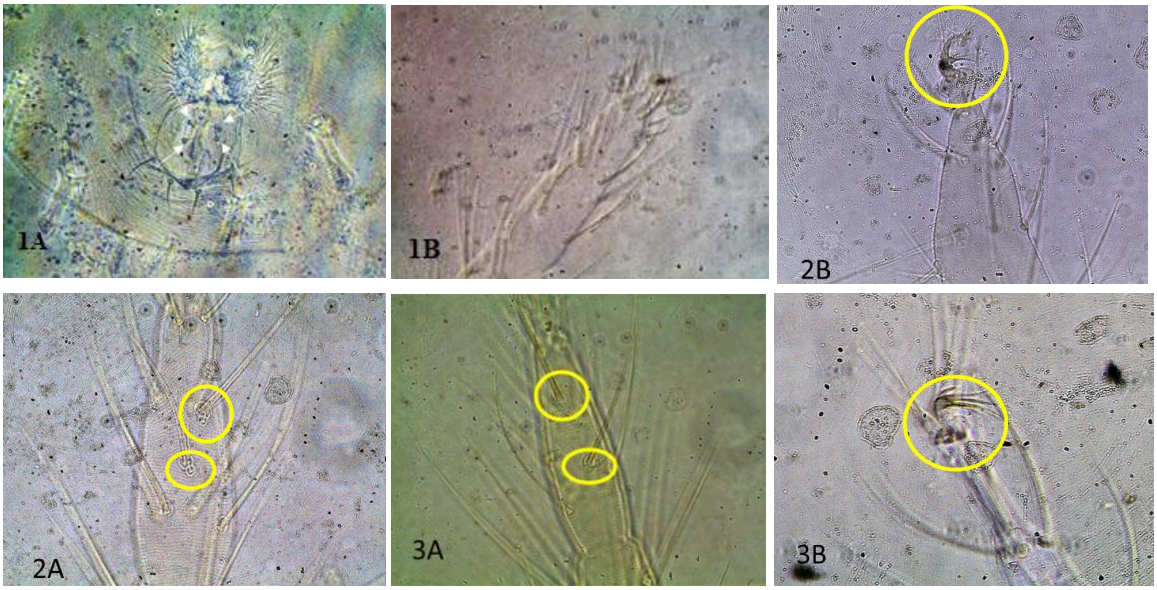


Fig. 1. Key characters of the genus *Eutetranychus* (100x); 1A. Anal setae; 1B. Tarsus I without empodium
Fig. 2. Key characters of the genus *Oligonychus* (100x); 2A. Duplex setae; 2B. Empodium
Fig. 3. Key characters of the genus *Tetranychus* (100x); 3A. Duplex setae; 3B. Empodium

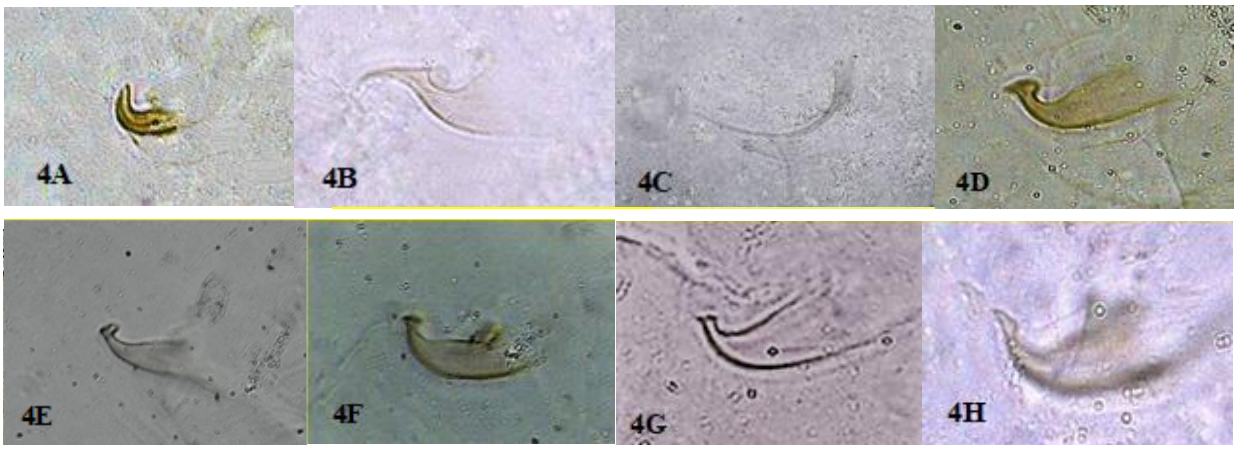


Fig. 4. Aedeagus of species of spider mites (100 x); 4A. *Euteranychus orientalis* 4B. *Oligonychus biharensis* 4C. *Tetranychus fijiensis;* 4D. *T. okinawanus* 4E. *T. neocaledonicus* 4F. *T. urticae* 4G. *T. truncates* 4H. *T. marianae*

The spider mites collected on different host plants from different localities during the study were identified by examining morphological features of specimens. The three genera *Tetranychus*, *Oligonychus* and *Eutetranychus* could be distinguished based on the structure of empodium (Fig. 1B, 2B, 3B) and position of duplex setae on tarsus I (Fig. 2A, 3A) (Gupta, 1985). The species of *Tetranychus* were identified based on the morphology of aedeagus, particularly the structure of aedeagal knob (Fig. 4 C - H) (Gupta, 1985; Gupta and Gupta, 1994; Ehara, 1995; Srinivasa et al., 2012; Zeity et al., 2016).

The study recorded *T. okinawanus* as the predominant mite species on ornamental plants. It recorded wider host range (8 host plants) and the associated host plants include rose, gerbera, adenium, balsam, marigold, chrysanthemum, orchid and cairo morning glory. All host plants recorded in this study, except adenium are new host record *for T. okinawan*us from India. This species was reported for the first time from India on the ornamental plant, *Adenium obesum* from a nursery in Thrissur district in Kerala (Zeity et al., 2016). Later it was reported on cucumber (Bennur et al., 2015; Lenin et al., 2015 and Lenin and Bhaskar, 2016), papaya, ashgourd, brinjal and cowpea (Arunima et al., 2017) from different localities of Kerala.

In the study, *T. truncatus* was recorded on marigold, cock's comb, and rose from different localities of Thrissur district. In India, *Tetranychus truncatus* was first reported from Northwestern Himalayan regions of Jammu and Kashmir and Himachal Pradesh (Rather, 1983). However, Gupta and Gupta (1994), stated that the record of *T. truncatus* on *Dahlia* sp. from Jammu and Kashmir could be *T. urticae*, which was known to infest Dahlia. Long years later, Srinivasa et al. (2012) reported *T. truncatus* from Karnataka on mulberry. In Kerala, *T. truncatus* was first reported by Bennur et al. (2015) who recorded the mite species on some vegetable crops. The mite also infests cucumber and amaranthus grown in polyhouses in Kerala (Lenin and Bhaskar, 2016). Later, Arunima (2017) reported *T. truncatus* on cowpea, pumpkin, tapioca, banana and Dahlia from different regions of Kerala. The mite has recently emerged as a serious pest of banana (Nendran) in Kerala (Bhaskar and Lenin, 2018). This study records three new host plants for *T. truncatus* from India viz., marigold, cock's comb, and rose.

The present study recorded *T. urticae* Koch on rose, chrysanthemum and gerbera from different localities of Thrissur district. The two spotted spider mite, *T. urticae* was first described by Koch in 1836 (Pritchard and Baker, 1955), and later found to be distributed throughout the tropical and sub-tropical parts of the world (Jeppson et al., 1975). Out breaks of *T. urticae* infestation on lady's finger and beans in Bangladesh has been reported by Gapud (1981). Biswas et al. (2004) reported that the mite infests vegetable crops and ornamental plants in Bangladesh. Tehri (2014) documented pest status of *T. urticae* on green house vegetables, ornamental and horticultural crops worldwide and reported its polyphagous nature. The spider mite, *T. urticae* is a serious pest on rose grown in polyhouse and open condition in Navsari, Gujrat (Desai et al., 2017). In Kerala, the two spotted spider mite, *Tetranychus urticae* was reported as a predominant species on vegetable crops viz., brinjal, bhindi, amaranthus and cowpea (Sudharma and Nair, 1999; Binisha and Bhaskar, 2013). Lekha and Kinathi (2019) reported *T. urticae* on brinjal, moringa and winged bean from Northern districts of Kerala. However, recent studies conducted by All India

Network Project on Agricultural Acarology to document spider mite diversity on crops of Kerala during 2013-2018 did not record *T. urticae* on vegetable crops. But in this study, *T. urticae* was found infesting rose grown both under polyhouse and open condition as well as on gerbera and chrysanthemum.

The mite species, *Tetranychus neocaledonicus* was recorded on ornamental plant zinnia from Vellanikkara, Thrissur. It is a cosmopolitan species in tropical and subtropical areas, infesting a wide variety of agricultural plants (Pritchard and Baker, 1955; Bolland et al., 1998). It was reported in India by Khot and Patel (1956), later by Manson (1963), Nassar and Ghai (1981) Gupta (1992); Gupta and Gupta (1994); Gupta, 1995; Gupta and Chatterjee, 1997; and Migeon (2015). Recently Lekha and Kinathi (2019) also reported *T. neocaledonicus* on brinjal, tomato and okra from Kerala. The reported host range of *T. neocaledonicus* include *Chrysanthemum* sp., *Dahlia* sp., *Gerbera* sp., *Helianthus annuus, Tagetes erecta, Gladiolus* sp., *Bauhinia* sp., *Bougainvillea* sp., *Jasminum* sp. and *Arachis pintoi* (Spider Mite Web, 2019).

The study recorded the mite species, *T. marianae* on rose from Vellanikkara. This is the first record of the species from Kerala. *Tetranychus marianae* was first described by McGregor in 1950 from USA. Later it was reported from 71 different host plants from different countries (Bolland et al., 1998). In India it was first reported from Karnataka, recently by Zeity et al. (2016) on *Centrocema pubescence*, and later only during this study.

In the study, *Oligonychus biharensis* was recorded on rose, bauhinia and pinto peanut. The mite is a native of India and described by Hirst in 1924. It was later reported by Nassar and Ghai (1981); Gupta (1992); Gupta and Gupta (1994). Its host range among ornamental plants include rose, bauhinia and hibiscus (Spider Mite Web, 2019).

The spider mite species, *E. orientalis* was recorded only on crape jasmine, while *T. fijiensis* was recorded only on cassia. *Eutetranychus orientalis* is a polyphagous mite reported on a wide range of crops (Spider Mite Web, 2019). In India *Tetranychus fijiensis* has been reported by Hirst (1924); Manson (1963); Daniel (1977); Gupta (1992); Gupta & Gupta (1994). Later it was recorded by Zeity et al. (2016) on *Arachis hypogea*, *Ficus racemosa*, *Mangifera indica*, *Ricinus communis* and *Zea mays*. *Cassia* sp. is a new host record for *T. fijiensis*.

The study on diversity of spider mites revealed that *T. okinawanus* is the predominant species infesting ornamental plants in Kerala. The study reports *T. marianae* for the first time in Kerala. The study has also shown that the ornamental plant, rose harbours many species of spider mites, indicating the need for imposing strict quarantine regulations for movement of planting materials of rose to avoid entry and invasion of mites into new areas. The study reports many new hosts for *T. okinawanus* and *T. truncatus*, indicating the potential of the mite species which were only recorded recently from Kerala, to turn invasive in Kerala's ecosystems is also brought out in the study.

REFERENCES

Spider mites web. 2019. http://www.montpellier.inra.fr/CBGP/spmweb (Accessed on 10.03.2019).

Arunima V. 2017. DNA barcoding of spider mites (Prostigmata: Tetranychidae) on major crop plants of Kerala. MSc (Ag) thesis. KAU, Thrissur. 59 pp.

Bennur S, Abida P S, Valsala P A, Mathew D, Bhaskar H. 2015. DNA barcoding of spider mites (Prostigmata: Tetranychidae) in vegetables using *COI* and *ITS*2 markers. Genome 58(5): 195.

Bhaskar H, Lenin N. 2018. Management of banana leaf mite, *Tetranychus truncatus* (Prostigmata: Tetranychidae), a new pest of banana. Book of abstracts, National seminar on frontiers in biological research. March 12-14, 2018. Department of Zoology, University of Calicut, Kerala, 9 p.

Biswas G C, Islam W, Haque M M, Saha R K, Hoque K M P, Islam M S, Haque M E. 2004. Some biological aspects of carmine mite, *Tetranychus cinnabarinus* Boisd. (Acari: Tetranychidae) infesting egg-plant from Rajshahi. Journal of Biosciences 4(5): 588-591.

Bolland H R, Gutierrez J, Flechtmann C H W. 1998. A world catalogue of the spider mite family (Acari: Tetranychidae). Brill Academic Publishers, Netherlands. 392 pp.

Desai S R, Patel K G, Shukla A. 2017. Seasonal incidence of spider mite (*Tetranychus urticae* Koch) (Acari: Tetranychidae) infesting rose under poly house condition. International Journal of Current Microbiology and Applied Sciences 6(9): 2661-2669.

Dhooria M S. 2016. Fundamentals of applied acarology. Springer, New York. 470 pp.

Ehara S. 1995. A New Species of *Tetranychus* (Acari, Tetranychidae) from the Ryukyu Islands. Japan Journal of Entomology 63 (1): 229-233.

Gapud V P. 1981. Insect and mite pest of plant crops in Bangladesh and their natural enemies. In: A Compendium for biological control in IPM. United States agency for International development agriculture research council/Chechi and company consulting Inc. 265 pp.

Gupta S K. 1985. Handbook. Plant mites of India. Zoological Survey of India, Calcutta. 520 pp.

Gupta S K. 1992. Arachnida: Plant mites (Acari). In: Ghosh, A. K. (ed.), Fauna of West Bengal (3rd Ed.). Zoological Survey of India, Calcutta. 61-211 pp.

Gupta S K. 1995. Plant mites (Acari). In: Alfred, J. R. B. (ed.), Fauna of Meghalaya (2nd Ed.). Zoological Survey of India, Culcutta. 17-50 pp.

Gupta S K, Chatterjee K. 1997. Acari: plant mites. Fauna of Delhi (6th Ed.). Zoological Survey of India, Culcutta. 485-532 pp.

Gupta S K, Gupta Y N. 1994. A taxonomic review of Indian Tetranychidae

(Acari: Prostigamata) with description of new species, re-descriptions of known species and keys to genera and species. Memoirs Zoological Survey of India 18: 1-196.

Gupta S K, Gupta Y N. 1994. A taxonomic review of Indian Tetranychidae (Acari: Prostigamata) with description of new species, re-descriptions of known species and keys to genera and species. Memoires of Zoological Survey of India. 18: 1-196.

Jeppson L R, Keifer H H, Baker E W. 1975. Mites injurious to economic plants. University of California Press. 614 pp.

Khot K N, Patil G P. 1956. Life history of the gladiolus mite, *Tetranychus equatorius* McGregor. Indian Journal of Science 18(2): 149-164.

Lekha C, Kinathi S. 2019. Phytophagous mites infesting vegetable crops of Kerala, India. Persian Journal of Acarology 8: 69-72.

Lenin N, Bhaskar H. 2016. Mite pests of vegetable crops under protected cultivation in Kerala. Entomon 41 (3): 305-308.

Lenin N, Bhaskar H, Abida P S, Mathew P M. 2015. Molecular approach in species determination of *Tetranychus* complex in polyhouse cucumber. Genome 58(5): 244.

Manson D C M. 1963. Mites of the families Tetranychidae and Tenuipalpidae associated with citrus in South East Asia. Acarologia 5: 351-364.

Migeon A. 2015. The Jean Gutierrez spider mite collection. Zookeys 489: 15-24.

Nassar O A, Ghai S. 1981. Taxonomic studies on tetranychoid mites infesting vegetable and fruit crops in Delhi and surrounding areas. Oriental Insects 15: 333-396.

Pritchard A E, Baker E W. 1955. A revision of the spider mite family Tetranychidae. Memoires of Pacific Coast Entomological Society. 472 pp.

Rather A Q. 1983. New records of five genera and eighteen species of phytophagous mites (Acarina) from India with notes on their host range, distribution and economic importance. In: Abstracts of 2nd All India Symposium on Acarology, Pune, 1983, 25-26 pp.

Srinivasa N, Gowda C C, Mallik B, Raghavendra P. 2012. New record of *Tetranychus truncatus* (Ehara) as a potential pest from Karnataka. Indian Journal of Entomology 74(4): 379-383.

Sudharma K, Nair G M. 1999. Occurrence of phytophagous mites and natural enemies on vegetables in Kerala. Insect Environment 5: 15-16.

Tehri K. 2014. A review on reproductive strategies in two spotted spider mite, *Tetranychus urticae* Koch 1836 (Acari: Tetranychidae). Journal of Entomology and Zoology Studies 2(5): 35-19.

Zeity M, Srinivasa N, Gowda C C. 2016. New records of spider mites and description of male of *Stylophoronychus baghensis* Prasad (Acari: Tetranychidae) from India. Oriental Insects 50(3): 119-128.

Zeity M, Srinivasa N, Gowda C C. 2016. New species, new records and re-description of spider mites (Acari: Tetranychidae) from India. Zootaxa 4085 (3): 416-430.

(Manuscript Received: November, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: May, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20277

Indian Journal of Entomology 84(1): 88-91 (2022) DoI.: 10.55446/IJE.2021.327

EFFICACY OF SUNFLOWER OIL FORMULATION AND CONIDIAL SUSPENSION OF *BEAUVERIA BASSIANA* AGAINST *SPODOPTERA LITURA* (F.)

Rajnish Rai*, Renu Pandey and Abhishek Kumar Tamta

Department of Entomology, College of Agriculture, G B Pant University of Agriculture and Technology, Pantnagar 263145, U S Nagar, Uttarakhand, India
*Email: rairavi603@gmail.com (corresponding author)

ABSTRACT

Oil formulation of entomopathogenic fungi *Beauveria bassiana* for its effect against tobacco caterpillar *Spodoptera litura* (F.) in six concentrations (1000x10^5, 700x10^5, 500x10^5, 250x10^5, 125 x10^5 and 75x10^5) in the form of sunflower oil formulation and conidial suspension of *B. bassiana* has been evaluated in this study. All the five concentrations showed mortality and maximum mortality was observed at 108 hr after treatment at maximum concentration (1000x10^5); and the least mortality of 23.33% was observed at the lowest concentration of 75x10^5. No significant differences were observed between sunflower oil formulation and conidial suspension.

Key words: *Beauveria bassiana*, *Spodoptera litura*, entomopathogenic fungus, oil formulation, conidial suspension, sunflower, mortality, efficacy

Tobacco caterpillar *Spodoptera litura* (F.) (Lepidoptera: Noctuidae) is an important polyphagous pest causing serious damage. All over the world, it damages more than 389 species of cultivated crop plants belonging to 109 families (Lin et al., 2019; Shankara Murthy et al., 2006; Barman et al., 2019) of which 40 genera are cultivated in India (Basu, 1981; Muthukrishnanet al., 2005). The serious incidence of this pest normally occurs with a good rainfall after a long dry spell (Chelliah, 1985); and it can cause 10 to 30% economic losses based on different crop phase and its invasion level in the field (Cheng et al., 2017,). The widespread and indiscriminate use of insecticides against this pest has led to resistance in many insects (Samanta et al., 2020), and it constitutes a serious risk to crop protection (Rao and Dhingra, 2000). Also, use of pesticides is hazardous to human health, flora, fauna, and even to the atmosphere (Mahmoud et al., 2014). Hence, pest management involving biocontrol agents is assuming prominence as an important strategy. Entomopathogenic fungi (EPF) like *Beauveria bassiana* (Balsamo) Vuillemin, *Metarhizium anisopliae* (Metchnikoff) and *Paecilomyces fumosorosesus* (Wize) Brown and Smith are now recognized as important entomopathogens (Wanida and Poonsuk 2012; Shoaib et al., 2012; Meikle et al., 2005). Many commercial formulations of EPF have been developed for crop insect pest management. Among the 171 products of EPF developed, products based on *M. anisopliae* and *B. bassiana* represent 33.92% of total products, and *Beauveria brongniartii* and *Isaria fumosorosea* products represent 5.81 and 4.10, respectively (Moorhouse et al., 1992; De Faria and Wraight, 2007). This study explores the preparation of EPF formulations and an their oil formulations. Some selected oil formulations are also evaluated against *S. litura* larvae for their efficacy as conidia oil formulation.

MATERIALS AND METHODS

The diseased samples were collected from the Crop Research Centre (CRC) and Avenue Plantation, Pantnagar during autumn and winter season. The samples of cadaver were then subjected to series of washing with sodium hypochlorite solution and a series of distilled water. Then aseptic inoculation protocol was followed. After pure culture of the local isolate, identification of the fungus was done and maintenance of culture was done by doing subculturing of the isolate. For identification various slides were prepared with lactophenol and methyl blue, and examined done for the morphological characters under microscope (Olympus Cx33). The culture plates of 15 days old *B. bassiana* were taken to prepare stock suspension. For the preparation of sunflower oil-based formulation, surfactant mixed in oil phase with spore suspension in aqueous phase was used. Conidial count of sunflower oil formulation and conidial suspension was assessed with Neubauer Haemocytometer, and the formulation

and suspension were subjected to serial dilution to get six concentrations of 1000, 700, 500, 250, 125 and 75x10^5 conidia/ ml. In control only water and two drops of 0.05% Tween 80 was added. To set the fungus colony forming units/ ml (C F U), 1 ml of sunflower oil formulation and conidial suspension was suspended in 9 ml distilled water for the serial dilution. Prepared serial dilution was plated at 1 ml/ plate on PDA media. The plate was gently rotated for uniform spreading of spore suspension and incubated at 25± 2^0C and 70% RH, with three replications. The C F U count was recorded on 7th day after plating.

The running culture of *S. litura* was maintained in the laboratory by standard rearing technique following Sabry and Khedr (2014) and Kumar and Srivastava (2016). From these, 3rd instar larvae were used for bioassay against *B. bassiana* developed conidial suspension and sunflower oil formulation. To evaluate the contact action or toxicity of formulation by larval atomization method (Thakur and Srivastava, 2019), different dilutions of respective myco-insecticide formulations were prepared in tap water by serial dilution method to get the six concentrations as given above. The virulence of *B. bassiana* was studied 12-120 hours after treatment (HAT) at every 12 hr interval. For each treatment there were 4 replications with 10 larvae/ replication. The observations on mortality obtained from bioassays were suitably analyzed by SPSS, the statistical probe and % mortality was subjected to DMRT analysis (Duncan, 1955).

RESULTS AND DISCUSSION

As given in Table 1, the sunflower oil formulation showed that none of the concentration caused any mortality in the treated larvae up to 24 HAT. At 36 HAT, the two concentrations i.e., 1000 and 700 x10^5 showed some mortality response (6.67%); and at 500x 10^5 it was 3.33%. The mortality increased with HAT, and at 48 HAT, mortality was observed in all except the lowest concentration of 75 x10^5, with maximum of 23.33% being at 1000 x10^5conc; at 60 HAT again no mortality was observed in the lowest concentration of 75 x10^5, but it was 13.33% at 72 HAT; at 72 HAT, maximum mortality was 70% at the highest concentration of 1000 x10^5, and complete (100%) mortality was observed at 108 HAT in this concentration of 1000x10^5 and at 120 HAT in 700x10^5. No other concentration could cause complete 100% mortality even up to 120 HAT. The lowest concentration could cause 23.33% mortality up to 120 HAT. With regard to conidial

Table 1. Mortality of *S. litura* on hours basis for different concentrations of sunflower oil and conidial suspension formulation of *B. bassiana*

Concentration	Treatment	12 HAT	12 HAT	24 HAT	24 HAT	36 HAT	36 HAT	48 HAT	48 HAT	60 HAT	60 HAT	72 HAT	72 HAT	84 HAT	84 HAT	96 HAT	96 HAT	108 HAT	108 HAT	120 HAT	120 HAT
1000x10^5	T1	0± 0^a	0± 0^a	0± 0^a	0± 0^a	6.67± 5.77^b	6.67± 5.77^a	23.33± 5.77^c	16.67± 5.77^c	50± 10^e	46.67± 5.77^e	70± 17.32^d	66± 15.27^d	83.33± 5.77^e	80± 0^e	93.33± 5.77^e	93.33± 5.77^e	100± 0^e	100± 0^e	100± 0^f	100± 0^f
700x10^5	T2	0± 0^a	0± 0^a	0± 0^a	0± 0^a	6.67± 5.77^a	6.67± 5.77^a	13.33± 5.77^b	10± 0^{bc}	36.67± 5.77^d	33.33± 5.77^d	63.33± 5.77^{cd}	60± 10^{cd}	73.33± 5.77^{de}	70± 10^{de}	86.67± 5.77^{de}	86.67± 5.77^{de}	93.33± 5.77^e	93.33± 5.77^e	100± 0^f	100± 0^f
500x10^5	T3	0± 0^a	0± 0^a	0± 0^a	0± 0^a	3.33± 5.77^a	3.33± 5.77^a	13.33± 5.77^b	6.67± 5.77^{ab}	30± 10^{cd}	26.67± 5.77^{cd}	50± 10^d	46.67± 11.54^c	63.33± 11.55^d	60± 10^d	73.33± 11.55^d	73.33± 11.55^d	80± 10^d	80± 10^d	86.67± 5.77^b	86.67± 5.77^c
250x10^5	T4	0± 0^a	0± 0^a	0± 0^a	0± 0^a	0.0± 0^a	0.0± 0^a	6.67± 5.77^{ab}	6.67± 5.77^{ab}	23.33± 5.77^{bc}	20± 0^{bc}	30± 10^b	26.67± 5.77^b	43.33± 5.77^c	40± 10^c	50± 10^c	50± 10^c	56.67± 11.55^c	56.67± 11.55^c	60± 10^d	60± 10^d
125x10^5	T5	0± 0^a	0± 0^a	0± 0^a	0± 0^a	0.0± 0^a	0.0± 0^a	3.33± 5.77^a	3.33± 5.77^{ab}	13.33± 5.77^b	13.33± 5.77^b	26.67± 5.77^{ab}	26.67± 5.77^b	30± 10^{bc}	30± 10^{bc}	30± 10^b	30± 10^b	33.33± 5.77^b	33.33± 5.77^b	33.33± 5.77^c	33.33± 5.77^c
75x10^5	T6	0± 0^a	0± 0^a	0± 0^a	0± 0^a	0.0± 0^a	0.0± 0^a	0.0± 0^a	0.0± 0^a	0± 0^a	0± 0^a	13.33± 5.77^{ab}	13.33± 5.77^{ab}	20± 10^b	20± 10^b	20± 10^b	20± 10^b	23.33± 5.77^b	23.33± 5.77^b	23.33± 5.77^b	23.33± 5.77^b
Control (Untreated)	T7	0± 0^a	0± 0^a	0± 0^a	0± 0^a	0.0± 0^a	0.0± 0^a	0.0± 0^a	0.0± 0^a	0± 0^a	0± 0^a	0± 0a	0± 0^a	0± 0^a	0± 0^a	0± 0^a	0± 0^a	0± 0^a	0± 0^a	0± 0^a	0± 0^a

suspension, up to 24 HAT no mortality was observed in any concentration; at 36 HAT, 1000 and 700 x10^5 showed 6.67% mortality; and at 500 x10^5 only 3.33% mortality was observed. The mortality response showed an increasing trend with more HAT, at 48 HAT, mortality was observed irrespective of concentration except the lowest of 75 x10^5, maximum of 16.67% being with 1000 x10^5 concentration followed by 10% at 700x$10^5$and lowest at 125x10^5 i.e., 3.33%. At 60 HAT again no mortality was observed in the lowest concentration, but at 1000 x10^5 it was 46.67%. With 72 HAT in 75x10^5 it was 13.33%, maximum being 66% with 1000 x10^5. Complete mortality was observed at 108 HAT with 1000 x10^5 and at 120 HAT in 700x10^5. No other concentration could cause complete (100%) mortality even up to 120 HAT, with the least value being 23.33% up to 120 HAT. Comparison between the two formulations revealed no differences in the contact toxicity of the *B. bassiana.* However, oil formulation showed a little higher toxicity. At 48 HAT the mortality in case of conidial suspension was 16.67%, and 23.33% at highest concentration of 1000x10^5 in case of oil formulation. In other concentrations at various HAT, oil formulation led to more toxicity as compared to conidial suspension (Table 1).

The efficacy of isolates of *B. bassiana* was evaluated against third instar of *S. litura* using the leaf spray method by Moorthi et al. (2011); these results revealed that at 96 HAT, 66.67, 73.33 and 80.0% mortality was obtained with the isolates Bb02, Bb09 and Bb10, respectively; LC_{50} values were 2.1x10^6, 3.6x10^7 and 1.2x10^7 conidia/ ml for these, respectively, and the LT_{50} value for Bb02 and Bb09 was 4.8 days, whereas it was 4.0 days for Bb10 @10^8spore/ ml. Asi et al. (2013) by larval dip method, the results revealed that the LC_{50} value for 3rd instar larvae was 1.11x 10^7 conidia/ ml for a local strain i.e., *B. bassiana* 25 at 10 days after treatment; and LT_{50} was 187 hours in *B. bassiana* 25 @ 1x 10^8conidia/ ml. Thus, formulations of *B. bassiana* can thus serve as an effective broad spectrum biocontrol agents.

ACKNOWLEDGEMENTS

The authors thank the Department of Entomology, GBPUA&T, Pantnagar for financial assistance.

REFERENCES

Asi M R, Bashir M H, Afzal M, Zia K, Akram M. 2013. Potential of entomopathogenic fungi for biocontrol of *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae). The Journal of Animal and Plant Sciences 23(3): 913-918.

Barman M, Gaur N, Joshi R, Pramod R, Mishra P. 2019. Rapd-analysis of populations of *Spodoptera litura* (f.) from Uttarakhand. Indian Journal of Entomology 81(4): 841-846.

Basu A C. 1981. Effect of different foods on the larval and post larval development of moth of *Prodenia litura* (Fab.). Journal of Bombay Natural History Society 44: 275-288.

Chelliah S. 1985. The tobacco cutworm *S.litura*problems and prospects of management. Jayaraj S (ed.). Integrated pest and disease management. TNAU, Coimbatore.

Cheng T, Wu J, Wu Y, Chilukuri R V, Huang L, Yamamoto K, Liu J. 2017. Genomic adaptation to polyphagy and insecticides in a major East Asian noctuid pest. Nature Ecology and Evolution 1(11): 1747.

De Faria M R, Wright S P. 2007. Mycoinsecticides and mycoacaricides: a comprehensive list with worldwide coverage and international classification of formulation types. Biological Control 43(3): 237-256.

Duncan D B. 1955. Multiple range and multiple F tests. Biometrics 11(1): 1-42.

Kumar R, Srivastava R P. 2016. Bioefficacy of some insecticides and mixed formulations against *Spodoptera litura* (Fab.). Journal of Entomological Research 40(3): 279-284.

Lin T, Chen X, Li B, Chen P, Guo M, Zhou X, Zhong S, Cheng X. 2019. Geographical origin identification of *Spodoptera litura* (Lepidoptera: Noctuidae) based on trace element profiles using tobacco as intermedium planted on soils from five different regions. Microchemical Journal 146: 49-55.

Mahmoud Y A, Salem H A, Shalaby S E, Abdel-Razak A S, Ebadah I M A. 2014. Residues in harvested tomato fruits. International Journal of Agricultural Research 9(4): 210-218.

Meikle W G, Mercadier G, Rosengaus R B, Kirk A A, Derouané F, Quimby P C. 2005. Evaluation of an entomopathogenic fungus, *Paecilomyces fumosoroseus* (Wize) Brown and Smith (Deuteromycota: Hyphomycetes) obtained from Formosan subterranean termites (Isop., Rhinotermitidae). Journal of Applied Entomology 129: 315-322

Moorhouse E R, Gillespie A T, Sellers E K, Charnley A K. 1992. Influence of fungicides and insecticides on the entomogenous fungus *Metarhizium anisopliae* a pathogen of the vine weevil, *Otiorhynchus sulcatus*. Biocontrol Science and Technology 2(1): 49-58.

Moorthi P V, Balasubramanian C, Kubendran T. 2011. Efficacy of local isolates of *Beauveria bassiana* against *Spodoptera litura* (F.) (Lepidoptera: Noctuidae). Journal of Biological Control 25(1): 22-25.

Muthukrishnan N, Ganapathy N, Nalini R, Rajendran R. 2005. Pest management in horticultural crops. New Madhura Publishers, Madurai. 325 pp.

Rao G R, Dhingra S. 2000. Variation in the efficacy of mixed formulation compromising vegetable oils and synthetic pyrethroids against susceptible (Delhi) and resistant (Guntur) larval populations of *Spodoptera litura*. Biocontrol Science and Technology 16: 221-32.

Romback M C. 1989. Production of *Beauveria bassiana* conidia in submerged culture. Entomophaga 5: 45-52.

Sabry H M, Kedar M A. 2014. Biochemical and histological variations induced by IGRs in *Spodoptera litura* (Boisd.). Global Journal of Environmental Sciences and Toxicology 1(2): 163-178.

Samanta S, Barman M, Nihal R, Samanta A. 2020. Bio-efficacy trials of Spinotetram 0.8% GR against yellow stem borer, *Scirpophaga Incertulas* and leaf folder, *Cnaphalocrocis medinalis* infesting rice. International Journal of Current Microbiology and Applied Sciences 9(2): 2711-2719.

Shankara Murthy M, Thippaiah M, Kitturmmath M S. 2006. Effect of neem formulations on larvae of tobacco cutworm, *Spodoptera litura* (Fab.). Insect Environment 12: 84-85.

Shoaib F, Mushtaq A S, Khan M, Muhammad N. 2012. Prevalence and effectiveness of *Metarhizium anisopliae* against *Spodoptera exigua* (Lepidoptera: Noctuidae) in Southern Punjab, Pakistan. Pakistan Journal of Zoology 44: 753-758.

Thakur H, Srivastava R P. 2019 Toxicity of diamide and spinosyn insecticides against tobacco caterpillar *Spodoptera litura* (F.). Indian Journal of Entomology 81(4): 864-869.

Wanida P, Poonsuk P. 2012. Evaluation of Strains of *Metarhizium anisopliae* and *Beauveria bassiana* against *Spodoptera litura* on the basis of their virulence, germination rate, conidia production, radial growth and enzyme activity. Mycology 40: 111-116.

(Manuscript Received: November, 2020; Revised: March, 2021;
Accepted: March, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20415

Indian Journal of Entomology 84(1): 92-96 (2022) DoI No.: 10.55446/IJE.2021.328

BIOLOGY AND NUTRITIONAL INDICES OF THE FALL ARMY WORM *SPODOPTERA FRUGIPERDA* (J E SMITH) ON MAIZE

P S Rajisha, N Muthukrishnan*, S Jeyarajan Nelson, R Jerlin[1], P Marimuthu[2] and R Karthikeyan[3]

Department of Agricultural Entomology; [1]Department of Seed Science and Technology; [2]Department of Agricultural Microbiology; [3]Department of Farm Management, Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India
*Email: nmkrish@tnau.ac.in (corresponding author)

ABSTRACT

Lifecycle, progressive growth of larval head capsule, and nutritional indices of *Spodoptera frugiperda* (J E Smith) on maize (Co-H6) were studied at the Department of Agricultural Entomology, TNAU, Coimbatore during 2018-19. Incubation, total larval, and pupal periods were observed as 2-3, 13-20, and 7-11 days, respectively. The total lifecycle of male and female was 33-46 and 35-47, respectively. The head width was observed to be 0.34, 0.60, 0.89, 1.32, 1.86, and 2.36 mm from the first to the sixth instars, respectively. Linear regression analysis showed a significant relationship between larval instars and head capsule width (R^2=0.0979); and geometric progression ratio was observed as 1.48. Nutritional indices were also studied for the third and fifth instar on the maize plants. Consumption index (CI) and approximate digestibility (AD) increased with larval age, while efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested food (ECD) were inversely related to age. These values for the third and fifth instar were- CI= 2.30 and 2.31; AD=35.7 and 40.29; ECI=18.33 and 12.21; ECD=51.33 and 30.3, respectively.

Key words: *Spodoptera frugiperda*, maize, fecundity, egg, larval, pupal periods, lifecycle, stages, larval instars, head capsule width, Dyar's law, nutritional indices, consumption, digestibility, conversion

The fall army worm (FAW) *Spodoptera frugiperda* (J E Smith) is an invasive polyphagous pest in India since 2018 (Shylesha et al., 2018; Mallapur et al., 2018). It is emerging as the most destructive pest of maize and has spread rapidly to all maize growing regions. Yield reductions in maize due to its feeding had been reported to be as high as 34% (Cruz, 1999; Williams and Davis,1990). Besides corn, it feeds on the leaves and stems of >350 plant species, including rice, sorghum, sugarcane, and wheat. Knowledge on its biology is important for identifying lifestages and for planning IPM strategies. This study analyses its biology at different crop growth stages on maize. The progressive growth of larval head capsule, and the nutritional indices are also brought out.

MATERIALS AND METHODS

The field collected larvae of FAW from maize fields of Tamil Nadu Agricultural University, Coimbatore were reared in the laboratory on 15-20 days old maize seedlings CoH-6 (26± 2^{0}C, 75- 80% RH) during July 2018. Larvae were fed with fresh leaves daily till pupation. On pupation, the pupae were transferred on to sand in plastic petridishes (90x 40 mm). The pupae were sexed based on the genital pore on the abdominal segments. In the ovipositional cage a pair of pupae (male and female each) were placed for emergence. On emergence of adults, potted maize plants of 15-20 days old were placed inside the cage (30x 30x 45cm) as ovipositional substrate. Adults were fed with 10% honey solution dipped in cotton swabs and placed in glass vials. The eggs laid were collected and used for studying the biology. On hatching, the larvae (n=15) were transferred separately into sterile container (one larvae/ container) containing maize leaf bits of early vegetative (15-20 days old seedling), vegetative stage (35-45 days old plant) and tassels (50-60 days old plant) and reared until pupation (n=10). Fresh food was provided regularly as per needs. Male and female longevity were observed with their release in a rearing cage with 10% honey provided and replenished daily as food. Duration of larval instars, prepupa, pupa, adult and preoviposition period were observed. Pairs up to 48 hr after emergence were used to study the adult phase, and longevity. The head capsule of the larvae of all the instars formed after each moult were collected and stored in 70% ethanol. The head capsule width was observed and measured under Leica stereozoom microscope (M205C) with version LAS4.0 image analyzer. Head capsule measurement data were

analyzed as per McClellan and Logan (1994), in which analysis of plot of mean instar sizes against a presumed instar number. Summary statistics and linear regression was calculated using Microsoft Excel 2007.

Prestarved and pre-weighed third and fifth instar (n=20) were transferred to containers with 10g leaves of 15-20 day old maize @ one larva/ container. The larvae were reared to the subsequent instar. Fresh food was provided regularly. Observations made daily included bodyweight of larva and weight of excreta after 24 hr/ larva using electronic balance (Model No. PGB 630). The following nutritional indices were calculated as per Waldbauer (1968) and Scriber and Slansky (1981).

1. Consumption index (CI): $CI = \frac{F}{TA}$
2. Approximate digestibility (AD): $AD = \frac{F-E}{F} \times 100$
3. Efficiency of conversion of ingested food in to body matter (ECI): $ECI = \frac{G}{F} \times 100$
4. Efficiency of conversion of digested food into body matter (ECD): $ECD = \frac{G}{F-E} \times 100$ where, F = Fresh weight of food eaten (g), T = Duration of the feeding period (days), A = Mean fresh weight of larvae during feeding period (g), G = Fresh weight gain of larvae during feeding period (g), E = Weight of excreta (g). The biology data were subjected to variance analysis and means compared by Tukey test through SPSS software. Data referring to the growth rate (cephalic capsule width) were analyzed through linear regression (p=0.05).

RESULTS AND DISCUSSION

Biology: The results are presented in Table 1. The eggs were laid in egg masses and the number of eggs/ mass was about 150-200. Eggs were laid one over the other in two to four layers on the surface of the leaves preferably on the dorsal side; these were pale white to creamish covered with greyish white scales; turned brown to black just before hatching; egg period ranged from 2-3 days. Larvae were pale green to dark brown with longitudinal stripes; third instar were characterized by an inverted Y-shape yellow coloured epiricanial suture on the head and it became prominent in the late instar; there were six distinct instars over a period of 14-19 days. Characteristically the *S. frugiperda* larva can be identified by the arrangement of dorsal setae in a typical square shaped arrangement on the VIII abdominal segment. Comparing the duration of each larval instar between maize growth stages; viz; early vegetative stage (15 days), vegetative stage (35-45 days), flowering stage (50-60 days), no significant difference was observed in late instars. But in early instars significant difference in duration was found. The early larval instars were shorter on early vegetative stage compared with the late ones. Similarly, Pannuti et al. (2015) reported that maize leaves developed during reproductive phase are not suitable for early instar development, but silk, tassel and kernel tissues in the reproductive phase had a positive effect on survival and development. The pupae were orange brown, changed to dark reddish brown with time; pupal period was about 8-11 days (9.56± 1.12). Kalyan et al. (2020) reported the pupal period as 8.96 days. Male adults closely resemble *S. litura*. Female moth had brown forewing with less distinct triangular markings. Hind wings were straw coloured with a dark brown margin. The total lifecycle of male and female ranged from 33-46 and 35-47 days, respectively. The female survived for 10.10 days with a range of 9-12 days compared to male (8.1 days) with a range of 7-10 days. No significant difference in duration of adult male and female life cycle was observed. Similarly, Deole and Paul (2018) reported that adults longevity was within 5-7days and the total lifecycle was completed in 28-35 days.

Morphometrics: Table 1 provides the larval head capsule width, and larvae when reared on maize variety Co H-6 passed through six instars; head width was 0.34, 0.60, 0.89, 1.32, 1.86 and 2.36 mm for first to sixth instars, respectively; thus, the head width fell into six well defined instars. Linear regression analysis showed significant relationship between larval instars and head capsule width ($Y= 0.408x-0.202$, $R^2=0.0979$). Dyar (1890) stated that the width of head capsule of lepidopterous larvae was more or less constant for given instar of a given species; also the successive larval instars of a given species showed more or less regular geometrical progression in the growth of head capsule. Dyar's ratio for laboratory populations of *S. frugiperda* were 1.76, 1.48, 1.48, 140, 1.26 for the first to last instars, respectively. The present study indicated that *S. frugiperda* had six larval instars and showed that the head capsule width (exuvia) is useful in separating the instars. These results on the head capsule width agree with those observed by Bailey and Chada (1968) for *S.frugiperda* fed with sorghum grain. Also, these corroborate with those found by Machado et al. (1985) working with *S.frugiperda* fed with kale.

Santos et al. (2002) studied the cephalic capsule width of *S. frugiperda* in different corn genotypes and

Table 1. Biology and nutritional indices of *S frugiperda* on maize

Stage of insect	Biology when fed with maize leaves obtained from different phases of growth						Geometric growth ratio using head capsule width as a parameter			Nutritional indices on maize			
	Early vegetative stage (15 days old seedling)		Vegetative stage (35-45 days old plant)		Flowering stage (50-60 days old plant)								
	Range (days)	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range (mm)	Mean ± SD	Geometric progression/ Dyar's ratio	CI	AD	ECI	ECD
Incubation period	2-3	2.45 ±0.46	2-3	2.40 ± 0.40	2-3	2.34 ± 0.45							
Larva 1st Instar	2-3.5	2.42 ± 0.49[a]	2-3	2.63 ± 0.48[ab]	2-3	2.91 ± 0.50[b]	0.32 -0.37	0.34 ± 0.01	1.76	-	-	-	-
2nd Instar	2-3	2.34 ± 0.40[b]	2-3.5	2.40 ± 0.52[ab]	2-4	2.54 ± 0.73[a]	0.52 -0.67	0.60 ± 0.05	1.48	-	-	-	-
3rd Instar	1-2.5	1.74 ± 0.38[ab]	1-2	1.60 ± 0.47[b]	1-2	1.90 ± 0.35[a]	0.82-0.96	0.89 ± 0.04	1.48	2.30	35.70	18.33	51.3
4th Instar	2-3	2.36 ± 0.48	1-3	2.06 ± 0.69	2-3	2.42 ± 0.47	1.29 -1.38	1.32 ± 0.03	1.40	-	-	-	
5th Instar	3-4	3.56 ± 0.48	3-5	3.72 ± 0.75	3-5	3.88 ± 0.72	1.81-1.93	1.86 ± 0.04	1.26	2.31	40.29	12.21	30.0
6th Instar	4-5	4.42 ± 0.49[ab]	4-6	4.76 ± 0.72[a]	3-6	4.08 ± 0.90[b]	2.10 -2.60	2.36 ± 0.16	-	-	-	-	-
Pupa	8-11	9.0 ± 1.15	8-11	9.56 ± 1.12	8-12	9.2 0 ± 1.04	-	Mean geometric progression	1.48	-	-	-	-
Adult male	7-9	7.8 ± 0.81	7-9	7.7 ± 0.77	8-10	8.8 0 ± 0.81	-	-	-	-	-	-	-
Adult female	9-12	10.52 ± 1.08	9-12	9.92 ± 1.11	9-11	9.88 ± 0.83	-	-	-	-	-	-	-

Mean followed by same letter in line do not differ statistically-Tukey test (p=0.05)

recorded values similar to those of this study with linear regression value of 0.998. Similar results were reported by Manjula et al. (2019) in *S. frugiperda* but for fifth and sixth instars, values were higher. Hutchinson and Tongring (1984) argued that Dyar's rule might result from a maximization of growth efficiency, assuming that the size of the first instar, the number of instars and the arithmetic mean of growth ratios are predetermined. Several factors such as parasitism (Jobin et al., 1992), temperature, food availability, locality, and rearing regimes may affect growth rates and morphometrics, either between populations or between individuals of the same population (Daly, 1985). However, the approximate constancy of growth ratios can as well be seen as resulting from the physiological base of moulting (Sehnal,1985). Dyar's hypothesis (1890) indicates that mean head capsule widths follow a geometrical succession in lepidopteran larval development. Dyar's theory may have more notoriety than utility, as it applies in some cases but not in others (Hutchinson and Tongring, 1984). Although Dyar's rule is strongly debated in lepidopteran head capsule analysis, the theory as well support the six instars of the FAW.

Nutritional indices: The results for nutritional indices of third and fifth instars of *S. frugiperda* are given in Table 1; these reveal that the CI and AD values increased as larva aged, while ECI and ECD were inversely related. These results agree with those of Firake and Behere (2020). Because of physiological and behavioral changes (Nation, 2000) the feeding period of fifth instar was lower than third and subsequently nutritional responses of these two larval instars were different. In the present study, AD, the percentage of food ingested and effectively assimilated by the insect, had lower percentages than those registered by Busato et al. (2002). The ECI and ECD are the general indices of an insects ability to use the food consumed for overall development and the efficiency of conversion of digested food in to growth, respectively (Nathan et al., 2005). Higher ECI and ECD values in third instar indicate their ability to cause higher damage to maize plants. But ECI and ECD values was found lower in fifth instars. Similar results were given by Firake and Behere (2020) when reared on maize and ginger. Deviation might be possible due to the age of the larva in a particular stadium at the time of weighing, as reported by Naseri et al. (2010).

ACKNOWLEDGEMENTS

The authors thank Dr N Chitra, Associate Professor, Department of Agricultural Entomology, TNAU, Coimbatore for support and manuscript correction. The financial support from the DST Inspire, Govt. of India is acknowledged.

REFERENCES

Bailey D L, Chada, H L. 1968. Effects of natural (sorghum) and artificial (wheat germ) diets on development of the corn earworm, fall armyworm, and southwestern corn borer. Journal of Economic Entomology 61(1): 257-260.

Busato G R, Grutzmacher A, Garcia, M. S, Giolo, F. P, Martins A F. 2002. Consumo e utilizaçao de alimento por *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) originaria de diferentes regiões do Rio Grande do Sul, das culturas do milho e do arroz irrigado. Neotropical Entomology 31(4): 525-529.

Cruz I, Figueiredo M C, Oliveira A C, Vasconcelos C A. 1999. Damage of *Spodoptera frugiperda* (Smith) in different maize genotypes cultivated in soil under three levels of aluminium saturation. International Journal of Pest Management 45(4): 293-296.

Daly H W. 1985. Insect morphometrics. Annual Review of Entomology 30: 415-438.

Deole S, Paul N. 2018. First report of fall army worm, *Spodoptera frugiperda* (JE Smith), their nature of damage and biology on maize crop at Raipur, Chhattisgarh. Journal of Entomology and Zoology Studies 6: 219-221.

Dyar H G. 1890. The number of molts of lepidopterous larvae. Psyche 5: 420-422.

Firake D M, Behere G T. 2020. Bioecological attributes and physiological indices of invasive fall armyworm, *Spodoptera frugiperda* (J E Smith) infesting ginger (*Zingiber officinale* Roscoe) plants in India. Crop Protection. pp.105-233.

Hutchinson G E. 1984. The possible adaptive significance of the Brooks-Dyar rule. Journal of Theoretical Biology 106: 437-439.

Jobin L, Hebert C, Bourassa J P. 1992. Head capsule width of larval populations of the gypsy moth (Lepidoptera: Lymantriidae) in Quebec, with reference to Dyar's hypothesis. Environmental Entomology 21: 89-93.

Kalyan D, Mahla M K, Babu S R, Kalyan R, Swathi P. 2020. Biological Parameters of *Spodoptera frugiperda* (J E Smith) under Laboratory Conditions. International Journal of Current Microbiology and Applied Science 9(5): 2972-2979.

Machado V L L, Gianotti E, Oliveira R M. 1985. Aspectos biológicos de *Spodoptera frugiperda* (J. E. Smith, 1797) (Lepidoptera: Noctuidae) em couve (*Brassica oleracea* L. var. *acephala*). Anais Da Sociedade Entomologica Do Brasil 1: 121-130.

Mallapur C P, Naik AK, Hagari S, Prabhu ST, Patil R K. 2018. Status of alien pest fall armyworm, *Spodoptera frugiperda* (JE Smith) on maize in Northern Karnataka. Journal of Entomology and Zoology Studies 6: 432-436.

Manjula K, Saheb Y, Sudheer M J, Rao A R. 2019. Studies on biology, feeding habits and natural enemies of fall armyworm, *Spodoptera frugiperda*, a new invasive pest in India. Journal of Entomology and Zoology Studies 7: 1245-1250.

McClellan Q C, Logan J A. 1994. Instar determination for the gypsy moth (Lepidoptera: Lymantriidae) based on the frequency distribution of head capsule widths. Environmental Entomology 23(2): 248-253.

Naseri B, Fathipour Y, Moharramipour S, Hosseininaveh V. 2010. Nutritional indices of the cotton bollworm, *Helicoverpa armigera*, on 13 soybean varieties. Journal of Insect Science 10(1): 151.

Nathan S S, Chung P G, Murugan K. 2005. Effect of biopesticides applied separately or together on nutritional indices of the rice leaf folder *Cnaphalocrocis medinalis*. Phytoparasitica 33(2): 187.

Nation J L. 2000. Insect physiology and biochemistry. CRC Press. 8 pp

Pannuti L. E. R, Paula-Moraes S V, Hunt T E, Baldin E L L, Dana L, Malaquias J V. 2016. Plant-to-plant movement of *Striacosta albicosta* (Lepidoptera: Noctuidae) and *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in maize (*Zea mays*). Journal of Economic Entomology 109(3): 1125-1131.

Santos L M D, Redaelli L R, Diefenbach L M G. 2003. Larval and pupal stage of *Spodoptera frugiperda* (JE Smith) (Lepidoptera: Noctuidae) in sweet and field corn genotypes. Brazilian Journal of Biology *63*(4): 627-633.

Scriber J M, Slansky J F. 1981. The nutritional ecology of immature insects. Annual Review of Entomology 26: 183-211.

Sehnal F, Aka H. 1990. Insect silk glands: their types, development and function, and effects of environmental factors and morphogenetic hormones on them. International Journal of Insect Morphology and Embryology 19(2): 79-132.

Shylesha A N, Jalali S K, Gupta A, Varshney R, Venkatesan, T, Shetty P, Ojha R, Ganiger C P, Navik O, Subharan K, Bhakthavalsalam N, Ballal C R. 2018. Studies on new invasive pest *Spodoptera frugiperda* (J.E Smith) (Lepidoptera: Noctuidae) and its natural enemies. Journal of Biological Control *32*(3): 145-51.

Waldbauer G P. 1968. The consumption and utilization of food by insects. Advanced Insect Physiology 5: 229-288**.**

Williams W P, Davis F M. 1990. Response of corn to artificial infestation with Fall Armyworm and southwestern corn borer larvae. Southwestern Entomologist 15(2): 163-166.

(Manuscript Received: December, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: May, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20416

Indian Journal of Entomology 84(1): 97-100 (2022) DoI No.: 10.55446/IJE.2021.329

EFFECT OF INSECTICIDES ON SUSCEPTIBILITY LEVEL AND DETOXIFYING ENZYMES IN COTTON LEAFHOPPER *AMRASCA (SUNDAPTERYX) BIGUTTULA* (ISHIDA)

K Shankarganesh*, V S Nagrare[1], M Amutha, Selvi C and S Bagyaraj

ICAR-Central institute for Cotton Research (CICR), Regional Station, Coimbatore 641003, Tamil Nadu, India
[1]ICAR-CICR, Shankar Nagar, Nagpur 440010, Maharashtra, India
*Email: shankarento@gmail.com (corresponding author)

ABSTRACT

The present study evaluated the relative susceptibility of insecticides viz., imidacloprid, thiamethoxam, thiacloprid, flonicamid, clothianidin, diafenthiuron, spiromesifen, thiodicarb and chlorpyriphos against field collected population of *Amrasca (S.) biguttula.* Out of nine insecticides, maximum susceptibility was observed with thiamethoxam. The descending order of susceptibility was observed as thiamethoxam> thiacloprid> diafenthiuron> spiromesifen> imidacloprid> clothianidin> flonicamid> thiodicarb> chlorpyriphos. Based on the relative toxicity value it was observed that the insecticides such as chlorpyriphos, thiodicarb, flonicamid and clothianidin were 14.04, 12.01, 9.43 and 9.41x, respectively less toxic as compared to thiamethoxam. The detoxification enzyme assay revealed that the activity of esterase was high in thiamethoxam and thiacloprid exposed leafhopper, while cytochrome p450 activity was high in spiromesifen, thiamethoxam and thiacloprid exposed ones. Elevated level of esterase and cytochrome p450 in the insecticide exposed leafhoppers indicates the probability of insecticide resistance development.

Key words: Cotton, *Amrasca* (*Sundapteryx*) *biguttula*, insecticides, resistance, susceptibility, detoxifying enzymes, cytochrome p450, esterases

Cotton (*Gossypium* sp.) is an important cash crop and also known as "white gold" grown in more than 83 countries across the world. Introduction of *Bt* cotton to control the bollworm complex resulted in the disruption of pest complex in cotton ecosystem. The minor sucking pests have attained major pest status in many parts of India (Mohan and Nandini, 2011). Among the sap sucking pests, the leafhopper also called Indian jassid, *Amrasca* (*Sundapteryx*) *biguttula* (Ishida) is major pest of cotton in India, Pakistan, Bangladesh, China, and North Africa (Murugesan et al., 2009; Saeed et al., 2015; Kranthi, 2017). Both adults and nymphs suck the sap from leaves and inject toxic saliva resulting in 'hopper burn' symptoms, which ultimately result in the loss of plant vigour and significant yield losses up to 50% (Atakan, 2009).

Indiscriminate use of insecticides has led to development of insecticide resistance in leafhoppers. The cotton leafhopper had been found to be resistant to conventional groups such as cyclodienes, organophosphates, and pyrethroids (Santhini and Uthamasamy, 1997; Chalam and Subbaratnam, 1999; Chalam et al., 2001). Also, the fact that the Bt cotton seeds sold in the market are imidacloprid treated adds to the development of resistance (Kshirsagar et al., 2012). In Punjab, Rajwinder and Kang (2015) observed the no serious levels of resistance to imidacloprid, dimethoate, monocrotophos, triazophos and acetamiprid in cotton leafhopper. Continuous and indiscriminate use of organophosphates and neonicotinoids has probably led to development of resistance (Sagar and Balikai, 2014). Substantial misuse of insecticides resulted in the development of resistance to organophosphates (Rajwinder and Kang, 2015) and neonicotinoids (Shreevani et al., 2012). The studies pertaining to susceptibility status of leafhopper to conventional and newer molecules are available. However, very less studies are available on the dynamics of detoxification enzymes towards in insecticide resistant cotton leafhopper populations. Hence, the present study to find out the susceptibility status of cotton leafhopper to most commonly used insecticides and the level of detoxification enzymes present in the insecticide exposed leafhoppers.

MATERIALS AND METHODS

The leafhopper samples were collected from the experimental farms and the toxicity assay of insecticides was carried out under laboratory condition (27±2^{0}C, 70% RH), at the Insectary, ICAR-CICR, RS, Coimbatore. The selection of the insecticide was based on the recommendations of Central Insecticide Board

and Registration Committee (CIBRC), Government of India and famers' practice. Neonicotinoids (imidacloprid 17.80%SL, thiamethoxam 25%WG, clothionidin 50%WDG and thiacloprid 21.7% w/w); organophosphate (chlorpyriphos 20%EC); carbamates (thiodicarb 75%WP); tetronic acids (spiromesifen 22.9%SC); pyridine carboxamide (flonicamid 50%WG); and insect growth regulator (diafenthiuron 50%WP) were included in the bioassay studies. Commercial formulations of insecticides were diluted to obtain the desired concentrations. Preliminary range finding tests were carried out to fix the test concentrations, which cause 20 to 80% mortality to the leafhoppers.

Leaf dip method (IRAC method No. 001) according to Nauen and Elbert (2003) was followed with slight modification for bioassay. Fresh tender cotton leaves (variety LRA 5166) with petioles free from any insect infestation and without any pre-exposure to insecticides were used. The leaves were washed thoroughly with running tap water and shade dried on blotting paper. Individual leaves were dipped into the desired concentration of insecticides with cut portions of petioles wrapped with wet cotton inside micro centrifuge tubes. Each treatment included five replicates and, in each replication, ten leafhopper adults were exposed. The bioassays were conducted in insect rearing chamber with the temperature, photoperiod, and RH conditions as mentioned earlier. Insect mortality was recorded at 24 hr after treatment. The leafhoppers were considered dead, if no coordinated movement or deficient response to external stimulus (i.e. when gently probed with a fine paintbrush) was observed under the light microscope. Mortality was estimated by counting the total number of dead and live insects. The survived adults of leafhopper in each treatment were transferred to -20^{0}C for further study on detoxification enzyme assay.

The survived adults exposed to insecticides were used for assessing the activity of detoxifying enzymes such as carboxylesterase (COE) and cytochrome p450 which are commonly implicated against organophosphates (OPs)/ carbamates/ nenonicotinoids in insects. Total COE activity was estimated using 1-naphthylacetate as substrate (Stumpf and Nauen, 2002) and the activity was measured at 450 nm continuously for 10 min at 27°C a SPECTRA maxplus384 absorbance microplate reader (Molecular Devices) and expressed in micromoles of napthol formed/ min/ µg protein. Cytochrome p450 activity was estimated and expressed in terms of general oxidase, which is an indirect measure of cytochrome p450 by heme-peroxidation using 3,3',5,5'-tetramethyl-benzidine dihydronchloride as a substrate (Brogdon et al. 1997). Absorbance was read at 620 nm against blanks (wells containing all reaction components except enzyme source) in a SPECTRA maxplus384 absorbance microplate reader (Molecular Devices) after the 5 min incubation. A standard curve for heme peroxidase activity was prepared using different concentrations of cytochrome C. Cytochrome p450 (general oxidase) activity obtained from plate reading was expressed as equivalent units (EU) of cytochrome p450/ milligram of protein by using the standard curve of cytochrome C and they were expressed as µg/ ml/ min. Protein content was estimated to compute specific activity of detoxification enzymes. Standard protocol given by Bradford, (1976) was followed for the estimation of total protein content in *A (S). biguttula*.

Necessary corrections were made with respect to natural mortality in the control using Abbott's formula (Abbott, 1925) and then the data was subjected to probit analysis as per Finney (1971). The LC_{50} and LC_{90} values, 95% confidence limits, standard errors, the slopes of the regression lines and χ^2 significance tests, were estimated by probit analysis using PoloPlus 2.0 software (LeOra Software, California, United States). The relative toxicity (RT) of tested insecticide to leafhopper was calculated by keeping the most toxic insecticide as unit i.e (1.00). Enzyme activity ratio (EAR) was calculated by comparing the enzyme activity in (insecticide exposed) / control (insecticide unexposed).

RESULTS AND DISCUSSION

The acute toxicity assay revealed that of the nine insecticides evaluated against *A. biguttula,* thiamethoxam was found to be more toxic (n=210, 3.06 mg ai·L) followed by thiacloprid (n=226, 3.06 mg ai-L). The descending order of susceptibility is thiamethoxam> thiacloprid> diafenthiuron> spiromesifen> imidacloprid> clothianidin> flonicamid> thiodicarb> chlorpyrifos. The relative toxicity (RT) value reveals that the insecticides such as chlorpyrifos, thiodicarb, flonicamid and clothianidin were 14.04, 12.01, 9.43 and 9.41 times less toxic respectively as compared to thiamethoxam (Table 1).

Insecticide exposure influences the level of esterase present in field population. As compared to control (unexposed to insecticide), the esterase activity increased due to insecticide exposure except for diafenthiuron. The activity was maximum in leafhopper exposed to thiamethoxam (21.614 uM napthol/ min/ mg protein) followed by imidacloprid (17.586 uM napthol/ min/ mg

Table 1. Relative toxicity of insecticides and the level of detoxifying enzymes in field populations of *A (S.) biguttula* in cotton

Insecticide	n	Slope	LC_{50} mg ai-L	Fiducial limit		RT*	LC_{99}	Enzyme activity			
				Min	Max			Esterase (uM napthol / min / mg protein)	EAR**	Mixed function oxidase (nM cyto / min / mg protein)	EAR
Imidacloprid	210	0.980+-0.172	13.07	3.85	27.84	4.28	26.57	17.586	1.22	81.47	0.93
Thiamethoxam	210	0.665+-0.124	3.06	1.26	6.012	1.00	25.95	21.614	1.50	117.30	1.34
Thiocloprid	210	0.411+-0.079	4.44	1.16	13.21	1.45	58.25	17.046	1.18	100.52	1.15
Flonicamid	210	0.541+-0.114	28.87	12.33	74.45	9.43	167.35	16.309	1.13	83.84	0.96
Clothionidin	210	0.653+-0.128	28.82	11.4	57.07	9.41	163.84	17.213	1.19	36.67	0.42
Diafenthiuron	210	0.862+-0.129	5.35	3.01	8.75	1.75	86.38	14.272	0.99	85.60	0.98
Spiromesifen	210	0.593+-0.111	5.61	2.32	12.07	1.83	81.55	16.507	1.14	118.17	1.35
Thiodicarb	210	0.914+-0.146	36.73	20.51	60.75	12.01	192.86	16.091	1.11	110.79	1.26
Chlorpyriphos	210	0.600+-0.138	42.55	19.04	97.42	14.04	283.95	16.504	1.14	98.23	1.12
Control	-	-	-	-	-	-	-	14.443	1.00	87.62	1.00

*Relative toxicity (RT) LC_{50} of test insecticide / LC_{50} of most toxic insecticide; **Enzyme activity ratio (EAR) = enzyme activity in field population (insecticide exposed)/ enzyme activity in field population (insecticide unexposed)

protein) and clothianidin ((17.213 uM napthol/ min/ mg protein). Based on the EAR it was observed that, all the insecticides were influenced by the level of esterase in the leafhopper. Similarly, insecticide exposure significantly influences the level of cytochrome p450. The activity was high in spiromesifen, thiamethoxam and thiacloprid exposed leafhopper. The elevated level of cytochrome p450 in the insecticide exposed leafhopper implies the probability of development of insecticide resistance. The values of enzyme activity ratios (EAR) for both the enzymes suggest the tolerance of leafhopper. Further, when compared to control, the EAR values were >1, which indicates role of detoxification enzymes in resistant development. The neonicotinoid insecticide, thiamethoxam was found to be more toxic followed by thiacloprid and imidacloprid. Application of neonicotinoids, imidacloprid and acetamiprid (Patel et al., 2017) and thiamethoxam (Rekha et al., 2017; Sesha MahaLakshmi and Prasad, 2020) reduced the leafhopper incidence. Next to thiamethoxam, thiacloprid, diafenthiuron and flonicamid were also found toxic. Application of diafenthiuron, flonicamid and fipronil in cotton reduced the incidence and enhanced the yield (Vimala et al., 2016; Kalyan et al., 2017). In the present study RT values reveal that chlorpyriphos, thiodicarb, flonicamid and clothianidin were 14.04, 12.01, 9.43 and 9.41x less toxic as compared to thiamethoxam.

India has a long history of insecticide resistance development in sucking pests of cotton including leafhopper (Santhini and Uthamasamy, 1997; 2011; Kshirsagar et al., 2012; Sagar and Balikai 2014; Rekha et al., 2017; Sesha Maha Lakshmi and Prasad, 2020). Metabolic resistance through detoxification enzymes is the most common phenomenon reported to occur in several species of insects showing resistance to insecticides (Devorshak and Roe, 1998; Li et al., 2007). Measurement of enzymatic activities of detoxification enzymes has been effectively used to gauge the level of tolerance to insecticides belonging to OP, carbamates and neonicotinoids in several species of insects and natural enemies (Saha et al., 2012; Srinivasa Murthy et al., 2014). Insecticide exposure significantly influences the level of mixed function oxidase in leafhopper. The MFOs activity was high in spiromesifen, thiamethoxam and thiacloprid exposed leafhopper. The elevated level of MFOs in the insecticide exposed leafhopper indicates the probability of development of insecticide resistance. Sagar et al., 2013 found relatively more MFOs activity in leafhoppers treated with organophosphates (monocrotophos, acephate, oxydemeton methyl and dimethoate) in major cotton growing districts of Karnataka, which indicated the role of MFOs in detoxification of insecticides.

ACKNOWLEDGEMENTS

Authors thank the Director, ICAR-Central Institute for Cotton Research (CICR) and Project Coordinator and Head, ICAR-CICR, RS, Coimbatore for facilitating the study.

REFERENCES

Abbott W S. 1925. A method of computing the effectiveness of an insecticide. Journal of Economic Entomology 18 (2): 265-267.

Atakan E. 2009. Damage assessment of the leafhopper complex [*Asymmetrasca decedens* (Paoli) and *Empoasca decipiens* Paoli] (Homoptera: Cicadellidae) in cotton. Journal of Pest Science 82 (3): 227-234.

Bradford M M. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein dye binding. Analytical Biochemistry 72 (1-2): 248-254.

Brogdon W G, Mcallister J C, Vulule J. 1997. Heme peroxidase activity measured in single mosquitoes identifies individuals expressing an elevated oxidase for insecticide resistance. Journal of the American Mosquito Control Association 13 (3): 233-237.

Chalam M, Subbaratnam G. 1999. Insecticide resistance in cotton leafhopper, *Amrasca biguttula biguttula* (Ishida) in Andhra Pradesh. Pest Management and Economic Zoology 7 (2): 105-110.

Chalam M, Subbaratnam G, Rao G. 2001. Role of mixed function oxidases in imparting resistance to the cotton leafhopper, *Amrasca biguttula biguttula* (Ishida). Pest Management and Economic Zoology 9 (1): 49-53.

Devorshak C, Roe R M. 1998. The role of esterases in insecticide resistance, Review on Toxicology 2: 501-537.

Kalyan R, Saini D, Meena B, Abhishek P, Pooja N, Shilpa V, Sonika J. 2017. Evaluation of new molecules against jassids and whiteflies of Bt cotton. Journal of Entomology and Zoology Studies 5 (3): 236-240.

Kranthi S. 2017. Forty years of cotton crop protection in India. Cotton Statistics and News No. 18 p. 3.

Kshirsagar S, Satpute N, Moharil M. 2012. Monitoring of insecticide resistance in cotton leafhoppers, *Amrasca bigutulla bigutulla* (Ishida). Annals of Plant Protection Sciences 20 (2): 283-286.

Li X C, Schuler M A, Berenbaum R. 2007. Molecular mechanisms of metabolic resistance to synthetic and natural xenobiotics. Annual Review of Entomology 52 (1): 231-253.

Mohan S, Nandini S. 2011. A promising entry for cotton leafhopper. Pestology 35 (6): 11-13

Murugesan N, Vimala R, Ramalingam A, Shunmugavalli N. 2009. Evaluation of an IPM module against insect pests of cotton with Bt and Non -Bt cotton hybrids. Proceedings. Conference on recent advances in applied zoology, March 30-31, 2009 ANJAC, Sivakasi. pp. 44-45.

Nauen R, Elbert A. 2003. European monitoring of resistance to insecticides in *Myzus persicae* and *Aphis gossypii* (Hemiptera: Aphididae) with special reference to imidacloprid. Bulletin of Entomological Research 93 (1): 47-54.

Patel G P, Tayde A R, Simon S. 2017. Evaluation of Bio-Rational and chemical insecticides against leafhopper, *Amrasca biguttula biguttula* (Ishida) and whitefly, *Bemisia tabaci* (Gennadius) on okra. Journal of Entomology and Zoology Studies 5 (4): 1966-1968.

Rajwinder K, Kang B. 2015. Status of insecticide resistance in leafhopper, *Amrasca biguttula biguttula* (Ishida) on cotton. Bioscan 10 (4): 1441-1444.

Rekha S, Prabhuraj A, Hosamani A C, Khan H. 2017. Bioassay of insecticides against okra leafhopper *Amrasca biguttula biguttula* (Ishida). International Journal of Plant Protection 10 (2): 364-368

Saeed R, Razaq M, Hardy I C. 2015. The importance of alternative host plants as reservoirs of the cotton leaf hopper, *Amrasca devastans* and its natural enemies. Journal of Pest Science 88 (3): 517-531.

Sagar D, Balikai R. 2014. Insecticide resistance in cotton leafhopper, *Amrasca biguttula biguttula* (ISHIDA)-A review. Biochemical and Cellular Archives 14 (2): 283-294

Sagar D, Balikai R, Khadi B. 2013. Insecticide resistance in leafhopper, *Amrasca biguttula biguttula* (Ishida) of major cotton growing districts of Karnataka, India. Biochemical and Cellular Archives 13(2): 261-265

Saha D, Roy S, Mukhopadhyay A. 2012. Seasonal incidence and enzyme-based susceptibility to synthetic insecticides in two upcoming sucking insect pests of tea. Phytoparasitica 40 (2): 105-115.

Santhini S, Uthamasamy S. 1998. Susceptibility of cotton leafhopper (*Amrasca devastans*) to insecticides in Tamil Nadu. Indian Journal of Agricultural Sciences 68 (3): 330-331.

Sesha Maha Lakshmi M, Prasad N V V S D. 2020. Insecticide resistance in field population of cotton leaf hopper, *Amrasca devastans* (Dist.) in Guntur, Andhra Pradesh, India, International Journal of Current Microbiology and Applied Science 9 (6): 3006-3011.

Shreevani G N, Sreenivas A G, Bheemanna M, Hosamani A C. 2012. Toxicity studies of neonicotinyls against leafhopper, *Amrasca biguttula biguttula* (Ishida)] on Bt cotton. Karnataka Journal of Agricultural Science 25 (4): 540-542

Srinivasa Murthy K, Ramya S L, Venkatesan T, Jalali S K, Verghese A. 2014. Biochemical basis of insecticide resistance and determination of esterase enzyme patterns in field collected populations of *Cotesia vestalis* (Haliday) (Hymenoptera: Braconidae) from India. Annals of Biological Research 5 (11):7-15.

Stumpf N, Nauen R. 2002. Biochemical markers linked to abamaectin resistance in *Tetranychus urticae* (Acari: Tetranychidae). Pesticide Biochemistry and Physiology 72 (2): 111-121.

Vimala V, Bheemanna M, Chowdary R, Reddy R S. 2016. Toxicity of neonicotinoids and conventional insecticides to south Indian populations of cotton leafhopper (*Amrasca biguttula biguttula*), Research Journal of Chemistry and Environment 20 (10): 21-25.

(Manuscript Received: December, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: April, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20418

Indian Journal of Entomology 84(1): 101-104 (2022) DoI No.: 10.55446/IJE.2021.330

ANTIOXIDANT ENZYMES IN COTTON MEALY BUG *PHENACOCCUS SOLENOPSIS* TINSLEY EXPOSED TO HIGH TEMPERATURE

K Shankarganesh*, K Rameash, C Selvi and S Bagyaraj

ICAR- Central Institute for Cotton Research, Regional Station, Coimbatore 641003, Tamil Nadu, India
*Email: shankarento@gmail.com (corresponding author)

ABSTRACT

Effect of high temperature on the antioxidant enzymes catalase (CAT), superoxide dismutase (SOD) and peroxidases (POD) in the third instar of *Phenacoccus solenopsis* was studied under laboratory condition. Temperature influences the level of antioxidant enzymes with exposure to high temperature (40^{0}C). There was a marked rise in catalase activity and the maximum activity (0.399 nmol/ min/ mg) was observed after 6 hr in Bhatinda population. Irrespective of the population, the activity of peroxidase was positively correlated with time of exposure, and maximum activity was observed in Sri Ganganagar (0.218 nmol/ min/ mg) population at 6 hr of exposure. Within the 3 hr of exposure the maximum activity of SOD (0.127 µM/ min /mg) was observed in Rajkot and at 4 hr (0.060± 0.019 µM/ min /mg) in Sri Ganganagar populations. With further increase in the period of exposure, significant reduction in the activity of SOD was observed, and it was maximum in Guntur populations (0.218 µM/ min/ mg) at 6 hr of exposure. Thus, the findings suggest that the exposure of mealybug to high temperature induce oxidative stress in *P. solenopsis.* In all the population high temperature stress induces the activity of antioxidant enzymes to overcome the oxidative cell damage in mealy bug.

Key words: Thermal stress, *Phenacoccus solenopis,* reactive oxygen species, catalase, superoxide dismutase, peroxidases, exposure, population variations,Bhatinda, Sri ganganagar, Rajkot, Guntur

The cotton mealy bug *Phenacoccus solenopsis* Tinsley is an important sucking pest of cotton reported in all cotton growing states of India. This occurs throughout the year, with peak infestations observed during April- May in central India and June- August in north India (Fand et al., 2014), when the temperature is very high. Being an ectothermic pest, its various life processes are severely affected by temperature (Prasad et al., 2012; Waqas et al., 2020). During thermal stress it is very important to maintain the homeostatic balance by preventing the oxidative stress as well as damage by reactive oxygen species. To overcome this insects have their own defense system of non-enzymatic scavengers and a series of antioxidant enzymes. In insects, the most important antioxidant enzymes are superoxide dismutase (SOD), peroxidase (POD), catalase (CAT) and glutathione S-transferase (GST) (Wang et al., 2001; Dubovskiy et al., 2008; Yang et al., 2010). These antioxidant enzymes play a major role in insects to protect cells and thus keeping the homeostatic balance by removing the oxidative stress. Catalase and peroxidase breaks H_2O_2 into H_2O and O_2 and SOD removes the O_2 through the method of dismutation to O_2 and H_2O_2. The effects of varying temperature regimes on developmental biology of various insects including mealybug had been well documented (Vennila et al., 2010; Nikam et al., 2010; Rishi Kumar et al., 2010; Prasad et al., 2012; Kumar et al., 2013). However, the studies on thermal stress induced effect over the major antioxidant enzymes in *P. solenopsis* have been less studied. Keeping this in view, the present study was aimed to understand the effect of high temperature 40^{o}C on the level of antioxidant enzymes, when exposed to 1 to 6 hrs.

MATERIALS AND METHODS

Mealybugs from the farmers' fields of six cotton growing states viz., Sri Ganganagar (Rajasthan), Bhatinda (Punjab), Saoner (Maharashtra), Bharuch (Gujarat), Guntur (Andhra Pradesh) and Perambalur (Tamil Nadu) were collected. These were established on sprouted potato in a plastic container under laboratory condition (27± 2^{0}C; 65% RH) following standard protocol (Nagrare et al., 2011). Samples required for thermal stress experiments were drawn from this culture. Second instar (7 days old, n=30) was selected from each population and exposed to 40^{o}C and 65%RH for varying periods (1- 6 hr). After the exposure, the cultures were transferred into a 2 ml centrifuge tube, with samples kept at 27°C serving as a control. A temperature controller was used in all stress treatments.

In order to check mortality, populations were allowed to recover at 27°C for 30 min after shock. Then the surviving ones were frozen immediately stored at -80°C until analysis. The treatments were replicated thrice.

The activities of antioxidant enzymes, including catalase (CAT), peroxidases (POD), superoxide dismutase (SOD) was measured using commercially available assay kits. Enzyme estimation was carried out by following the manufacturer's protocol and the absorbance was read in a microplate reader (Multiskan EX, Labsystems Inc., Franklin, MA, USA). For determination of enzyme expression level, single mealybug which was subjected to thermal stress experiment was homogenized in respective sample buffer (100 µl of phosphate buffer; pH 7.5), centrifuged at 15,000 rpm for 10 min at 4°C and the resultant supernatant was used for protein content and enzymatic activity analysis. Supernatants obtained from these homogenates were used to determine the CAT, POD and SOD activities according to the Cai et al. (2019) with slight modifications.

The CAT activity was determined with a catalase assay kit (# 707002, Cayman Chemical Co., Ann Arbor, MI, USA) as per manufacturer's instruction. The CAT assay buffer (100mM potassium phosphate, pH 7.0) and sample buffer (25mM potassium phosphate pH 7.5, containing 1mM EDTA and 0.1% BSA) was used for measuring the absorbance at 540 nm due to H_2O_2 decomposition. Enzyme activity was calculated as concentration of hydrogen peroxide reduced/ min/ mg protein. One unit is defined as the amount of enzyme that will cause the formation of 1.0 nmol of formaldehyde/ min at 25°C. The specific activity peroxidase was expressed in nmol/ min/ mg protein. Peroxidase activity was assayed with commercially available assay kit (#MAK092, Sigma-Aldrich) by measuring the amount of H_2O_2 reduced during the assay at a wavelength of 570 nm (homogenization buffer consist of 100 µl of phosphate buffer; pH 7.5) and assay buffer 100 µl (50mM Tris-HCl, pH-7.6 containing 5 mM EDTA). The specific activity peroxidase was expressed in nmol/ min/ mg protein.

The SOD activity was determined using a SOD determination kit (#19160, Sigma-Aldrich, St. Louis, MO, USA). The activity of SOD was quantified by the sum of inhibition or the decrease in colour development at 450 nm. SOD activity was standardized using cytochrome c and xanthine oxidase coupled assay. The specific activity SOD was expressed in µM/ min/ mg protein. Protein concentrations of individual samples were determined kit (Himedia) using bovine serum albumin as a standard (Bradford, 1976) and absorbance was read at 595 nm (Labsystem Multiskan EX, Lab systems Inc., Franklin, MA, USA) after the incubation period of samples and reagents for 15 min (25°C) in micro titer plates.

RESULTS AND DISCUSSION

The activity of antioxidant enzyme (SOD, POD and CAT) in *P. solenopsis* was significantly affected due to high temperature (40°C) exposure. In Saoner population, maximum catalase activity was observed at 2 hr after exposure (0.172 nmol/ min/ mg) and further increase in the period of exposure resulted in reduction in the activity of the catalase. Gradual increase in the activity of catalase was noticed in Bhatinda, Rajkot and Guntur populations and the maximum activity (1.666 nmol/ min/ mg) was observed at 6 hr of exposure in Guntur and Perambalur population. In response to the period of exposure, peroxidase activity with 40°C exposed *P. solenopsis* was in increasing trend. The maximum activity was observed in Guntur population at 0. 218 nmole / min / mg at 6 hr of exposure followed by Bhatinda, Rajkot and Saoner populations. While, in Perambalur, the maximum peroxidase activity (0.127 nmol/ min/ mg) was observed at 5 hr after exposure. Exposure of 3rd instar of *P. solenopsis* to high temperature influenced the activity of superoxide dismutase (SOD). Increasing trend in the activity was observed in Bhatinda, Saoner and Guntur populations from 1- 6 hr after exposure. The maximum activity of SOD was observed in Guntur populations (0.218 µM/ min/ mg). In Sri Ganganagar the maximum activity of SOD reached at 4 hr but showed a significant reduction in the activity of SOD at 6 hr of exposure (Table 1).

Temperature is one of the most key environmental factors that bring out physiological changes in most of the organisms (Jia et al., 2011). As insects are ectotherms, suffers losses from physiological fitness and sometimes leads to death (Dillon et al., 2009). Catalase and SOD are the most important antioxidant enzymes against ROS. Superoxide dismutase catalyses the dismutation of superoxide radicals to H_2O_2 and O_2, and constitutes the most important enzyme in cellular defense because its activation directly modulates the amounts of O_2 and H_2O_2 (Foyer and Noctor 2000; Thannickal and Fanburg 2000). In the present study, temperature stress significantly influenced the activities of antioxidant enzymes in insects. The overall activity of

Table 1. Activity of antioxidant enzymes in field populations of *P. solenopsis* exposed to high temperature (40°C)

Period of exposure (Hrs)	Sriganganagar	Bhatinda	Rajkot	Saoner	Guntur	Perambalur
	Catalase (nmol/ min/ mg ± SEm)					
Control	0.093 ± 0.003	0.134 ± 0.001	0.184 ± 0.007	0.119 ± 0.002	0.311 ± 0.009	0.090 ± 0.016
1	0.111± 0.002	0.110 ± 0.006	0.203 ± 0.002	0.125 ± 0.002	0.407 ± 0.009	0.203 ± 0.003
2	0.125 ± 0.001	0.119 ± 0.004	0.213 ± 0.124	0.172 ± 0.007	1.073 ± 0.008	0.252 ± 0.002
3	0.159 ± 0.003	0.108 ± 0.033	0.243 ± 0.002	0.141 ± 0.001	1.081 ± 0.001	0.247 ± 0.006
4	0.180 ± 0.006	0.179 ± 0.002	0.267 ± 0.004	0.134 ± 0.001	1.106 ± 0.006	0.199 ± 0.024
5	0.243 ± 0.002	0.246 ± 0.002	0.290 ± 0.002	0.125 ± 0.003	1.250 ± 0.005	0.283 ± 0.009
6	0.161± 0.006	0.399 ± 0.005	0.295 ± 0.004	0.126 ± 0.002	1.666 ± 0.403	0.235 ± 0.019
	Peroxidase (nmol/ min/ mg ± SEm)					
Control	0.023 ± 0.016	0.034 ± 0.002	0.089 ± 0.009	0.066 ± 0.002	0.173 ± 0.038	0.081 ± 0.001
1	0.034 ± 0.006	0.012 ± 0.052	0.084 ± 0.044	0.060 ± 0.003	0.177 ± 0.003	0.086 ± 0.024
2	0.050 ± 0.006	0.051 ± 0.075	0.087 ± 0.028	0.069 ± 0.005	0.185 ± 0.036	0.094 ± 0.043
3	0.057 ± 0.013	0.052 ± 0.029	0.103 ± 0.031	0.072 ± 0.003	0.175 ± 0.088	0.104 ± 0.005
4	0.060 ± 0.019	0.058 ± 0.007	0.112 ± 0.024	0.075 ± 0.141	0.192 ± 0.033	0.126 ± 0.022
5	0.028 ± 0.006	0.062 ± 0.032	0.096 ± 0.007	0.077 ± 0.061	0.183 ± 0.038	0.127 ± 0.006
6	0.023 ± 0.001	0.063 ±0.004	0.097 ± 0.005	0.124 ± 0.001	0.218 ± 0.088	0.124 ± 0.046
	Superoxide dismutase (µM/ mg/ min ± SEm)					
Control	0.050 ± 0.006	0.034 ± 0.002	0.089± 0.009	0.066 ± 0.002	0.173 ± 0.038	0.081± 0.001
1	0.034 ± 0.006	0.012 ± 0.052	0.084 ± 0.044	0.060 ± 0.003	0.177 ± 0.003	0.086 ± 0.024
2	0.023 ± 0.016	0.051 ± 0.075	0.087± 0.028	0.069 ± 0.005	0.185 ± 0.036	0.094 ± 0.043
3	0.057 ± 0.013	0.052 ± 0.029	0.103± 0.031	0.072 ± 0.003	0.192 ± 0.033	0.104 ± 0.005
4	0.060 ± 0.019	0.058 ± 0.007	0.112± 0.024	0.075 ± 0.141	0.183 ± 0.038	0.126 ± 0.022
5	0.028 ± 0.006	0.062 ± 0.032	0.096± 0.007	0.077 ± 0.061	0.175 ± 0.088	0.127 ± 0.006
6	0.023 ± 0.001	0.063 ± 0.004	0.097± 0.005	0.124 ± 0.001	0.218 ± 0.088	0.124 ± 0.046

CAT, POD and SOD increased with period of exposure to ambient temperature in all the populations of *P. solenopsis* (Waqas et al., 2020b; Shankarganesh et al., 2020). The CAT activity increased at 40°C as compared to control. Under thermal stress condition the CAT activity increased in parasitized Oriental fruit fly larvae (Cai et al., 2019). Similarly, the activity of POD was significantly higher in all the populations. Depending upon the period of thermal stress the SOD activity in the *P. solenopsis* was significantly influenced. Early or initial-stage of exposure to temperature changes resulted in oxidative stress regulated by antioxidant enzymes, but continued stress caused by varied temperature exposure resulted in decreased SOD activity.

Jia et al. (2011) showed that the activities of CAT, peroxidase (POX) and SOD significantly increased in *Bacterocera dorsalis* (Hendel) in response to thermal stress. However, prolonged exposure to heat or cold shock resulted in decreased activities of CAT, GST and SOD accompanied by impaired antioxidant capacity and high levels of oxidative stress. In *Panonychus citri* and *Propylaea japonica*, the high temperature exposure increased the levels of SOD and GST (Yang et al., 2010; Zhang et al., 2015). Similar results were observed in the aphid parasitoid *Aphidius gifuensis* when the pupae and adults were exposed to temperature above 30°C; activities of GST, SOD, CAT and POD significantly increased (Kang et al., 2017). The effects of temperature on the activity of antioxidant enzymes in larvae of *B. dorsalis* parasitized by *Diachasmimorpha longicaudata* (Wang et al., 2013; Cai et al., 2019) and *Paracoccus marginatus* parasitized by *Acerophagus papayae* (Shankarganesh et al., 2020) indicated that CAT, POD and SOD together, have an important role in preventing the insect suffering from oxidative damage with ROS induced by heat stress. This basic information will certainly help in predicting the direct or indirect effect temperature stress on population dynamics of *P. solenopsis* under varied environmental conditions and thereby to frame management strategies against this mealy bug.

ACKNOWLEDGEMENTS

Authors thank the Department of Science and Technology, Extra Mural Research Grant (Individual Centric) for financial support and the institutional support from Director, ICAR-Central Institute for Cotton Research (CICR) and Project Coordinator and Head, ICAR-CICR, RS, Coimbatore.

REFERENCES

Bradford M M. 1976. A rapid and sensitive method for the quantization

of microgram quantities of protein utilizing the principle of protein-dye binding. Analytical Biochemistry 72: 248-254.

Cai P, Wang Y, Yi C, Zhang Q, Xia H, Lin J, Yang H Z J, Ji Q, Chen J. 2019. Effects of temperature on the activity of antioxidant enzymes in larvae of *Bactrocera dorsalis* (Diptera: Tephritidae) parasitized by *Diachasmimorpha longicaudata* (Hymenoptera: Braconidae): Optimizing the mass rearing of this braconid by varying the temperature. European Journal of Entomology 116: 1-9.

Dillon M E, Wang G, Garrity P A, Huey R B. 2009. Thermal preference in *Drosophila*. Journal of Thermal Biology 34: 109-119.

Dubovskiy I M, Martemyanov V V, Vorontsova, Y L, Rantala M J, Gryzanova E V Glupov V V. 2008. Effect of bacterial infection on antioxidant activity and lipid peroxidation in the midgut of *Galleria mellonella* L. larvae (Lepidoptera, Pyralidae). Comparative Biochemistry and Physiology, Part C, 148: 1-5.

Fand B B, Henri E Z T, Mahesh K, Bal, Santanu K, Singh, Naveen P, Rao D V K N, Kamble Ankush L, Nangare Dhananjay D, Minhas, Paramjit S. 2014. Predicting the impact of climate change on regional and seasonal abundance of the mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) using temperature driven phonology model linked to, Ecological Modeling 288: 62-78.

Foyer C H, Noctor G. 2000. Tansley Review 112. Oxygen processing in photosynthesis: regulation and signaling. New Phytologist 146: 359-388.

Jia F X, Dou W, Hu F, Wang J J. 2011. Effects of thermal stress on lipid peroxidation and antioxidant activities of Oriental fruit fly, *Bacterocera dorsalis* (Diptera: Tephritidae). Florida Entomologist 94: 956-963.

Kang Z W, Liu F H, Liu X, Yu W B, Tan X L, Zhang S Z, Tian H G, Liu T X. 2017. The potential coordination of the heat-shock proteins and antioxidant enzyme genes of *Aphidius gifuensis* in response to thermal stress. Frontiers in Physiology 8: 976.

Kumar S, Jaspreet K, Sidhu Hamm J C, Kular J S, Mahal M S. 2013. Effects of temperature and relative humidity on the life table of *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on cotton. Florida Entomologist 96: 19-28.

Nagrare V S, Kranthi S, Kumar R, Dharajothi B, Amutha M, Deshmukh A J, Bisane K D, Kranthi K R. 2011. Compendium of cotton mealybugs. Technical Bulletin. Central Institute for Cotton Research, Nagpur. 42 pp.

Nikam N D, Patel B H, Korat D M. 2010. Biology of invasive mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on cotton. Karnataka Journal of Agricultural Sciences 23: 649-651.

Prasad Y G, Prabhakar M, Sreedevi G, Ramachandra Rao G, Venkateswarlu B. 2012. Effect of temperature on development, survival and reproduction of the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on cotton. Crop Protection 39: 81-88.

Rishi Kumar, Jat S L, Pal V, Chauhan, R. 2010. Biology of the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Psuedococcidae) in India. Entomon 34: 189-192.

Shankarganesh K, Selvi C, Karpagam C. 2020. Effects of thermal stress on the antioxidant defenses in *Paracoccus marginatus* Williams and Granara de Willink (Homoptera: Pseudococcidae) parasitized by *Acerophagus papayae* Noyes and Schauff (Encyrtidae: Hymenoptera). International Journal of Tropical Insect Science 10.1007/s42690-020-00222-8

Thannickal V J, Fanburg B L. 2000. Reactive oxygen species in cell signaling. The American Journal of Physiology- Lung Cellular and Molecular Physiology 279: 1005-1028

Vennila S, Deshmukh A J, Pinjarkar D, Agarwal M, Ramamurthy V.V, Joshi S, Kranthi K R, Bambawale O M. 2010. Biology of the mealybug, *Phenacoccus solenopsis* on cotton in the laboratory. Journal of Insect Science 10: 1-9.

Wang Y, Guo JJ, Chen JH, Ji QE. 2013. The changes of the activity of four enzymes in larvae of *Bactrocera dorsalis* (Hendel) parasitized by *Diachasmimorpha longicaudata*. Chinese Journal of Tropical Crops 34: 335-338

Wang Y, Oberley L W, Murhammer D W. 2001. Antioxidant defense systems of two lepidopteran insect cell lines. Free Radical Biology and Medicine 30: 1254-1262.

Waqas M S, Lin L, Shoaib A A Z, Cheng X, Zhang Q, Elabasy A S S, Shi Z. 2020a. Effect of constant and fluctuating temperature on the development, reproduction, survival, and sex ratio of *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae). Environmental Entomology 49: 553-560.

Waqas M S, Saad Elabasy A S, Zaky Shoaib A A, Cheng X, Zhang Q, Shi Z. 2020b. Lethal and sublethal effect of heat shock on *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae), Journal of Thermal Biology https://doi.org/10.1016/j.jtherbio.2020.102679.

Yang L H, Huang H, Wang J J. 2010. Antioxidant responses of citrus red mite, *Panonychus citri* (McGregor) (Acari: Tetranychidae), exposed to thermal stress. Journal of Insect Physiology 56: 1871-1876.

Zhang S, Fu W, Li N, Zhang F, Liu T. 2015. Antioxidant responses of *Propylaea japonica* (Coleoptera: Coccinellidae) exposed to high temperature stress. Journal of Insect Physiology 73: 47-52.

(Manuscript Received: December, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: May, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20419

Indian Journal of Entomology 84(1): 105-108 (2022) DoI.: 10.55446/IJE.2021.26

EFFECT OF IPM MODULES ON MAJOR PESTS AND THEIR NATURAL ENEMIES IN KING CHILLI *CAPSICUM CHINENSE* IN NORTHEAST INDIA

Rojeet Thangjam*, Veronica Kadam[1], R K Borah[2], D K Saikia[2], P D Nath[3] and H R Singh[4]

College of Horticulture, Central Agricultural University (Imphal), Thenzawl, Mizoram 796186, India
[1]College of PG Studies in Agricultural Sciences, Central Agricultural University (Imphal), Umiam, Meghalaya 793103, India
[2]Department of Entomology; [3]Department of Plant Pathology, Assam Agricultural University, Jorhat, Assam 785013, India
[4]KVK, Central Agricultural University (Imphal), Andro, Manipur 795049, India
*Email: rojeetthangjam@gmail.com (corresponding author)

ABSTRACT

A field experiment to evaluate some IPM modules against major pests viz., *Aphis gossypii*, *Myzus persicae*, *Bemisia tabaci* and their natural enemies viz., coccinellids and spiders occurring in king chilli *Capsicum chinense* Jacquin was carried out during rabi (2014-16) at Jorhat, Assam. The results revealed that module M2 with seedling root dip treatment with imidacloprid 17.8 SL @ 40g a.i./ ha + growing of border crop (okra)+ spraying of imidacloprid 17.8SL @ 40g a.i./ ha at 20 days after transplanting at 15 days interval is the most effective in suppressing aphids and whitefly followed by lambdacyhalothrin instead of imidacloprid in both the seasons. The insecticidal treatment modules had a significant effect on the pest and the viral diseases, thereby increasing the yield, with maximum yield obtained in module M_2 (3564.44 kg/ ha) and with a maximum cost-benefit ratio of 1: 4.85.

Key words: *Capsicum chinense*, IPM modules, *Aphis gossypii*, *Myzus persicae*, *Bemisia tabaci*, coccinellids, spiders, imidacloprid, lambdacyhalothrin, seed treatment, spray, yield, cost benefits, Assam

King chilli (*Capsicum chinense* Jacquin) is a semiperennial crop grown extensively in the Northeastern region. This is one of the hottest chilli, with a pleasant and palatable aroma (Baruah et al., 2014), and an important cash crop in the region. Parasar and Deka (2013) reported that this chilli's cost-benefit ratio/ ha was 1: 11.85 in Assam. However, this chilli attracts many insect pests and highly susceptible to viral diseases, which hamper its production. Begam et al. (2016), Thangjam et al. (2017) and Buragohain et al. (2017) reported 19 species of arthropod pests from king chilli, of which sucking pests viz., *Aphis gossypii*, *Myzus persicae* and *Bemisia tabaci* are the primary pests in Assam transmitting major viral diseases. Talukdar et al. (2015) and Baruah et al. (2016) also reported Cucumber Mosaic Virus (CMV), Potato Virus Y (PVY), Tomato spotted wilt virus (TSWV) and ChLCV from this chilli transmitted by aphids, thrips and whitefly, respectively. These deseases reduce the productivity of the crop. Since little work has been done on the management of king chilli's pests, the present study evaluates few IPM modules against the major pests.

MATERIALS AND METHODS

Two field experiments were conducted during rabi 2014-15 and 2015-16 in the Experimental Farm, Department of Horticulture, Assam Agricultural University, Jorhat (26º47´N,94º12´E). The experiment was laid out in an area of 331.5 m^2 following the randomized block design (RBD) with 6 treatments and 4 replications, with each plot measuring 7.5m^2 (3x 2.5m), and the inner spacing between replications and plots were 1 and 0.5 m, respectively. The local variety seeds were sown on 15th September 2014 and transplanted on 10th January 2015 for the first experiment; and sowing was on 20th September 2015 and transplanting on 14th January 2016. A spacing of 75x75 cm was maintained and all the recommended package of practices were followed. The details of the IPM modules are as follows: M1=Soil solarisation of nursery bed for 15 days followed by application of organic amendment (neem cake) @ 50 g/ m^2 +nylon netting (50 mesh size) of nursery+ clean cultivation (weeding and hoeing) at 15 days interval or as and when necessary and

spraying of NSKE @4% at 20 days after transplanting at 15 days interval (4 sprays); M2= Seedling root dip treatment with imidacloprid 17.8SL @ 40 g a.i./ ha for 30 min just before transplanting+ growing of border crop (okra) 30 days before transplanting the main crop and spraying of imidacloprid 17.8SL @ 40g a.i./ ha at 20 days after transplanting at 15 days interval (4 sprays); M3= Seedling root dip treatment with imidacloprid 17.8SL @ 40 g a.i./ ha for 30 min just before transplanting+ growing of border crop (marigold) 30 days before transplanting the main crop+ spraying of emamectin benzoate 5%SG @ 10 g a.i./ ha at 20 days after transplanting at 15 days interval (4 sprays); M4= Seedling root dip treatment with imidacloprid 17.8SL @ 40 g a.i./ ha for 30 min just before transplanting+ growing of border crop (maize) 30 days before transplanting the main crop and spraying of lambda cyhalothrin 5EC @ 25 g a.i./ ha starting from 20 days after transplanting (4 sprays); M5= Releases of *Trichogramma chilonis* 6 times @ 1 lakh/ ha/ week at 10 days interval+ spraying of *Beauveria bassiana* @ 2ml/ l at 15 days interval starting from 20 days after transplanting (4 sprays)+ application of spinosad 45SC @ 45 g a.i./ ha starting from 20 days after transplanting (4 sprays)+ installation of yellow sticky traps @ 25 traps/ ha at the time of transplanting; and M6= Untreated control.

During the study, 19 pest species viz., *A. gossypii*, *M. persicae*, *B. tabaci*, *Bactrocera latifrons*, *Scirtothrips dorsalis* and *Polyphagotarsonemus latus*, *Gryllotalpa africana*, *Cofana* sp., *Empoasca* sp., *Amrasca biguttula biguttula*, *Sogatella* sp., *Coccus* sp., *Phenacoccus* sp., *Monolepta signata*, *Spodoptera litura*, *Orvasca* sp., *Agrotis ipsilon*, *Blattella* sp. and *Tetranychus* sp. were observed; however, the incidence of most of these were negligible except the sucking pests, coccinellid beetle and spiders. Therefore these ones were considered for the study. The incidence of insect pests and their natural enemies were recorded from nursery to harvesting at fortnightly interval starting from February's 1st fortnight. For recording the sucking insect pests (aphids and whiteflies), five plants were randomly selected/ plot. The number of insects was recorded from each plant from the top, middle and bottom canopy using a magnifying lens and expressed in numbers/ leaf. The larger ones like e coccinellids and spiders were recorded by counting their number on five plants selected randomly/ plot. The % disease incidence was also calculated by counting the number of infected plants. The Benefit**:** Cost ratio was calculated using the pooled data (2014-16), considering the cost of production and the benefit obtained from each module's yield. The ratio then was estimated over the net return. Net return was calculated by subtracting the total cost of production from the total return. For obtaining the total return, the wholesale price of king chilli (Rs. 250/ kg) was used. The data were subjected to ANOVA using SPSS 16v. The differences between treatments were ascertained by Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

The results of the pooled data (2014-16) reveal that the modules M_2- Seedling root dip treatment with imidacloprid 17.8SL @ 40 g a.i./ ha for 30 min just before transplanting+ growing of border crop (okra) 30 days before transplanting the main crop and spraying of imidacloprid 17.8SL @ 40g a.i./ ha at 20 days after transplanting at 15 days interval (4 sprays) and M_4- Seedling root dip treatment with imidacloprid 17.8SL @ 40 g a.i./ ha for 30 min just before transplanting+ growing of border crop (maize) 30 days before transplanting the main crop and spraying of lambda cyhalothrin 5EC @ 25 g a.i./ ha starting from 20 days after transplanting (4 sprays) were found to be the most effective against aphids and whitefly. However, these modules reveal a negative effect on the coccinellids and spiders. The module M_2 was observed to lead to the least number of aphids (0.15/ leaf) followed by M_4 (0.24/ leaf) and both were on par. The least effective module was found to be M_6 with the highest number of aphids (3.07/ leaf) followed by M_5 (1.38/ leaf) Similar trend was also observed with whitefly- M_2 and M_4 led to the least incidence of whitefly (0.04 and 0.11/ leaf respectively) and were on par (Table 1). These results agree with those of Baruah et al. (2016) on seed treatment with imidacloprid @ 0.25/ l, nursery netting and foliar spray with imidacloprid @ 2ml/ l at 15 days interval in *Bhut Jolokia*. Nadaf (2002) also observed that seed treatment and seedling dip with imidacloprid followed by three sprays is effective in transplanted chilli. Chiranjeevi et al. (2002) also found that seedling root dip with imidacloprid followed by foliar spray of imidacloprid at 15 days interval and foliar spraying of lambda-cyhalothrin were found to be very effective against aphids in chilli. Pawar et al. (2016) and Begum et al. (2016) also found that imidacloprid 17.8 SL @ 20g to 50 g a.i./ ha very effective against aphids and whiteflies in okra and brinjal. Similar results were also reported by Patil et al. (2002), Pandey et al. (2010), Varghese and Mathew (2012) and Das (2013).

The predators coccinellid beetles and spiders were

Tables 1. Effect of IPM modules on sucking pests and their natural enemies in king chilli with their cost benefits (2014-16, pooled)

Treatment modules	Aphid (Number leaf^{-1})	Whitefly (Number leaf^{-1})#	Coccinellid beetles (Number plant^{-1})#	Spiders (Number plant^{-1})#	Viral diseaxe incidecne 60 DAT$	Viral diseaxe incidecne 90 DAT$	Viral diseaxe incidecne 120 DAT$	Viral diseaxe incidecne 150 DAT$
M_1	0.70 (1.09)^{b}	0.21 (0.84)^{b}	0.35 (0.92)^{b}	0.38 (0.94)^{c}	3.13^{a} (10.18)	7.29^{ab} (15.66)	12.50^{bc} (20.70)	19.79^{b} (26.41)
M_2	0.15 (0.81)^{a}	0.04 (0.73)^{a}	0.20 (0.83)^{a}	0.23 (0.85)^{b}	1.04^{a} (5.85)	3.13^{a} (10.18)	5.21^{a} (13.19)	7.29^{a} (15.66)
M_3	0.78 (1.13)^{b}	0.31 (0.90)^{c}	0.65 (1.07)^{d}	0.35 (0.92)^{c}	6.25^{b} (14.48)	9.38^{b} (17.83)	16.67^{c} (24.09)	23.96^{b} (29.31)
M_4	0.24 (0.86)^{a}	0.11 (0.78)^{a}	0.25 (0.87)^{a}	0.15 (0.80)^{a}	2.08^{a} (8.29)	4.17^{a} (11.78)	8.33^{ab} (16.78)	11.46^{a} (19.79)
M_5	1.38 (1.37)^{c}	0.38 (0.94)^{c}	0.44 (0.97)^{c}	0.53 (1.01)^{d}	9.38^{c} (17.83)	15.63^{c} (23.28)	25.00^{d} (30.00)	34.38^{c} (35.90)
M_6	3.07 (1.89)^{d}	0.60 (1.05)^{d}	0.92 (1.19)^{e}	0.72 (1.10)^{e}	14.59^{d} (22.45)	30.21^{d} (33.34)	43.75^{e} (41.41)	56.25^{d} (48.59)
S.Ed. (±)	0.14	0.04	0.04	0.02	1.11	1.80	1.96	1.96
$CD_{(0.05)}$	0.37	0.12	0.09	0.06	2.92	4.74	5.14	5.14

Treatment modules	Total cost of cultivation (Rs./ ha)	*Yield (kg/ ha)	Gross returns (Rs./ ha)	Net returns (Rs./ ha)	B:C ratio
M_1	183781	2303.98	575995.00	392214.00	2.13 : 1
M_2	152201	3564.44	891110.00	738909.00	4.85 : 1
M_3	176318	2100.15	525037.50	348719.50	1.98 : 1
M_4	153881	2687.94	671985.00	518104.00	3.37 : 1
M_5	145691	1511.41	377852.50	232161.50	1.59 : 1
M_6	116181	1059.29	264822.50	148641.50	1.28 : 1

M1=Soil solarisation of nursery bed for 15 days followed by application of organic amendment (neem cake) @ 50 g/ m^2 +nylon netting (50 mesh size) of nursery+ clean cultivation (weeding and hoeing) at 15 days interval or as and when necessary and spraying of NSKE @4% at 20 days after transplanting at 15 days interval (4 sprays); M2= Seedling root dip treatment with imidacloprid 17.8SL @ 40 g a.i./ ha for 30 min just before transplanting+ growing of border crop (okra) 30 days before transplanting the main crop and spraying of imidacloprid 17.8SL @ 40g a.i./ ha at 20 days after transplanting at 15 days interval (4 sprays); M3= Seedling root dip treatment with imidacloprid 17.8SL @ 40 g a.i./ ha for 30 min just before transplanting+ growing of border crop (marigold) 30 days before transplanting the main crop+ spraying of emamectin benzoate 5%SG @ 10 g a.i./ ha at 20 days after transplanting at 15 days interval (4 sprays); M4= Seedling root dip treatment with imidacloprid 17.8SL @ 40 g a.i./ ha for 30 min just before transplanting+ growing of border crop (maize) 30 days before transplanting the main crop and spraying of lambda cyhalothrin 5EC @ 25 g a.i./ ha starting from 20 days after transplanting (4 sprays); M5= Releases of *Trichogramma chilonis* 6 times @ 1 lakh/ ha/ week at 10 days interval+ spraying of *Beauveria bassiana* @ 2ml/ l at 15 days interval starting from 20 days after transplanting (4 sprays)+ application of spinosad 45SC @ 45 g a.i./ ha starting from 20 days after transplanting (4 sprays)+ installation of yellow sticky traps @ 25 traps/ ha at the time of transplanting; and M6= Untreated control. *Data are pooled mean; #Figures in the parentheses are √X+0.5 transformed values; $ Figures in the parentheses angular transformed values; In a columns, mean followed by similar letters do not differ statistically by DMRT (p= 0.05); DAT= Days after transplanting; Price of king chilli/ kg Rs. 250

significantly suppressed by the modules with systemic insecticides i.e, M_2 and M_4 led to the least number of coccinellids and spiders due to imidacloprid and lambda cyhalothrin; in these coccinellids (0.20 and 0.25/ plant, respectively) were less, followed by M_1 (0.35/ plant). The module M_4 with lambda cyhalothrin led to the least number of spiders (0.15/ plant) followed by M_2 (imidacloprid as a foliar spray- 0.23/ plant) and significantly differing from each other (Table 1). Maximum number of spiders were observd in M_6- untreated control (0.72/ plant) followed by M_5 (0.53/ plant) and were significantly different. Similar results were obtained by Sechser et al. (2003), Seal et al. (2006) and Khani et al. (2012) with imidacloprid proved to be harmful to coccinellids. Karthikeyan et al. (2008), Fritz et al. (2013) and Rodrigues et al. (2013) observed that spiders were significantly reduced with lambda cyhalothrin was sprayed in rice. Sasikumar and Kumar (2012) also observed that the spiders are reduced with foliar application of lambda cyhalothrin and imidacloprid in sesame crop and Sherawat et al. (2015) with imidacloprid on spiders in Pakistan. The pooled data presented in Table 1 reveals that there was a significant reduction in viral disease incidence in all the treatment modules, ranging from 7.29 to 56.25% at 150 days after transplanting; and among the modules, M_2 was the most effective (7.29 %) followed by M_4 (11.46%) which were on par. These results corroborate with those of Pandey et al. (2010) and Panduranga et al. (2011). Baruah et al. (2016) also observed that seed treatment with imidacloprid @ 0.25/ l + nursery net + foliar spray with imidacloprid @ 2ml/ l at 15 days interval up to 60 days after transplantation was found to be the most effective in reducing the viral disease complex in *Bhut Jolokia*. Raju S.G. (2010) who observed imidacloprid as the most effective minimizing the vector of chilli leaf curl virus as well as disease incidence in chilli. The insecticidal treatment modules

had significant effect not only in reducing the aphids and whitefly pests, and viral diseases, but also increased the yield- maximum yield was obtained in module M_2 (3564.44 kg/ ha). The Benefit: Cost ratio was also more in module M_2 (4.85: 1). Similar results were obtained by Baruah (2014) and Begam (2015) in hot chilli from Assam.

ACKNOWLEDGEMENTS

The authors thank Dr L K Hazarika, Retd Professor and Head, Department of Entomology and Mr S N Phukan, Asst Professor, Department of Agricultural Statistics, Assam Agricultural University, Jorhat for their precious advice, encouragement and help.

REFERENCES

Baruah B R. 2014. Transmission and integrated management of viral disease complex of *Bhut Jolokia*. M Sc (Agri) Thesis, Assam Agricultural University, Jorhat, India.

Baruah B R, Kashyap A, Nath P D. 2016. Incidence, detection and integrated management of viral disease complex in Bhut Jolokia, a chilli cultivar in Assam. Annals of Plant Protection Sciences 24(1): 136-141.

Baruah S, Zaman Md K, Rajbongshi P, Das S. 2014. A review on recent researches on *Bhut Jolokia* and pharmacological activity of capsaicin. International Journal of Pharmaceutical Sciences Review and Research 24(2): 89-94.

Begam N. 2015. Incidence and management of insect pests of hot chilli, *Capsicum chinense* Jacq. M Sc (Agri) Thesis, Assam Agricultural University, Jorhat, India.

Begam N, Saikia D K, Borkakati R N. 2016. Seasonal incidence of major insect pests and their natural enemies of *Bhut Jolokia*. Annals of Plant Protection Sciences 24(2): 259-264.

Begum K R, Patil S, Mohite P. 2016. Evaluation of newer molecules of insecticides against sucking pest complex infesting okra. Indian Journal of Applied Research 6(2): 30-34.

Buragohain P, Saikia D K, Borkakati R N, Dutta B C, Thangjam R. 2017. Pest complex and the population dynamics of major pests of *Bhoot jolokia.* Ecology, Environment and Conservation 23(3): 265-272.

Chiranjeevi C H, Reddy I P, Neeraja G, Narayanamma M. 2002. Management of sucking pests in chilli (*Capsicum annuum* L.). Vegetable Science 29(2): 197.

Das G. 2013. Efficacy of Imidacloprid, a nicotinoid group of insecticide against the infestation of chilli aphid, *Myzus Persicae* (Hemiptera: Aphididae). International Journal of Biological Sciences 2(11): 154-159.

Fritz L L, Heinrichs E A, Machado V, Andreis T F, Pandolfo M, de Salles S M, de Oliveira J V, Fiuza L M. 2013. Impact of lambda-cyhalothrin on arthropod natural enemy populations in irrigated rice fields in southern Brazil. International Journal of Tropical Insect Science 33(3): 178-187.

Karthikeyan K, Jacob S, Purushothman S M, Revi S. 2008. Effect of spinosad against major insect pests and natural enemies in rice ecosystem. Journal of BioIogical Control 22(2): 315-320.

Khani A, Ahmadi F, Ghadamyari M. 2012. Side effects of Imidacloprid and Abamectin on the mealybug destroyer, *Cryptolaemus montrouzieri.* Trakia Journal of Sciences 10(3): 30-35.

Nadaf A M. 2002. Testing of IPM modules for the management of *Helicoverpa armigera* Hubner in chilli. M Sc (Agri) Thesis, University of Agricultural Sciences, Dharwad, Karnataka, India.

Pandey S K, Mathur A C, Srivastava M. 2010. Management of leaf curl disease of chilli (*Capsicum annuum* L.). International Journal of Virology 6(4): 246-250.

Pandurange G S, Vijayalakshmi K, Reddy K L. 2011. Evaluation of insecticides for managing of *Bemisia tabaci* and MYMV disease in mung bean. Annals of Plant Protection Sciences 19: 295-298.

Parasar I, Deka N. 2013. Bhut Jolokia: A viable crop to mitigate the effect of climate change. Proceedings. Seminar on climate change and climate resilient agriculture. B N College of Agriculture.18th and 19th March, 2013. p. 143.

Patil A S, Patil P D, Patil R S. 2002. Efficacy of different schedule doses of imidacloprid against sucking pest complex of chilli (*Capsicum annuum* L.). Pestology 26: 31-33.

Pawar S A, Zanwar P R, Lokare S G, Dongarjal R P, Sonkamble M M. 2016. Efficacy of newer insecticides against sucking pests of okra. Indian Journal of Entomology 78(3): 257-259.

Raju S G. 2010. Studies on chilli leaf curl complex disease. Ph D Thesis, University of Agricultural Sciences, Dharwad, Karnataka, India.

Rodrigues E N L, Mendonca Jr M de S, Fritz L L, Heinrichs E A, Fiuza L. 2013. Effect of the insecticide lambda-cyhalothrin on rice spider populations in southern Brazil. Zoologia 30(6): 615-622.

Sasikumar K, Kumar K. 2012. Effect of certain insecticides on spider population in sesame. Journal of Biopesticides 5(2): 135-139.

Seal D R, Ciomperlik M, Richards M L, Klassen W. 2006. Comparative effectiveness of chemical insecticides against the chilli thrips, *Scirtothrips dorsalis* Hood (Thysanoptera: Thripidae), on pepper and their compatibility with natural enemies. Crop Protection 25: 949-955.

Sechser B, Ayoub S, Monuir N. 2003. Selectivity of emamectin benzoate to predators of sucking pests on cotton. Journal of Plant Diseases and Protection 110(2): 184-194.

Sherawat S M, Butt A, Tahir H M. 2015. Effects of pesticides on agrobiont spiders in laboratory and field. Pakistan Journal of Zoology 47(4): 1089-1095.

Talukdar J, Saikia A K, Borah P. 2015. Survey and detection of the diseases of *Bhut Jolokia* (*Capsicum chinense* Jacq.) in Assam. Journal Crop and Weed 11: 186-192.

Thangjam R, Borah R K, Saikia D K. 2017. Pest complex of king chilli, *Capsicum chinense* Jacquin in Assam, Northeast India. The Bioscan 12(4): 2069-2073.

Varghese T N, Mathew T B. 2012. Evaluation of newer insecticides against chilli aphids and their effect on natural enemies. Pest Management in Horticultural Ecosystems 18(1): 114-117.

(Manuscript Received: December, 2020; Revised: March, 2021;
Accepted: March, 2021; Online Published: July, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20420

Indian Journal of Entomology 84 (1): 109-111 (2022) DoI.: 10.55446/IJE.2021.27

NATURAL ENEMIES OF RICE WHITE STEM BORER *SCIRPOPHAGA FUSCIFLUA* (HAMPSON) IN HIMACHAL PRADESH

VIKAS TANDON* AND AJAI SRIVASTAVA[1]

Department of Entomology; [1]Rice and Wheat Research Centre, Malan 176047, Himachal Pradesh, India
CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur 176062, Himachal Pradesh, India
*Email: tandonvikas8763@gmail.com (corresponding author)

ABSTRACT

Fortnightly surveys were made to study natural enemies of white stem borer (WSB) *Scirpophaga fusciflua* (Hampson) in rice. The surveys revealed that the predators of *S. fusciflua* first appeared in the second fortnight of July, with the peak during second fortnight of September during 2016 and 2017; and their relative proportion was- spiders (49.4% and 51.2%), dragonflies (22.2% and 22.6%) and damselflies (28.4% and 26.2%). Four species of parasitoids viz., egg- *Telenomus* sp. and *Tetrastichus* sp., larval- *Stenobracon* sp. and pupal parasitoids- *Xanthopimpla punctata* were observed from egg mass, larvae and pupae collected from Kangra valley of Himachal Pradesh. During 2016 and 2017, the % parasitization was observed to be maximum in the first fortnight of October (53.5 and 62.0%) followed by second fortnight of September (36.4 and 49.1%), respectively.

Key words: *Scirpophaga fusciflua*, rice, predators, parasitoids, Himachal Pradesh, Khangra valley, parasitisation, egg, larval, pupal parasitoids, predators, spiders, odonates

Rice is attacked by a complex set of insect pests, and these have their natural enemies. Amongst these, stem borers are important (Dhaliwal and Arora, 1996), In India, 18 stem borer species belonging to family Pyralidae and three species belonging to family Noctuidae are known (Banerjee, 1964; Kapur, 1967). The predominant are the yellow- *Scirpophaga incertulas* (Walker), striped- *Chilo suppressalis* (Walker) and pink- *Sesamia inferens* (Walker) stem borers. Of these the *S. incertulas* is the most dominant in India (Muralidharan and Pasalu, 2006); while *Scirpophaga fusciflua* Hampson is the predominant borer species in Himachal Pradesh and distributed nearly in all the rice growing areas and recently it was identified (Srivastava et al., 2012). Natural enemies play a major role in maintaining such pests below economic threshold levels; however, their parasitism/ predation efficacy vary with place and time depending on several factors. Many parasitoids and predators in rice ecosystem were observed by Kumar et al. (1997) in Kangra valley of Himachal Pradesh (India). However, the information with respect to natural enemies associated with *S. fusciflua* is lacking from Kangra valley, as it has been only recently found. Keeping these in view, the present study on the natural enemies associated with *S. fusciflua* from the north mid hills of Himachal Pradesh.

MATERIALS AND METHODS

Study was carried out at the Chaudhary Sarwan Kumar Himachal Pradesh Agricultural University (CSK HPAU), Rice and Wheat Research Centre, Malan (Himachal Pradesh) during 2016 and 2017, this lies in Kangra valley (32°07.180 N, 76°25.065 E, 961 masl). The fortnightly surveys of rice fields focused on the abundance of predators were made with observations using sweep; for observations on parasitoids, 10 egg masses were randomly collected from the unsprayed plot at fortnightly interval and brought to the laboratory for the emergence of parasitoids and larvae; egg mass was identified following Srivastava et al. (2012). These egg masses were kept separately in glass vials (10x 5 cm dia) provided with sufficient moisture to prevent desiccation of larvae and leaves. Egg masses were observed daily for number of larvae hatched. In the other hand 50 damaged tillers (dead heart/ white ear) were collected at fortnightly intervals from field and larvae were collected. These oobservations on the parasitoids were made under laboratory conditions (26±1,85-90%RH). Based on the parasitoid emerged from eggs, larvae and pupae the % parasitization was calculated. The data were subjected to statistical analysis with data transformed through CPCS- 1 software as per Gomez and Gomez (1984).

Table 1. Predators and parasites associated with *S. fusciflua* (kharif 2016, 2017)

Year	Predator groups	Adults caught/ 125 sweeps								LSD (P=0.05)	$F_{2,23}$	Relative proportion (%)
		July-I	July-II	Aug-I	Aug-II	Sept-I	Sept-II	Oct-I	Oct-II			
2016	**S**piders	0.0 (0.707)^{f}	0.0 (0.707)^{f}	2.0 (1.559)^{e}	6.0 (2.544)^{c}	10.0 (3.230)^{b}	17.0 (4.179)^{a}	4.0 (2.112)^{d}	1.0 (1.225)^{e}	(0.389)	0.144	49.4
	Damselflies	0.0 (0.707)^{c}	2.0 (1.559)^{b}	4.0 (2.091)^{ab}	6.0 (2.529)^{a}	4.0 (2.112)^{ab}	5.0 (2.318)^{a}	2.0 (1.559)^{b}	0.0 (0.707)^{c}	(0.594)	0.020	28.4
	Dragonflies	0.0 (0.707)^{c}	1.0 (1.225)^{bc}	3.0 (1.814)^{ab}	5.0 (2.327)^{a}	5.0 (2.339)^{a}	3.0 (1.814)^{ab}	1.0 (1.171)^{c}	0.0 (0.707)^{c}	(0.616)	1.075	22.2
	Total	0.0 (0.707)^{f}	3.0 (1.171)^{def}	9.0 (1.858)^{bcd}	17.0 (2.481)^{abc}	19.0 (2.569)^{ab}	25.0 (2.800)^{a}	7.0 (1.642)^{cde}	1.0 (0.880)^{ef}	(0.912)	1.917	100.0
2017	**S**piders	0.0 (0.707)^{f}	1.0 (1.171)^{ef}	3.0 (1.858)^{cd}	5.0 (2.339)^{bc}	11.0 (3.389)^{a}	15.0 (3.932)^{a}	6.0 (2.544)^{b}	2.0 (1.470)^{de}	(0.612)	0.754	51.2
	Damselflies	0.0 (0.707)^{d}	2.0 (1.559)^{c}	3.0 (1.858)^{bc}	7.0 (2.727)^{a}	4.0 (2.084)^{b}	4.0 (2.112)^{b}	2.0 (1.559)^{c}	0.0 (0.707)^{d}	(0.510)	0.893	26.2
	Dragonflies	0.0 (0.707)^{e}	1.0 (1.171)^{de}	2.0 (1.559)^{cd}	5.0 (2.339)^{ab}	6.0 (2.535)^{a}	3.0 (1.858)^{bc}	2.0 (1.470)^{cd}	0.0 (0.707)^{e}	(0.641)	0.731	22.6
	Total	0.0 (0.707)^{e}	4.0 (1.344)^{cde}	8.0 (1.774)^{bcd}	17.0 (2.476)^{ab}	21.0 (2.687)^{a}	22.0 (2.643)^{a}	10.0 (1.904)^{abc}	2.0 (0.998)^{de}	(0.802)	4.327	100.0

Parasitization of *S. fusciflua* egg masses, larvae and pupae

Period	Parasitization (%) 2016					Parasitization (%) 2017				
	Egg parasitoid		Larval parasitoid	Pupal parasitoid	Total parasitization (%)	Egg parasitoid		Larval parasitoid	Pupal parasitoid	Total parasitization (%)
	Telenomus sp.	*Tetrastichus* sp.	*Stenobracon* sp.	*Xanthopimpla punctata*		*Telenomus* sp.	*Tetrastichus* sp.	*Stenobracon* sp.	*Xanthopimpla punctata*	
July-I	0.0 (0.707)d	0.0 (0.707)d	0.0 (0.707)b	0.0 (0.707)b	0.0 (0.707)	0.0 (0.707)c	0.0 (0.707)c	0.0 (0.707)b	0.0 (0.707)c	0.0 (0.707)
July-II	0.0 (0.707)d	0.0 (0.707)d	0.0 (0.707)b	0.0 (0.707)b	0.0 (0.707)	0.0 (0.707)c	0.0 (0.707)c	0.0 (0.707)b	0.0 (0.707)c	0.0 (0.707)
Aug-I	0.0 (0.707)d	0.0 (0.707)d	0.0 (0.707)b	0.0 (0.707)b	0.0 (0.707)	0.0 (0.707)c	3.7 (2.047)b	0.0 (0.707)b	0.0 (0.707)c	3.7 (1.043)
Aug-II	3.8 (2.072)c	4.3 (2.196)c	0.0 (0.707)b	0.0 (0.707)b	8.1 (1.420)	9.1 (3.094)a	0.0 (0.707)c	0.0 (0.707)b	0.0 (0.707)c	9.1 (1.305)
Sept-I	11.5 (3.461)b	8.9 (3.060)b	0.0 (0.707)b	0.0 (0.707)b	20.5 (1.986)	7.4 (2.810)b	11.8 (3.503)a	0.0 (0.707)b	0.0 (0.707)c	19.2 (1.933)
Sept-II	13.6 (3.749)a	22.8 (4.830)a	0.0 (0.707)b	0.0 (0.707)b	36.4 (2.499)	0.0 (0.707)c	0.0 (0.707)c	24.1 (4.963)a	25.0 (5.047)b	49.1 (2.856)
Oct-I	0.0 (0.707)d	0.0 (0.707)d	36.8 (6.111)a	16.7 (4.146)a	53.5 (2.917)	0.0 (0.707)c	0.0 (0.707)c	0.0 (0.707)b	62.0 (8.112)a	62.0 (2.507)
LSD (P=0.05)	(0.235)	(0.132)	(0.110)	(0.085)	(NS)	(0.151)	(0.152)	(0.055)	(0.190)	(NS)
F 2,20	0.323	0.667	1.000	1.000	*F* 3,20 0.249	1.006	1.525	1.000	1.557	*F* 3,20 0.531

I: First fortnight; II: Second fortnight; Mean value within columns bearing same letters not significantly different- LSD (p = 0.05); Figures in parentheses square root transformed values

RESULTS AND DISCUSSION

Three predators viz., spiders, dragonflies and damselflies were found associated with *S. fusciflua*. white stem borer (Table 1); during 2016, of all predators, spiders shared 49.4% of total diversity, and in during 2017 it amounted to 51.2%. These predators first appeared in second fortnight of July (3.0 adults/ 125 sweeps) during 2016 and remained active up to second fortnight of October; maximum numbers of predators recorded was during second fortnight of September (25.0 adults/ 125 sweeps), which was statistically at par with first fortnight of September (19 adults/ 125 sweeps) and second fortnight of August (17 adults/ 125 sweeps); the least numbers of predators observed in first fortnight of July and second fortnight of October (LSD = 0.912, $F_{2.23}$ = 1.917, P = 0.05). Whereas, during 2017, predators were found from second fortnight of July (4.0 adults/ 125 sweeps) to second fortnight of October (2.0 adults/ 125 sweeps) with maximum being 22.0 adults/ 125 sweeps during second fortnight of September. These results corroborate those of Deng and Jin (1985), who observed *Conocephalus* sp. as a predator of rice stem borer which preyed on the egg masses. Bhardwaj and Pawar (1987) enlisted this predator on rice insect pests in Madhya Pradesh.

The emergence of parasitoids during 2016 given in Table 1 reveal four species viz., *Telenomus* sp., *Tetrastichus* sp., *Stenobracon* sp. and *Xanthopimpla punctata*. The parasitization initiated from second fortnight of August and remained until first fortnight of October. During first fortnight of October, maximum parasitization was observed with the larval parasitoid (36.8%) followed by pupal parasitoids *X. punctata* (16.7%) and the total parasitization was 53.5%; during 2017, the parasitization was first observed in first fortnight of August with 3.7% reaching a peak in first fortnight of October (62.0%). The parasitization by *X. punctata* (25.0%) was followed by larval parasitoid (24.1%) in second fortnight of September. Present results corroborate with those of Ganeshwari and Kumar (2019) who found three parasitoids *i.e. Telenomus* sp., *Trichogramma* sp. and *Tetrastichus* sp. with parasitization ranged from 23.70 to 58.84%. Chakraborty (2012), Manju et al. (2002), Kishore et al. (2003) reported that egg masses were parasitized by the *Telenomus beneficiens, Trichogramma japonicum* and *Tetrastichus schoenobii*. Lakshmi et al. (2010) revealed that egg parasitoids played an important role in population regulation of stem borer by parasitizing 95% of the egg masses.

REFERENCES

Banerjee S N. 1964. Paddy pests. Entomology in India. Entomological Society of India. Indian Agricultural Research Institute, New Delhi. pp. 92-97.

Bhardwaj D, Pawar A D. 1987. Predators of rice insect pests in Chhattisgarh region, M.P., India. International Rice Research Newsletter 12(5): 35.

Chakraborty K. 2012. Relative composition of egg parasitoid species of yellow stem borer, *Scirpophaga incertulas* Wlk. in paddy field at Uttar Dinajpur, West Bengal, India. Current Biotica 6: 42-52.

Deng G Y, Jin M X. 1985. Study on a predacious Katydid, *Conocephalus* sp. Chinese Journal of Biological Control 1(4):8-11.

Dhaliwal G S, Arora R. 1996. An estimate of yield losses due to insect pests in Indian Agriculture. Indian Journal of Ecology 23: 70-73.

Ganeshwari, Kumar S. 2019. Studies on relative composition of egg parasitoids of rice yellow stem borer, *Scirpophaga incertulas* (Walker) in kharif 2017. Journal of Pharmacognosy and Phytochemistry 8(3): 4821-4822.

Kapur A P. 1967. Taxonomy of stem borers. Proceedings. Symposium on major insect pests of rice plant. International Rice Research Institute, Philippines. The Johns Hopkins Press, Baltimore, MD, pp.3-43.

Kishore P, Barman A K, Gahukar R T. 2003. Current status of natural enemies with special reference to parasitoids and predators of major stem borers of cereals. Journal of Entomological Research 27(1): 29-70.

Kumar S, Kaul B, Kumar S. 1997. Natural enemies of rice stem borers in Kangra valley of Himachal Pradesh. Journal of Biological Control 11(1-2): 69-71.

Lakshmi V J, Surekha K, Pasalu I C. 2010. Parasitization of rice yellow stem borer, *Scirpophaga incertulas* (Walker) egg masses. Annals of Plant Protection Science 8(2): 366-369.

Manju S, Thangaraju D, David P M. 2002. Egg parasitism in rice yellow stem borer, *Scirpophaga incertulas* (Walker). Indian Journal of Plant Protection 30(1): 91.

Muralidharan K and Pasalu I C. 2006. Assessments of crop losses in rice ecosystems due to stem borer damage (Lepidoptera: Pyralidae). Crop protection 25: 409-417.

Reuolin S J, Soundararajan R P, Sridharan S. 2018. Influence of different stages of rice crop on yellow stem borer, *Scirpophaga incertulas* (Walker) and its egg parasitoids. Journal of Entomology and Zoology Studies 6(2): 804-807.

Srivastava A, Singh P S, Ram L, Salaia R, Singh A. 2012. New record of *Scirpophaga fusciflua* Hampson from North India. Journal of Rice Research 5(1&2): 61-62.

(Manuscript Received: December, 2020; Revised: March, 2021;
Accepted: March, 2021; Online Published: July, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20421

Indian Journal of Entomology 84(1): 112-114 (2022) DoI.: 10.55446/IJE.2021.80

MANAGEMENT OF INSECT PESTS OF BOTTLE GOURD IN POLYHOUSE

Liyaqat Ayoub*, Munazah Yaqoob, Sajad H Mir, Masrat Siraj, Fazil Fayaz Wani[1], Mohmmad Aasif Sheikh, Jameela Rasool, Sheikh Salma Irshad and Audil Gull[2]

Division of Entomology; [1]Division of Pathology; [2]Division of Genetics and Plant breeding, Sher-e-Kashmir University of Agricultural Sciences and Tech. of Kashmir, Shalimar, Srinagar 190019, UT of Kashmir, India
*Email: liyaqatayoub@gmail.com (corresponding author)

ABSTRACT

This study on the insect pests of bottle gourd *Lagenaria siceraria* grown in polyhouse revealed the incidence of whitefly *Trialeurodes vaporariorum* and melon aphid *Aphis gossipii* from 26th to 38th standard week (SW). The peaks in incidence were observed in 34th SW (*T. vaporariorum*- 12.99 ± 1.18/ leaf and *A. gossypii*- 52.5 ± 9.60/ leaf. The incidence of these exhibited a positive correlation with temperature and a negative one with relative humidity. When insecticides were evaluated against these in polyhouse, after two sprays, imidacloprid 17.8SL (0.45 ml) was superior. Imidacloprid 17.8SL (0.3 ml) and dimethoate 30EC (1 ml) provided efficient control.

Key words: *Trialeurodes vaporariorum*, *Aphis gossipii*, bottle gourd, polyhouse, population dynamics, relative humidity, temperature, imidacloprid, neem oil, natural enemies

Bottle gourd is one of the most important crops although considered as a poor man's crop (Milind and Satbir, 2011). It is grown both under open field as well as protected conditions, and its production under polyhouse is gaining importance. Polyhouses are generally considered to be free from pests and diseases, as these act as a physical barrier (Rathee et al., 2018). Various constructional flaws and the use of infested planting material, however, facilitate the entry of pests, and the congenial microclimate is favourable for the multiplication of pests (Kaur et al., 2010. Common and important polyhouse pests of bottle gourd include aphids, thrips, white flies, caterpillars, leaf miners, mealy bugs and mites. Some of these transmit diseases and thus are often more serious (Bessin et al., 1997). This study explores the major insect pests of bottle gourd in polyhouse at the Faculty of Agriculture, Wadura, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (34°20' N, 74° 24' E, 1610 masl)

MATERIALS AND METHODS

Bottle gourd seedlings were raised in polyhouse as per recommended package of practices. Initially, the incidence of whitefly *Trialeurodes vaporariorum* and aphid *Aphis gossipii* were observed on whole plant (Heathcote, 1972) while the basal, middle and terminal leaves were taken as a composite unit in later stage (Satpathy, 1973); *A. gossypii* incidence was observed by taking 10 cm apical portion of the plant (Vashisth et al., 2013). An infrared thermometer (Fluke 59 Max + Esp) and hygrometer (Homesoul) were used in the polyhouse to monitor temperature (°C) and relative humidity (%). Two sprays of insecticides were applied, at peak incidence (1st spray) followed by 2nd spray at 14 days after first. The data on incidence/ leaf and reduction were observed on 1, 3, and 7 days after treatment (DAT), and these were subjected to ANOVA for statistical analysis.

RESULTS AND DISCUSSION

The results revealed that *T. vaporariorum* commenced from 26th standard week (SW)- 0.87 ± 0.81/ leaf reaching a peak- 12.99 ± 1.18/ leaf in 34th SW, then declined to 0.03 ± 0.02/ leaf in 38th SW (Fig. 1). Janu and Dahiya (2017) observed that *Bemisia tabaci* on American cotton started in 24th SW and reached to peak in 34th SW; Sharma et al. (2004) also reported the first appearance in June. Purohit et al. (2006) and Roomi (2014) observed whitefly attaining its peak in August and September. Similarly, *A. gossipii*, commenced from 26th SW- 1.6± 1.20/ leaf, and reached its peak- 52.5± 9.60/ leaf in 34th SW, and then disappeared in 38th SW. (Fig. 1). Thamilarasin (2016) observed maximum incidence of aphids on cow pea under protected conditions from 60-90 days of sowing which in the present study coincides with mid-August. *Trialeurodes vaporariorum* exhibited a positive correlation (0.550294) with temperature (°C)

Table 1. Reduction in incidence of *T. vaporariorum* and *A.gossypii* on bottle gourd with insecticides under polyhouse

Treatment	Conc. (%)	Dosage per water	Pre-count (No/leaf)	Whitefly (*Trialeurodes vaporariorum*) Mortality (%) 1 DAS	1 DAS	7 DAS	Cumulative mean	Pre-count (No/leaf	Mortality (%) 3 DAS	7 DAS	Cumulative mean
Dichlorvos 76 EC	0.076	1	11.00	52.6 (46.50)cd	61.3 (51.54)d	66.5 (54.62)d	60.13	6.4	*50.9 **(45.53)bcd	66.0 (54.30)d	80.7 (63.91)d	65.86
Dimethoate 30 EC	0.030	1	9.67	61.4 (51.61)bc	70.4 (57.06)bc	71.4 (57.68)bc	67.73	4.5	57.2 (49.16)abc	78.3 (62.21)b	93.5 (75.28)bc	76.33
Imidacloprid 17.8 SL	0.008	0.45	10.77	76.2 (60.85)a	79.0 (62.71)a	80.2 (63.57)a	78.46	4.3	63.8 (52.98)a	100.0 (90.00)a	100.0 (90.00)a	87.93
Imidacloprid 17.8 SL	0.005	0.30	11.43	64.1 (53.21)ab	71.8 (57.92)b	73.9 (59.28)b	69.93	5.3	57.9 (49.52)ab	77.7 (61.84)bc	93.9 (75.72)b	76.5
Imidacloprid 17.8 SL	0.002	0.15	11.00	40.4 (39.46)def	44.9 (42.66)f	47.7 (43.08)f	44.33	6.9	20.5 (26.91)fg	35.1 (36.35)fg	70.9 (57.35)g	42.1
Chlorpyriphos 20 EC	0.02	1	11.33	44.9 (42.05)de	53.5 (47.03)e	55.8 (48.33)e	51.4	6.9	36.4 (37.10)e	55.6 (48.21)de	77.7 (61.80)e	56.56
Neem oil	0.03	2	11.77	13.9 (21.35)g	22.7 (28.42)g	28.0 (31.95)g	21.53	11.6	24.4 (29.62)f	35.9 (36.81)f	74.0 (59.36)f	44.76
Control (water)			10.43	7.2 (12.82)h	0.0 (0.07)h	0.9 (4.32)h	2.7	10.4	2.8 (7.01)h	5.9 (10.80)h	6.4 (14.60)h	5.03
C.D. ($p \leq 0.05$)				8.43	1.80	3.40			5.23	7.04	1.21	
Melon aphid (*Aphis gossypii*)												
Dichlorvos 76 EC	0.076	1	34.10	35.5 (36.51)d	60.9 (51.33)d	63.5 (52.87)d	53.3	17.6	*76.5 **(60.97)b	86.4 (68.34)d	86.8 (68.68)d	83.23
Dimethoate 30 EC	0.030	1	34.43	54.1 (47.30)ab	84.6 (66.91)ab	89.5 (71.06)b	76.06	13.1	71.9 (57.99)bcd	93.3 (75.00)b	97.0 (80.03)bc	87.40
Imidacloprid 17.8 SL	0.008	0.45	35.53	60.5 (51.08)a	89.7 (71.27)a	93.9 (75.70)a	81.36	10.1	81.1 (64.19)a	100.0 (90.00)a	100.0 (90.00)a	93.70
Imidacloprid 17.8 SL	0.005	0.30	35.10	50.3 (45.15)bc	83.2 (65.85)bc	86.8 (68.73)bc	73.43	13.3	75.6 (60.41)bc	93.0 (74.70)bc	97.1 (80.23)b	88.56
Imidacloprid 17.8 SL	0.002	0.15	35.33	20.9 (27.08)f	39.8 (39.10)ef	41.9 (40.34)f	34.2	30.4	44.4 (41.79)f	55.9 (48.39)f	76.3 (60.87)ef	58.80
Chlorpyriphos 20 EC	0.02	1	35.53	34.0 (35.62)de	42.8 (40.83)e	47.7 (43.65)e	41.5	29.7	55.2 (47.97)e	75.0 (59.97)e	77.2 (61.47)e	69.13
Neem oil	0.03	2	34.80	10.2 (17.91)g	26.9 (31.16)g	31.2 (33.96)g	22.76	34.7	1.1 (4.77)g	26.3 (30.85)g	45.1 (42.17)g	24.16
Control (water)			33.43	0.3 (1.91)h	0.0 (0.7)h	0.0 (0.7)h	0.1	33.4	0.4 (2.00)h	0.4 (2.00)h	0.0 (0.7)h	0.3
C.D.($p \leq 0.05$)			5.98	3.57	3.51	-		3.52	2.33	1.10		

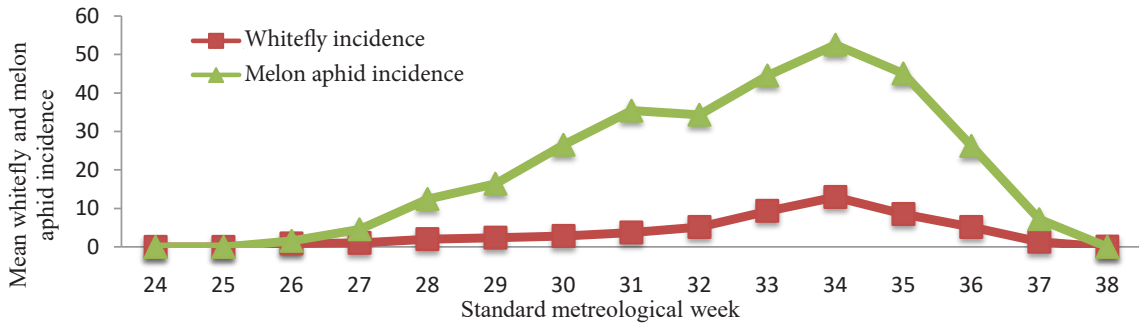


Fig. 1. Incidence of *Trialeurodes vaporariorum* and *Aphis gossypii* on bottle gourd in polyhouse

and a negative correlation (-0.58528) with relative humidity (%). *Aphis gossipii* also revealed a positive correlation (0.625765) with temperature (°C) and negative one (-0.67032) with relative humidity (%). Kharbade et al. (2015) observed a positive correlation of *Polyphagotarsonemus latus* in capsicum with maximum and minimum temperature and negative correlation with relative humidity.

The maximum reduction of 78.46% of *T. vaporariorum* was observed with higher dose of imidacloprid 17.8 SL (0.45 ml) after first spray; after 2nd spray, also there was 87.93% reduction (Table 1); after 2nd spray, cumulative reduction of 87.93% was observed. With *A. gossipii*, 81.36% reduction was observed with higher dose of imidacloprid 17.8 SL (0.45 ml) after first spray; after 2nd spray, it was 93.70% (Table 1). Raghuraman et al. (2008) observed that imidacloprid 17.8 SL was superior in checking whitefly in cotton, and imidacloprid 17.8 SL @ 0.3-0.5ml has been suggested in tomato (Anonymous, 2015). Kar (2017) however, found dimethoate 30EC as more effective against sucking pests of cotton.

REFERENCES

Anonymous. 2015. Major uses of pesticides (Registered under the Insecticides Act, 1968). Government of India, Ministry of Agriculture, Department of Agriculture and Cooperation, Directorate of Plant Protection, Quarantine and Storage. Central Insecticides Board and Registration Committee, Faridabad.

Bessin R, Anderson R G, Townsend L H. 1997. Greenhouse insect management. Cooperative Extension Service. http://entomology.ca.uky.edu/ento60.

Heathcote G C. 1972. Aphid technology. H V Van Emden (ed.). Academic Press, New York. 105 pp.

Janu A, Dahiya K K. 2017. Influence of weather parameters on population of whitefly, *Bemisia tabaci* in American cotton (*Gossypium hirsutum*). Journal of Entomology and Zoology Studies 5(4): 649-654.

Kar A. 2017. Bioefficacy evaluation of imidacloprid 17.8% SL and thiamethoxam against whitefly on tomato and their effect on natural enemies. Journal of Entomology and Zoology Studies 5(3): 1064-1067.

Kaur S, Kaur S, Srinivasan R, Cheema D S, Lal T, Ghai T R, Chandha M L. 2010. Monitoring of major pests on cucumber, sweet pepper and tomato under net-house conditions in Punjab, India. Pest Management in Horticultural Ecosystems 16(2): 148-155.

Kharbade S B, Tamboli N D, Chormule A J. 2015. Population dynamics and management of capsicum mite, *Polyphagotarsonemus latus* Bank. Annals of Plant Protection Sciences 23(2): 257-260.

Milind P, Satbir K. 2011. Is bottle gourd a natural guard? International Research Journal of Pharmacy 2(6): 13-17.

Purohit D, Ameta O P, Sarangdevot, S.S. 2006. Seasonal incidence of major insect pests of cotton and their natural enemies. Pestology 30 (12): 24- 29.

Raghuraman M, Birth, Ajantha, Gupta G P. 2008. Bioefficacy of acetamiprid against sucking pests in cotton. Indian Journal of Entomology 70(4): 319-325.

Rathee M, Singh N V, Dalal P K, Mehra S. 2018. Integrated pest management under protected cultivation: A review. Journal of Entomology and Zoology Studies 6(2): 1201-1208.

Roomi. 2014. Population dynamics of different insect pests and arthropods natural enemies on various Bt. cotton gene events, M Sc Thesis, CCS Haryana Agricultural University, Hisar.

Satpathy J M. 1973. Evaluation of soil treatments with granular insecticides for control of aphids on brinjal. Journal of Research Odisha University of Agriculture and Technology 3: 57-62.

Sharma P D, Jat K L, Takar B L. 2004. Population dynamics of insect pests of American cotton (*Gossypium hirsutum* L.) in Haryana. Journal of Cotton Research and Development 18: 104-106.

Thamilarasi N. 2016. Management of pests of cowpea and salad cucumber in polyhouse. MSc Thesis, Kerala Agricultural University, Vellayani, Thiruvananthapuram.

Vashisth S, Chandel Y S, Kumar S. 2013. Observations on insect-pest problems of polyhouse crops in Himachal Pradesh. Journal of Entomological Research Society 37 (3): 253-258.

(Manuscript Received: December, 2020; Revised: March, 2021;
Accepted: March, 2021; Online Published: November, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20422

Indian Journal of Entomology 84(1): 115-118 (2022) DoI.: 10.55446/IJE.2021.31

EFFECT OF SHOOT NUMBER, DIAMETER AND LAC ENCRUSTATION THICKNESS ON KUSMI BROODLAC YIELD OF *KERRIA LACCA* FROM *FLEMINGIA SEMIALATA*

L Chanu Langlentombi, N N Rajgopal* and Soumen Ghosal

ICAR-Indian Institute of Natural Resins and Gums, Ranchi 834010, Jharkhand, India
*Email: raju924rg@gmail.com (corresponding author)

ABSTRACT

This study aims to identify the significant factors affecting kusmi broodlac yield and the relationship between the broodlac yield and the relevant factors for providing the practical basis of maximizing this yield. The regression analysis between the yield and independent variables revealed that the major factors influencing yield include encrustation thickness followed by shoot diameter in a significantly positive relationship. The yield was increasing up to 12 shoots/ plant and started declining after this.

Key words: *Kerria lacca*, kusmi, aghani, *Flemingia semialata*, host plant, broodlac, yield, regression, multicollinearity test, shoots/ diameter, encrustation thickness, positive relationship, 12 shoots/ plant

Lac insects constitute a family, the Tachardiidae (=Kerriidae) (Varshney, 1999; Ben-Dov and Lit, 1998), of morphologically distinctive scale insects that produce resinous secretion which thrives on > 400 tree species (Sharma, 2017). *Kerria lacca* (Kerr) is the most commonly cultivated lac insect in India, with kusmi and rangeeni strains (Kapur, 1962; Ramani, 2005). Kusum (*Schleichera oleosa* Oken), palas (*Butea monosperma* Lam.), ber (*Ziziphus mauritiana* Lam.) and bushy host semialata (*Flemingia semialata* Roxb.) are the commercial lac hosts (Sharma, 2017). In India, the central lac producing states are Jharkhand, Chhattisgarh, Madhya Pradesh, West Bengal, and Maharashtra and Odisha, contributing >90% (Meena et al., 2019; Yogi et al., 2017), and plays crucial role in maintaining the sustainable livelihood of the forest and subforest dwellers (Yogi et al., 2017). Semialata, one of the promising host plant species for lac cultivation, gives an economically fair yield of lac (Srivastava et al., 2002). It is shrubby, leguminous, fast-growing, short height, highly responsive to coppicing with ratooning property and can inoculate lac after one year of plantation (Kumar et al., 2015). The kusmi strain that is superior in quality can be inoculated in semialata for summer (jethwi) and winter (aghani) crop. Due to such propitious traits, farmers widely accept cultivating this plant in their farmland for lac production. With high market demand for lac in other countries, increase in productivity of lac is a crucial need. Broodlac, the lac sticks with mature gravid female insects, ready to give rise next generation by crawler emergence, can be influenced by several factors, such as encrustation thickness, shoot diameter, settlement density, length of shoots etc. Encrustation thickness is directly related to high resin productivity and crawler emergence from the unit brood, and hence it is a good indicator of broodlac yield. In lac yield, shoot diameter and number of shoots play an essential role in governing lac yield (Ghosal and Mishra, 2009; Ghosh et al., 2018). This study analyzes the relationship between number of shoots, shoot diameter and encrustation thickness with broodlac yield. Also, explores the major factors influencing broodlac yield.

MATERIALS AND METHODS

The experiment was conducted at the Institute Research Farm, ICAR-Indian Institute of Natural resins and Gums in March 2020. The data was recorded from 67 randomly selected plants with shoots varying from 1-24/ plant at the harvesting time of the aghani crop (kusmi winter crop). The observations like shoot diameter and encrustation thickness were recorded, along with encrustation diameter covering shoot. Measurement was taken at the middle of the lac encrustation length and for shoot diameter, measurement was taken at both the ends of the encrustation length where lac was not present using a digital Vernier caliper. The formula- encrustation thickness = (encrustation diameter covering shoot- shoot diameter)/ 2 for each shoot was used and averaged. The variables analysed include- broodlac yield (g)/ shoot as dependent variable (y) and three independent variables i.e., x_1= no. of shoots/ plant, x_2= mean encrustation thickness (mm)/ shoot, and x_3= shoot diameter (mm)/ shoot. Statistical analysis was performed using SPSS 25 and R Studio. The relationships were evaluated using

bivariate and multivariate regression analysis and Pearson correlation coefficients and a two-tailed test of significance (α= 0.05). In addition, a multicollinearity test among the independent variables was performed, and pairwise comparisons and variance inflation factor (VIF) test were made for all the variables to predict a situation where two or more variables are highly linearly correlated. To find the optimum number of shoots to be retained for enhancing yield, a polynomial function curve was developed between the broodlac yield (g)/ shoot and no. of shoots/ plant.

RESULTS AND DISCUSSION

The data given in Table 1 reveal that no. number of shoots/ plant, encrustation thickness (mm)/ shoot, shoot diameter (mm)/ shoot and broodlac yield (g)/ shoot (n=67) were 8.12± 0.60, 4.15± 0.13, 12.80± 0.23 and 105.69± 5.12, respectively; of these 25% (Q_1) yield of broodlac was laid below 79.1 (g)/ shoot; and in addition, 75% (Q_3) of observations for shoot diameter was laid down from ≤14.3 mm/ shoot. The correlation coefficients reveal that the correlation between the independent variable is ≤±50% (Fig. 1- positive correlations in blue and negative in red; colour intensity and the size of circles being proportional to the correlation coefficients). The VIF value for the number of shoots/ plant, encrustation thickness (mm)/ shoot and shoot diameter (mm)/ shoot were 1.08, 1.20 and 1.29, respectively; however, since the VIF values are <10, there is no collinearity effect. The simple linear regression analysis of broodlac yield (g)/ shoot reveals that no. of shoots and shoot thickness are significantly correlated, while encrustation thickness is not significantly correlated (α= 0.05) (Fig. 2a-c); and Fig. 2d reveals that broodlac yield/ shoot increases till 12 shoots and declines thereafter. The multiple

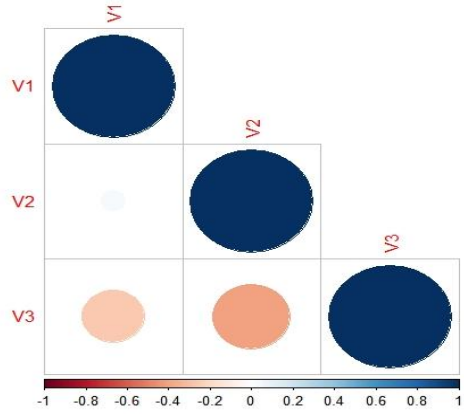


Fig. 1. Correlation coefficients- no. of shoots/ plant (V_1); encrustation thickness (mm)/ shoot (V_2); shoot diameter (mm)/ shoot (V_3)

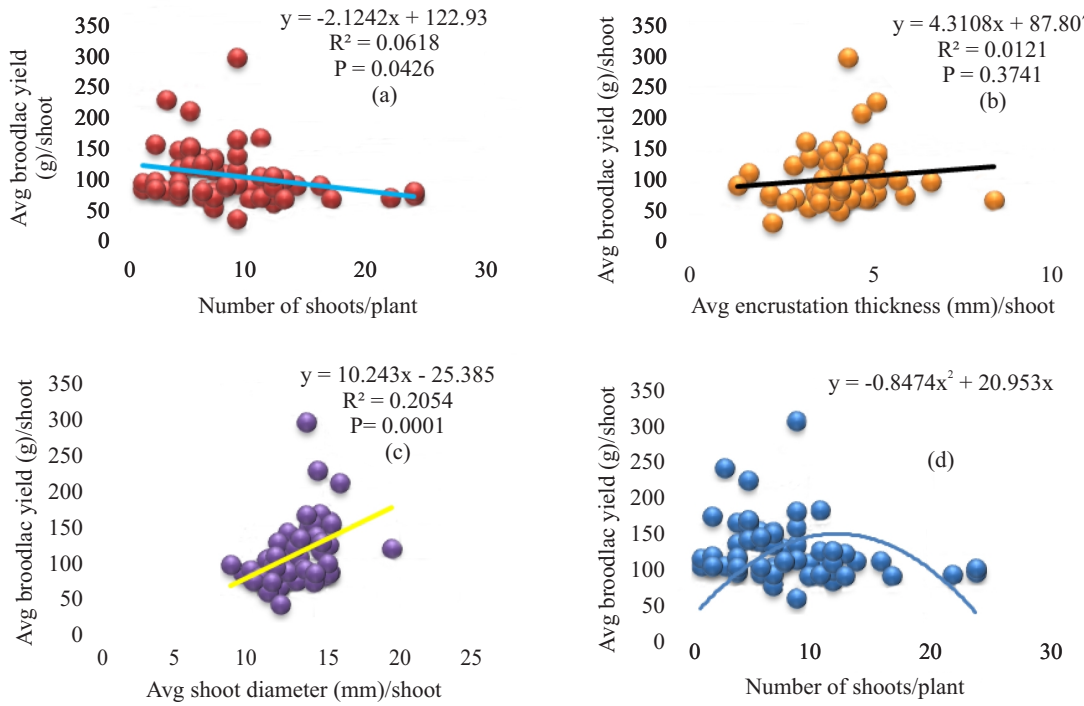


Fig. 2. Simple linear regression of broodlac yield (g)/ shoot- vs no. of shoots/plant (a), encrustation thickness (mm)/ shoot (b), shoot diameter (mm)/ shoot (c); and Polynomial function curve- broodlac yield (g)/shoot vs. no. of shoots/ plant (d)

linear regression analysis reveals that encrustation thickness and shoot diameter exhibit a significant effect on the broodlac yield; and no. of shoots with significant effect (α= 0.05), and there exists a positive relationship between broodlac yield and encrustation thickness and shoot diameter; 95% confidence interval for encrustation thickness and thickness of shoot were 4.80, 22.63 and 7.29, 17.54, respectively. The negative value of intercept indicates that the expected value of broodlac yield is <0 when all independent variables were set to 0. The most important factors affecting broodlac yield was encrustation thickness, as it has a high coefficient followed by shoot diameter. The results also reveal that 28.7% of the broodlac yield gets explained by the variation of encrustation thickness and the shoot diameter the estimated equation will be thus- broodlac yield = -103.76-0.98 No. of shoots/plant + 13.36 encrustation thickness (mm)/ shoot + 12.65 shoot diameter (mm)/ shoot (Table 1).

Thus, the effective way to increase the broodlac yield will be by shoot diameter, ultimately increasing encrustation thickness, with maintaining number of shoots/ plant up to 12 shoots. Sticklac weight/ bush increased significantly with increase in shoots/ bush up to 9 shoots of F. semialata (Anon., 2002). The present results corroborate with those of Ghosal et al. (2011), that thickness of broodlac encrustation is the most important factor governing the settlement of lac insect, followed by phunki (empty broodlac) scrap weight and weighted living cell weight in kusum tree. With the maturity of lac insect, the cell size of insect and resin content increases (Meena et al., 2019), leading to an increase in encrustation thickness, which maximizes lac production and, ultimately, the crawler emergence also increases. Larger shoot diameter provided more surface area for insect settlement, thus increasing lac productivity/ unit area. Ghosh et al. (2018) observed that the length and width of new shoots of palas had significant and positive correlation with kusmi broodlac yield ratio (0.67 and 0.50, respectively).

ACKNOWLEDGEMENTS

Authors thank the Director, ICAR-IINRG, Ranchi for his continuous encouragement and providing funds and facilities. All technical personnel who helped to record the field data are acknowedged.

REFERENCES

Anonymous. 2002. Annual Report. Indian Lac Research Institute, Ranchi. pp. 18-19.

Ben-Dov Y, Lit I L. 1998. Stabilizing Kerriidae as the family-group name of the lac insects (Hem., Coccoidea). Bulletin de la Societe Entomologique de France 103(5): 455-456.

Ghosal S, Mishra Y D. 2009. Canopy structure of ber (*Zizyphus mauritiana*) trees influencing lac yield. Environment and Ecology 27(4A): 1879-1881.

Ghosal S, Ramani R, Mishra Y D. 2011. Influence of thickness of branch, phunki scrap weight, weighted living cell and *kusmi* encrustation thickness on broodlac quality. Annals of Entomology 29(1):1-5.

Ghosh J, Lohot V D, Ghosal S. Singhal V, Thamilarasi K. 2018. Pruning for tree vigour and lac productivity of Palas variant Swadi (*Butea monosperma*) in Chhotanagpur Plateau of Jharkhand. Journal of Pharmacognosy and Phytochemistry SP1: 1714-1717.

Kapur A P. 1962. The lac insect. A monograph on lac. Mukhopadhyay

Table 1. Descriptive statistics, multiple linear regression [Broodlac yield vs. no. of shoot/ plant, encrustation thickness (mm)/ shoot and shoot diameter (mm)/ shoot]

Variables	N	Min	Max	Mean	Std. error	Std. Dev	Q_1	Q_3
No. of shoots/ plant	67	1.00	24.00	8.12	0.60	4.91	5	11
Encrustation thickness (mm)/ shoot	67	1.31	8.34	4.15	0.13	1.07	3.6	4.6
Shoot diameter (mm)/ shoot	67	8.54	19.44	12.80	0.23	1.86	11.4	14.3
Broodlac yield (g)/ shoot	67	36.20	294.67	105.69	5.12	41.94	79.1	126.6

Variables	Coefficients (b)	Std. error	t_{cal} value	P value	95.0% CI for b
Intercept	-103.76	47.48	-2.18	0.033	(-198.64, -8.88)
Number of shoots/ plant	-0.98	0.92	-1.05	0.294	(-2.82, 0.86)
Avg. encrustation thickness (mm)/ shoot	13.36	4.46	2.99	0.004	(4.80, 22.63)
Avg. shoot diameter (mm)/ shoot	12.65	2.57	4.75	0.000	(7.29, 17.54)

Model 1	R	R square	Adj. R square	F_{cal} value	P value
	0.566	0.320	0.287	9.876	0.000

Dependent Variable: broodlac yield (g)/shoot; CI: Confidence Interval

B, M S Muthana (eds.). Indian Lac Research Institute, Ranchi. pp. 59-89.

Kumar A, Jaiswal A K, Singh A K, Yogi R K (eds.). 2015. Advances in lac production, processing, product development and value addition. ICAR-IINRG, Ranchi. 206 pp.

Meena S C, Sharma K K, Rana B S, Swami H, Lekha, Thamilarashi K. 2019. Study of productivity linked parameters of lac insect, *Kerria lacca* (Kerr) on *Flemingia macrophylla*. Journal of Entomology and Zoology Studies **7**(3): 505-509.

Ramani R. 2005. Genetics of lac insects. Gleanings in Entomology, Ramamurty V V, Singh V S, Gupta G P, Paul A V N (eds.). IARI, New Delhi. pp. 266-280.

Sharma K K. 2017. Lac insects and host plants. Industrial Entomology. Springer, Singapore. pp. 157-180.

Srivastava S C, Mishra Y D, Kumar P, Sharma K K, Ramani R, Yadav S K. 2002. Genetic variation in lac-productivity linked attributes and character correlation of *Flemingia* spp. (Papilionaceae). Legume Research-An International Journal 25(3): 188-191.

Varshney R K. 1999. Tachardiidae versus Kerriidae as family name of the lac insects (Hemiptera: Coccoidea). Bionotes 1(3): 61-62.

Yogi R K, Jaiswal A K, Sharma K K. 2017. Commercial utility of ber (*Ziziphus mauritiana*): A mean for livelihood security. Fruits for livelihood: production technology and management practices. Dutta A K, Mondal B (eds.). Agrobios (India), Jodhpur. pp. 453-472.

(Manuscript Received: January, 2021; Revised: April, 2021;
Accepted: April, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21001

Indian Journal of Entomology 84 (1): 119-121 (2022) DoI.: 10.55446/IJE.2021.32

RECENT REPORT OF ZYGOPTERAN *ISHNURA RUFOSTIGMA RUFOSTIGMA* SELYS FROM UTTARAKHAND

C Susanth Kumar[1], S S Anooj* and B S Arya Meher[1]

Department of Agricultural Entomology, College of Agriculture,
Kerala Agricultural University, Padannakkad, Kasaragod 671314, Kerala, India
[1]Warblers and Waders, Prakriti, SNRA-20, Souhruda Nagar,
Indira Nagar, Peroorkada P. O, Thiruvananthapuram 695005, Kerala, India
*Email: anooj227@gmail.com (corresponding author)

ABSTRACT

Ruby dartlet *Ishnura rufostigma rufostigma* (Selys 1876) (Zygoptera: Coenagrionidae) occurs in Central and East India and Nepal. The earlier records of this species are from Assam, Madhya Pradesh, Manipur, Bihar, Meghalaya, Nagaland and West Bengal. This study documents it from Bhimtal, Nainital district, Uttarakhand and it is a recent record for the species from the region after forty years.

Key words: Ruby dartlet, *Ishnura rufostigma rufostigma,* Western Himalaya, Coenagrionidae, Bhimtal, Uttarakhand, species diagnosis

The order Odonata includes 6212 species globally (Schorr and Paulson, 2020). A total of 588 species of Odonata are reported occurring in Bangladesh, Bhutan, India (including Andaman and Nicobar Islands), Nepal, Pakistan and Sri Lanka (Kalkaman, et al., 2020). Subramanian and Babu (2017) enlisted 488 species and 27 subspecies in 154 genera and 18 families in their checklist of Odonata of India. The species distribution of high altitude Odonata especially in ecologically fragile regions like the Himalaya in general has not been explored. Few genera with closely resembling species and polymorphism, in particular, require focused study. *Ishnura* Charpentier is such a genus, with about nine species and subspecies reported from India (Kalkaman et al., 2020). They are small sized and slender build, body rather more robust and abdomen rather shorter than in the genus *Ceriagrion* Selys; colour non-metallic, usually bright reddish-orange marked more or less with black, or blue or green marked with black; females polychromatic but isochromatic in *Ishnura rufostigma* Selys (Fraser, 1933).

Out of various species groups present in the genus; the *Ishnura rufostigma* group consist of four taxa *viz*. *I. rufostigma* Selys, *I. annandalei* Laidlaw, *I. mildredae* Fraser and *I. carpentieri* Fraser differentiated from each other by the pattern on the abdomen and by the shape of anal appendages (Vick, 1986). *Ishnura inarmata* Calvert from Kashmir which was initially included in the species group was considered as a distinct species (Asahina, 1991; Vick, 1986). Further, Asahina (1991), considered *I. carpentieri* Fraser and *I. mildredae* Fraser as synonyms to *I. annandalei* Laidlaw and suggested two subspecies of *I. rufostigma* Selys viz. *I. rufostigma rufostigma* Selys from Central and East India and Nepal, with males without black dorsally on second abdominal segment (S2) and seventh abdominal segment (S7), and *I. rufostigma annandalei* Laidlaw from East India, Myanmar, Thailand, Laos, South China and Vietnam with black dorsally on S2 and S7. Sanmartin-Villar et al. (2016) who studied in detail the polymorphism in *I. rufostigma* Selys refuted this considering *I. rufostigma rufostigma* Selys and *I. rufostigma annandalei* Laidlaw as separate subspecies based on the blue spot on eighth abdominal segment (S8). However, he had not disagreed on considering them as two subspecies based on other abdominal patterns. The recent checklist of dragonflies and damselflies of Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka also shows *I. rufostigma* Selys as consisting of two subspecies *I. rufostigma rufostigma* Selys and *I. rufostigma annandalei* Laidlaw (Kalkaman et al., 2020). The above complexes make *Ishnura* Charpentier an interesting one especially in unravelling its distribution, in the lesser studied higher altitudes of Himalaya. Keeping this in mind a study was undertaken in the vicinity of an undisturbed forest patch in Bhimtal, Nainital district to find out new distribution records to the state of Uttarakhand.

MATERIALS AND METHODS

The study was done on 17th and 18th September 2015 at the Butterfly Research Centre (BRC), Bhimtal,

Uttarakhand during the first Annual Butterfly Meet, Bhimtal 2015, organised by BRC, Bhimtal. Bhimtal (29.35°N 79.5667°E) is a town and Nagar panchayat in Nainital district in the state of Uttarakhand, India situated at 1370 masl. BRC situated 2 km (approx.) from Bhimtal Lake, is surrounded with pine forests, hillocks and meadows and is at the foothills of Himalayas. The study area was in the vicinity of an undisturbed forest patch adjoining the BRC. Field surveys were done in morning between 8.00 and 10.00 hr, focusing on slow flying smaller damselflies which prefers low perches like short grasses and shrubs. Field photographs were captured using Canon EOS 550D DSLR camera mounted with Canon EOS 75-300mm USM Zoom lens. The species identity was established following description by Fraser (1933), Vick (1986) and Sanmartin-Villar et al. (2016). The subspecies identity was confirmed based on Asahina (1991) and Mitra and Babu (2010).

RESULTS AND DISCUSSION

The survey resulted in the recent confirmed report of *I. rufostigma rufostigma* Selys from Uttarakhand after 40 years. On 17th September 2015, 8.30 hr a single male damselfly belonging to genus *Ishnura* Charpentier was seen perching on a small shrub (Fig. 1a) in the lawn in front of Butterfly Research Centre. On 18th September 2015 morning 9.50 hr in the same spot a similar male individual was again observed resting on a grass (Fig.1b). Based on the key characters furnished by Fraser (1933) viz. ornage-red ground colour and black colouration of abdominal segments 8-10 the species identity was confirmed as *I. rufostigma* Selys. Labrum pale blue without any black base, postclypeus glossy steely black, beneath of head bluish, shallow posterior lobe of thorax, antehumeral stripes pale blue; laterally pale blue, pale yellow beneath; a minute black spot on upper part of postero-lateral suture. Legs pale yellow with black spines. The pterostigma of the forewing very narrow, elongated diamond shaped, its outer angle very acute, bright brick red; the pterostigma of hind wing much smaller but the same shape dirty yellow. Arc distinctly distal to the level of outer antenodal nervure. Abdomen bright reddish-orange, with a quadrate dorso-basal black spot on first segment, and broadly black on dorsum of segments 8 to 10, the intervening segments unmarked. Anal appendages ochreous, the inferiors tipped with black and about half the length of segment; superiors very short, rounded, deeply excavate on the inner under-sides, ending in a robust spine directed in and slightly down (Fraser, 1933).

Asahina (1991) suggested two subspecies of *I. rufostigma* Selys i.e. *I. rufostigma rufostigma* Selys from Central and East India and Nepal, with males without black dorsally on second abdominal segment (S2) and seventh abdominal segment (S7), and *I. rufostigma annandalei* Laidlaw from East India, Myanmar, Thailand, Laos, South China and Vietnam with black dorsally on S2 and S7. The subspecies level identity of the specimen found from BRC was confirmed as *I. rufostigma rufostigma* Selys based on key characters furnished by Asahina (1991) and Mitra and Babu (2010) *viz.* brick red pterostigma of forewing and absence of black dorsally on S2 and S7 (Fig.1 a, b).These two characters differentiated it from the closest subspecies *I. rufostigma annandalei* Laidlaw. Also the anal appendages of *I. rufostigma rufostigma* Selys are slightly robust and inferiors are longer as compared to that of *I. rufostigma annandalei* Laidlaw.

Mitra and Babu (2010) had furnished distribution of *I. rufostigma rufostigma* Selys from India as from Assam, Madhya Pradesh, Manipur, Bihar, Meghalaya, Nagaland, West Bengal. The check list presented by Prasad and Varshney (1995) also furnishes the distribution of *I. rufostigma rufostigma* Selys as

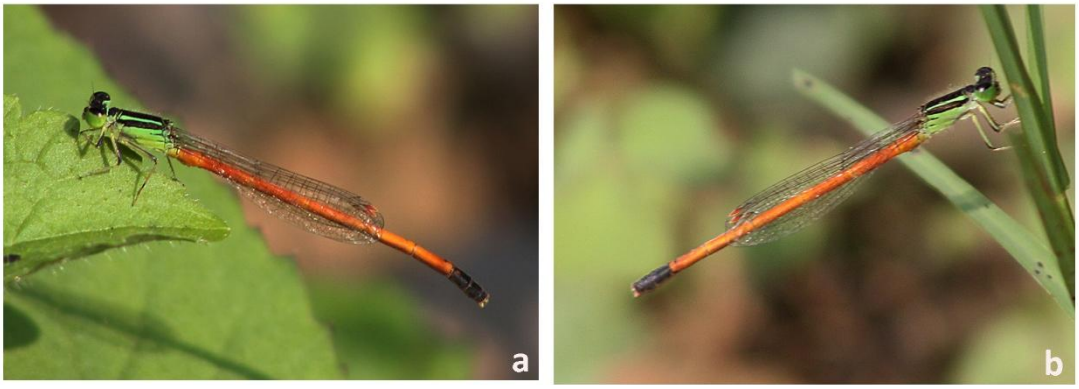


Fig. 1a, b: male *Ishnura rufostigma rufostigma* (Butterfly Research Centre, Bhimtal, Uttarakhand)

Assam, Bihar, Madhya Pradesh, Manipur, Meghalaya, West Bengal and Western Himalayas; and does not specify the presence in Uttarakhand part of Western Himalayas. Only the range assigned by Asahina (1991) i.e. Central and East India and Nepal, is being considered in the recent checklist of dragonflies and damselflies of Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka by Kalkaman et al. (2020). Prasad and Mondal (2010) records four species/ subspecies of *Ishneura* from the Uttarakhand which includes *I. rufostigma rufostigma* Selys. This report of *I. rufostigma rufostigma* Selys by Prasad and Mondal (2010) is based on a study by Kumar and Prasad (1981) wherein they have mentioned it as *I. rufostigma* Selys reported from Nainital; which is the latest known report of the subspecies from Uttarakhand.

Thus the present sighting of *I. rufostigma rufostigma* Selys from the premises of BRC, Bhimtal, Uttarkhand is the recent record of this species from Uttarakhand state, nearly after forty years. Uttarakhand is bestowed with many high altitude lakes, streams, pine forests, hillocks and meadows which are ideal habitats for many rare odonates. Their status in these ecosystems are indicators of the level of purity and health of aquatic ecosystems. Hence there need to be further surveys in the Western Himalayan region and also the Eastern India (where both the subspecies coexist) of this particular odonate species and their subspecies to get a complete picture of the distribution status.

ACKNOWLEDGEMENTS

The authors thank Mr Peter Smetacek, Director, Butterfly Research Centre, Bhimtal for providing facilities and field support. Dr R K Varshney, Ex-Additional Director, Zoological Survey of India, Kolkata and Dr J R B Alfred, Ex-Director, Zoological Survey of India, Kolkata are acknowledged for their support; also Dr Abhiram Chandran, Mrs Laina Balan, G Santhosh Kumar and all the members of Warblers and Waders are acknowledged for their field support and encouragement.

REFERENCES

Asahina S. 1991a. A taxonomic revision of the *Ishnura rufostigma* group of Southeast Asia. Tombo 34: 2-22.

Fraser F C. 1933. The fauna of British-India including Ceylon and Burma, Odonata. Vol. I. Taylor and Francis Ltd., London. 436 pp.

Kalkaman V J, Babu R, Bedjantic M, Conniff K, Gyeltshen T, Khan M K, Subramanian K A, Zia A, Orr A G. 2020. Checklist of the dragonflies and damselflies (Insecta: Odonata) of Bangladesh, Bhutan, India, Nepal, Pakistan and Srilanka. Zootaxa 4849 (1): 1-84.

Kumar A, Prasad M. 1981. Field ecology, zoogeography and taxonomy of the Odonata of Western Himalaya, India. Records of Zoological Survey of India, Occasional paper 20: 1-118.

Mitra T R, Babu R. 2010. Revision of Indian species of the families Platycnemididae and Coenagrionidae (Insecta: Odonata: Zygoptera): Taxonomy and zoogeography. Records of Zoological Survey of India, Occasional Paper 315: 1-104.

Prasad M, Mondal S D. 2010. Odonata: Zygoptera; Fauna of Uttarakhand, State Fauna Series 18(2): 17-28. Director, Zoological Survey of India, Kolkata.

Prasad M, Varshney R K. 1995. A checklist of the Odonata of India including Larval Studies. Oriental Insects 29: 385-428.

Sanmartin-Villar I, Whang H M, Cordero-Rivera A. 2016. Colour polymorphism in *Ishnura rufostigma.* Odonotlogica 45(1/2): 77-86.

Schorr M, Paulson D. 2020. World Odonata List. http://www.pugetsound.edu/academics/ academicresources/slater-museum/biodiversity-resources/dragonflies/world-odonata-list2/.

Subramanian K A. 2017. A checklist of Odonata of India. Zoological Survey of India, Kolkata, Version 3.0. www.zsi.gov.in.

Vick G S.1986. A note on the group of species allied to *Ishnura rufostigma* Selys (Zygoptera: Coenagrionidae). Odonatologica 1593: 347-351.

(Manuscript Received: January, 2021; Revised: April, 2021;
Accepted: April, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21005

Indian Journal of Entomology 84(1): 122-125 (2022) DoI.: 10.55446/IJE.2021.332

EFFICACY OF SOIL INSECTICIDES AGAINST SUCKING PESTS OF POTATO

Mohd Abas Shah*, Subhash Katare[1], Anuj Bhatnagar[2], Sanjeev Sharma[3], Murlidhar J Sadawarti[1] and Shiv Pratap Singh[3]

ICAR-Central Potato Research Institute (CPRI)- Regional Station, Jalandhar 144003, Punjab, India
[1]ICAR-CPRI- Regional Station, Gwalior 474020, Madhya Pradesh, India
[2]ICAR-CPRI- Regional Station, Modipuram 250110, Uttar Pradesh, India
[3]ICAR-CPRI, Shimla 171001, Himachal Pradesh, India
*Email: mabas.shah@icar.gov.in (corresponding author)

ABSTRACT

Field experiments were conducted at three locations for two seasons, 2018 to 2020 to evaluate the efficacy of soil insecticides against sucking pests of potato. Lowest cumulative mean number of whiteflies was observed with fipronil 0.3G @ 25 kg/ ha, and it was on par with its dose of 20 kg/ ha, cartap hydrochloride 4G @ 20 and @ 25 kg/ ha; overall reduction in whiteflies over control ranged between 56.70 and 59.04% at Jalandhar; 53.17 to 60.89% at Modipuram, and 57.33 to 62.40% at Gwalior. Similar trends were noted for aphids, leaf hoppers and thrips. Based on tuber yield and benefit cost ratio, cartap hydrochloride 4G @ 20 kg/ ha (2.62) and fipronil 0.3G @ 20 kg/ ha (2.47) were found to be the most effective against the sucking pests of potato. Hence, both these can be recommended in potato in place of phorate 10G.

Key words: Systemic insecticides, *Bemisia tabaci*, *Empoasca* spp., seed potato, cartap hydrochloride, fipronil, phorate, granular formulations, viruses, tuber yield

Potato crops are infested by a number of insect pests which can cause substantial reduction in tuber yield. Among the sucking pests, aphids and whiteflies are the most important, as these inflict major damage by transmission of viruses limiting disease free seed production with a progressive decline in yield. More than 15 species of aphids are known to infest potato in India (Bhatnagar et al., 2018), along with cotton whitefly *Bemisia tabaci* (Gennadius) (Shah et al., 2019). In addition, leafhoppers such as the potato leaf hopper (*Empoasca devastans* Distant, *E. fabae* Harris), cotton leafhopper (*Amrasca biguttula biguttula* (Ishida)) and thrips (*Thrips palmi* Karny) cause substantial damage (Bhatnagar, 2007; 2008). The incidence of leaf hoppers and thrips is higher in warmer areas and in early season potato crops. These sucking pests have been managed with systemic insecticides. Other than the foliar applications, soil application of phorate 10G leads to significant reduction in the incidence of sucking pests (Nirula, 1962; Nirula and Kumar, 1969; Rizvi et al., 1976). Among the new pesticides suitable for soil incorporation, cartap hydrochloride and fipronil are gaining popularity. Due to continued use of phorate 10G, its efficacy has been found to be not up to the mark. Hence, this study evaluated cartap hydrochloride and fipronil granular formulations against the major sucking pests of potato.

MATERIALS AND METHODS

Field experiments were conducted at three locations namely, Jalandhar (Punjab; 31°16'34" N, 75°32'55" E), Modipuram (Meerut, Uttar Pradesh; 29°04'24" N, 77°42'25" E) and Gwalior (Madhya Pradesh; 26°16'53" N, 78°13'00" E) for two seasons, 2018-19 and 2019-20. Experiments were laid out in randomised complete block design, with eight treatments and three replications. The treatments included cartap hydrochloride 4G @ 15, 20 and 25 kg/ ha, fipronil 0.3G @ 15, 20, 25 kg/ ha, and phorate 10G @ 15 kg/ ha along with untreated control. At Jalandhar, efficacy of the insecticides was evaluated against the cotton whitefly and aphids (various species); against the cotton whitefly and leafhoppers at Modipuram; and against the cotton whitefly and thrips at Gwalior. These were applied once at the time of earthing-up, 30 days after planting. The control treatment was without soil application of insecticides. The crops were raised following the recommended package of agronomic practices without any other crop protection measures.

Observations on the number of insects i.e. adult whiteflies, adults, 3rd and 4th instar nymphs of aphids, and adults and pre-adult nymphs of leaf/ hoppers and thrips were taken from five randomly selected plants/ plot (plot size 3.6 x 3.2 m) one day before treatment

(pre-count) and 3, 5, 10, 20, 30 and 40 days after soil incorporation of insecticides. The per cent reduction in pest population size over control was calculated using the Henderson-Tilton formula (Henderson and Tilton, 1955). The total tuber yield in all experiments was recorded on whole plot basis. The data on number of insects, % reduction over control and tuber yield were subjected to ANOVA after appropriate transformation. The treatment means were separated by least significant difference (LSD, p=0.05). For benefit cost analysis, the cost of insecticide application was calculated as cost of insecticide and labour units required for its incorporation while as the price of harvested potato was calculated as per the prevailing market rate. Benefit cost ratio was calculated using the following formula-

$$\text{Benefit - Cost ratio} = \frac{\text{Net return (Rs/ ha)}}{\text{Cost of treatment (Rs/ ha)}}$$

RESULTS AND DISCUSSION

Bemisia tabaci: The effect of soil incorporated insecticides on the incidence of whitefly was evaluated at all the three locations (Jalandhar, Modipuram and Gwalior) over the two seasons (2018-19 and 219-20). The effect of insecticide treatments was significant on the incidence at all the locations (F = 66.16; d.f. = 7, 14; *p* = 0.00 at Jalandhar; F = 17.08; d.f. = 7, 14; p = 0.00 at Modipuram; F = 25.34; d.f. = 7, 14; p = 0.00 at Gwalior) (Table 1). Lowest incidence was recorded with fipronil 0.3G @ 25 kg/ ha which was on par with fipronil 0.3G @ 20 kg/ ha, cartap hydrochloride 4G @ 20 kg/ ha and cartap hydrochloride 4G @ 25 kg/ ha. The overall reduction over control ranged between 53.17 and 62.40% at the three locations.

Aphids (various species): Among the collected aphid samples, *Rhopalosiphum rifiabdominale* (Sasaki) (rice root aphid), *Aphis gossypii* Glover (cotton or melon aphid), *Aphis nasturtii* Kaltenbach (buckthorn-potato aphid), *Myzus persicae* (Sulzer) (peach-potato aphid) and *R. nymphaeae* (L.) (water lily aphid) were predominant. The effect of insecticide treatments was significant on the cumulative incidence of aphids (F = 41.20; d.f. = 7, 14; p = 0.00) at Jalandhar (Table 1). Among the treatments, fipronil 0.3G @ 25 kg/ ha performed best and was on par with fipronil 0.3G @ 20 kg/ ha, cartap hydrochloride 4G @ 20 kg/ ha and cartap hydrochloride 4G @ 25 kg/ ha. The cumulative reduction in the incidence over control ranged between 59.80 and 60.78% with these treatments.

Leaf hoppers: The effect of insecticide treatments was significant on the cumulative incidence (F = 25.83; d.f. = 7, 14; p = 0.00) at Modipuram (Table 1). Among the treatments, fipronil 0.3G @ 20 and 25 kg/ ha, and cartap hydrochloride 4G @ 20 and 25 kg/ ha performed best and were on par with each other. The reduction in incidence ranged between 58.60 and 65.94% with these treatments.

***Thrips palmi*:** The effect of insecticide treatments was significant on the cumulative number of thrips at Gwalior (F = 341.31; d.f. = 7, 14; p = 0.00) (Table 1). Among the treatments, fipronil 0.3G @ 20 and 25 kg/ ha, and cartap hydrochloride 4G @ 20 and 25 kg/ ha performed best and were on par with each other. The reduction over control ranged between 60.87 and 61.11% with these treatments. The effect of insecticides on the incidence of whiteflies, aphids, leafhoppers and thrips was significant from 5– 10 to 40 days after incorporation. The granular formulations of cartap hydrochloride and fipronil have been found effective for the management of many sucking and chewing pests and are currently being used for pest management in many crops. Either or both the insecticides are reported to successfully reduce the incidence of stem borers and leaf folder and brown plant hoppers in rice (Lal, 2006; Dhaka et al., 2011; Abro et al., 2013; Kharbade et al., 2015; Sandhu and Dhaliwal, 2016; Guruprasath and Ayyasamy, 2019), onion thrips (Pathak et al., 2018) and sugarcane wooly aphids (Mane et al., 2016) to mention a few.

Yield and benefit cost analysis: The effect of treatments was non-significant for total tuber yield at all the locations however, insecticide treated plots recorded slightly higher yield as compared to untreated control. Among the four insecticide treatments that provided highest suppression in insect populations, highest cost benefit ratio was for cartap hydrochloride 4G @ 20 kg/ ha and fipronil 0.3G @ 20 kg/ ha (2.62 and 2.47, respectively (Table 2). Further, no phytotoxicity symptoms were associated with any of the insecticide treatments.

Therefore, it is concluded that the soil incorporation of cartap hydrochloride 4G @ 20 kg/ ha or fipronil 0.3G @ 20 kg/ ha at earthing-up in potato crops can be recommended for the management of sucking pests (aphids, whiteflies, leafhopers and thrips) in potato crops in place of phorate 10G.

Table 1. Efficacy of soil insecticides against *B. tabaci*, aphids, leafhoppers and thrips in potato

No.	Treatments	Jalandhar			Modipuram			Gwalior			Jalandhar			Modipuram			Gwalior		
		Pre-count	Mean post-count	% reduction	Pre-count	Mean post-count	% reduction	Pre-count	Mean post-count	% reduction	Pre-count	Mean post-count	% reduction	Pre-count	Mean post-count	% reduction	Pre-count	Mean post-count	% reduction
		B. tabaci									aphid			leafhopper			thrips		
1.	Cartap Hydrochloride 4 G @ 15 kg/ ha	15.00 (3.96)	5.83 (2.61)^{c}	42.78	3.67 (2.15)	3.11 (2.02)^{b}	34.27	13.50 (3.80)	6.58 (2.75)^{b}	39.52	5.00 (2.44)	3.56 (2.13)^{b}	37.25	7.33 (2.88)	3.72 (2.17)^{b}	34.33	18.67 (4.42)	10.44 (3.38)^{b}	43.04
2.	Cartap Hydrochloride 4 G @ 20 kg/ ha	14.00 (3.85)	4.11 (2.26)^{a}	56.84	3.33 (2.07)	2.00 (1.73)^{a}	53.17	13.33 (3.78)	4.50 (2.34)^{a}	58.13	5.00 (2.44)	2.28 (1.80)^{a}	59.80	7.33 (2.88)	2.22 (1.79)^{a}	60.41	18.67 (4.43)	7.17 (2.85)^{a}	60.87
3.	Cartap Hydrochloride 4 G @ 25 kg/ ha	16.00 (4.11)	4.44 (2.33)^{a}	59.04	3.67 (2.15)	1.89 (1.69)^{a}	59.90	12.67 (3.68)	4.17 (2.27)^{a}	59.24	5.00 (2.44)	2.28 (1.80)^{a}	59.80	7.67 (2.94)	2.17 (1.77)^{a}	63.06	18.33 (4.39)	7.00 (2.82)^{a}	61.11
4.	Fipronil 0.3 G @ 15 kg/ ha	14.33 (3.86)	5.44 (2.54)^{c}	44.06	3.00 (1.98)	3.00 (1.99)^{b}	22.75	13.67 (3.82)	6.50 (2.73)^{b}	40.97	4.67 (2.35)	3.44 (2.10)^{b}	34.87	7.00 (2.82)	3.56 (2.13)^{b}	33.99	19.33 (4.50)	10.19 (3.34)^{b}	46.33
5.	Fipronil 0.3 G @ 20 kg/ ha	15.33 (4.03)	4.50 (2.34)^{ab}	56.70	3.67 (2.15)	2.06 (1.74)^{a}	56.49	12.83 (3.71)	4.42 (2.32)^{a}	57.33	5.33 (2.50)	2.39 (1.84)^{a}	60.48	6.67 (2.76)	2.11 (1.76)^{a}	58.60	19.33 (4.50)	7.44 (2.90)^{a}	60.78
6.	Fipronil 0.3 G @ 25 kg/ ha	13.67 (3.82)	3.83 (2.19)^{a}	58.63	3.67 (2.15)	1.83 (1.68)^{a}	60.89	14.00 (3.86)	4.25 (2.28)^{a}	62.40	5.00 (2.44)	2.22 (1.79)^{a}	60.78	7.67 (2.94)	2.00 (1.73)^{a}	65.94	18.33 (4.38)	7.00 (2.82)^{a}	61.09
7.	Phorate 10 G @ 15 kg/ Ha	15.67 (4.06)	6.11 (2.66)^{c}	42.57	3.33 (2.06)	3.17 (2.04)^{b}	26.55	13.17 (3.76)	6.42 (2.72)^{b}	39.63	4.67 (2.37)	3.39 (2.09)^{b}	35.92	7.33 (2.88)	3.78 (2.18)^{b}	33.34	19.33 (4.50)	10.97 (3.45)^{b}	42.22
8.	Control	15.33 (3.98)	10.44 (3.38)^{d}	–	4.33 (2.30)	5.61 (2.57)^{c}	–	13.67 (3.82)	11.03 (3.46)^{c}	–	5.00 (2.44)	5.67 (2.58)^{c}	–	7.33 (2.88)	5.67 (2.58)^{c}	–	19.33 (4.50)	19.00 (4.47)^{c}	–
SEm		0.31	0.04		0.07	0.04		0.14	0.04		0.13		0.04	0.04	0.06		0.14	0.03	
CD (p = 0.05)		NA	0.14		NA	0.13		NA	0.13		NA		0.12	NA	0.18		NA	0.09	

Values from pooled data of two seasons; Pre-count- Pretreatment count; Mean-post count- Cumulative mean of post-treatment counts, % reduction; % reduction over control; values in parentheses square root transformed as √x+0.5; NA –Not applicable

Table 2. Benefit cost ratio of soil insecticides in potato

No.	Treatments	Jalandhar	Modipuram	Gwalior	Mean
1.	Cartap hydrochloride 4G @ 15 kg/ ha	1: 1.16	1: 1.38	1: 1.39	1: 1.31
2.	Cartap hydrochloride 4G @ 20 kg/ ha	1: 3.00	1: 2.95	1: 1.91	1: 2.62
3.	Cartap hydrochloride 4G @ 25 kg/ ha	1:2.62	1: 2.93	1: 1.92	1: 2.49
4.	Fipronil 0.3G @ 15 kg/ ha	1: 1.04	1: 1.47	1: 1.39	1: 1.30
5.	Fipronil 0.3G @ 20 kg/ ha	1: 2.60	1: 2.92	1: 1.90	1: 2.47
6.	Fipronil 0.3G @ 25 kg/ ha	1: 2.62	1: 2.94	1: 1.91	1: 2.49
7.	Phorate 10G @ 15 kg/ ha	1: 0.80	1: 1.32	1: 1.29	1: 1.14
8.	Control	-	-	-	-

Sale price of potato- Rs. 600/ q; cost for soil incorporation of insecticides- Rs. 650/ ha; cartap hydrochloride 4G- Rs. 112/ kg, fipronil 0.3G- Rs. 115/ kg; phorate 10G- Rs. 85/ kg

REFERENCES

Abro G H, Syed T S, Shah A H, Cui J, Sattar M, Awan M S. 2013. Efficacy and economics of different insecticides against stem borers, *Scirpophaga incertulas* (Walker) in rice crop. Pakistan Journal of Zoology 45(4): 929-933.

Bhatnagar A, Jandrajupalli S, Venkateswarlu V, Malik K, Shah M A, Singh B P. 2017. Mapping of aphid species associated with potato in India using morphological and molecular taxonomic approaches. Potato Journal 44(2): 126-134.

Bhatnagar A. 2007. Incidence and succession of thrips, leafhoppers and whitefly in combination of planting dates and potato varieties. Annals of Plants Protection Sciences 15(1): 101-105.

Bhatnagar A. 2008. Insect associated with potato in Madhya Pradesh. Pest Management in Horticultural Ecosystem 13(2): 21-24.

Dhaka S S, Prajapati C R, Singh D V, Singh R. 2011. Field evaluation of insecticides and bio-pesticides against rice leaf folder, *Cnaphalocrocis medinalis* (Guenee). Annals of Plant Protection Sciences 19(2): 324-326.

Guruprasath S, Ayyasamy R. 2019. Bioefficacy of newer formulation of fipronil 0.8 G against brown planthopper of rice, *Nilaparvata lugens* (Stal.). Journal of Entomological Research 43(3): 283-287.

Henderson C F, Tilton E W. 1955. Tests with acaricides against the brown wheat mite. Journal of Economic Entomology 48: 157-161.

Kharbade S B, Chormule A J, Tamboli N D. 2015. Bio-efficacy of granular insecticides against *Nilaparvata lugens* (Stal.) in rice under field condition. Annals of Plant Protection Sciences 23(2): 250-252.

Lal R. 2006. Effect of fipronil on the incidence of stem borers in basmati rice. Pesticide Research Journal 18(2): 146-149.

Mane M A, Mohite P B, Patil S A. 2016. Population dynamics and management of sugarcane woolly aphids, *Ceratovacuna lanigera* (Zehntner) (Hemiptera: Aphididae) with new molecules of insecticides. International Journal of Advanced Research 4(10): 2047-2050.

Nirula K K, Kumar B. 1969. Soil application of systemic insecticides for the control of aphid vectors, leaf roll and Y viruses in potato. Indian Journal of Agricultural Sciences 39: 699-702.

Nirula K K. 1962. Insecticidal control of the spread of leaf roll and virus Y in potatoes. Indian Potato Journal 4: 1-6.

Pathak M K, Pandey M K, Gupta R C, Gupta P K. 2018. Evaluation of different insecticides against onion thrips in onion seed production. International Journal of Current Microbiology and Applied Sciences 7(7): 4204-4207.

Rizvi S M A, Chandla V K, Bist B S. 1976. Evaluation of some systemic granular insecticides against *Myzus persicae* Sulzer on potatoes. Potato Research 19: 183-185.

Sandhu G S, Dhaliwal N S. 2016. Evaluation of different insecticides against major insect pests of rice in Punjab. International Journal of Plant Protection 9(1): 187-192.

Shah M A, Malik K, Bhatnagar A, Katare S, Sharma S, Chakrabarti S K. 2019. Effect of temperature and cropping sequence on the infestation pattern of *Bemisia tabaci* in potato. Indian Journal of Agricultural Sciences 89(11): 1802-7.

Simon-Delso N, Amaral-Rogers V, Belzunces L P, Bonmatin J M, Chagnon M, Downs C, Furlan L, Gibbons D W, Giorio C, Girolami V, Goulson D. 2015. Systemic insecticides (neonicotinoids and fipronil): trends, uses, mode of action and metabolites. Environmental Science and Pollution Research 22(1): 5-34.

(Manuscript Received: January, 2021; Revised: February, 2021;
Accepted: March, 2021; Online Published: July, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21014

Indian Journal of Entomology 84(1): 126-128 (2022) DoI.: 10.55446/IJE.2021.333

EFFICACY OF INSECTICIDES AGAINST PINK STEM BORER *SESAMIA INFERENS* WALKER INFESTING BARNYARD MILLET *ECHINOCHLOA FRUMENTACEA*

M Roopika*, G Srinivasan and M Shanthi

Department of Agricultural Entomology,
Agricultural College and Research Institute (TNAU), Madurai 625104, Tamil Nadu, India
*Email: roobika1997@gmail.com (corresponding author)

ABSTRACT

Pink stem borer *Sesamia inferens* causes deadheart and white ear symptoms by boring into stem and peduncle region causing yield losses in barnyard millet. A field trial to find out efficacy of cartap hydrochloride 4G, chlorantraniliprole 18.5SC, flubendiamide 20WG, emamectin benzoate 5SG, spinetoram 11.7SC and phorate 10G against *S. inferens* was carried out in Tamil Nadu. Spinetoram 11.7SC (92.63%) was the most effective followed by flubendiamide 20WG (90.56%). Phorate 10G (81.57%) was found to be less effective. Plots treated with spinetoram 11.7SC gave maximum yield (9.57 q/ ha) with the cost benefit ratio of 1:3.08 followed by flubendiamide 20% WG (8.91 q/ ha) with the cost benefit ratio of 1:3.42. Phorate 10 G was the least performing treatment with 29.62% increase in yield over control with the cost benefit ratio of 1:2.84. Control plot recorded 44.5% less yield when compared to treated plots.

Key words: *Sesamia inferens*, *Echinochloa frumentacea*, insecticides, deadheart, white ear, spinetoram, chlorantraniliprole, phorate, yield, cost benefit ratio

Barnyard millet (*Echinochloa frumentacea* Link*)* belongs to the family Poaceae, is a multi-purpose crop cultivated for both food and fodder (Gomashe, 2017). It is a very good source of nutrients like proteins and dietary fibers. The grains are good source of carbohydrates, fibers and minerals like zinc and iron when compared to other major cereals (Renganathan et al*.,* 2020). The nutritional contents per 100g of barnyard millet grains are 11.6 g protein, 74.3 g carbohydrates, 5.8 g fat, 14 mg calcium, 15.2 mg iron, 14.7 g crude fibers, 121 mg phosphorus, 4.4 mg minerals and 300 k.cal of energy (Changmei and Dorothy, 2014). The demand for this crop has been recently hiked because of its high nutrient content. Barnyard millet is damaged by several insect pests like defoliators, stem borers and sap feeders. Among them, pink stem borer, *Sesamia inferens* Walker (Noctuidae: Lepidoptera) is a serious pest in barnyard millet (Gahukar and Reddy, 2019). In peninsular India, it causes more damage throughout the year (Santhosh et al., 2008). Adults lay eggs inside the leaf sheath in clusters. After hatching, the larva bores into the stem and feeds inside. During panicle emergence, the infestation causes white chaffy panicles which is termed as white ear (Reddy et al*.,* 2003). Though many studies have been done for the management of pink stem borer in different crops, yet no study is done on their infestation and control in barnyard millet. Hence, the present study was undertaken to identify the suitable insecticides for the management of *S. inferens* in barnyard millet.

MATERIALS AND METHODS

The experiment was conducted in the fields of Agricultural College and Research Institute, Madurai. The efficacy of six insecticides viz., cartap hydrochloride 4G, chlorantraniliprole 18.5SC, flubendiamide 20WG, emamectin benzoate 5SG, spinetoram 11.7SC and phorate 10G were evaluated in MDU-1 variety of barnyard millet. All the recommended agronomic practices were followed except plant protection chemicals. The pretreatment count was taken one day before every spray. Two rounds of insecticidal spray were given on 30 and 50 days after germination. The granules were applied in the leaf whorls and others were given as foliar spray. The total number of tillers and deadhearts were counted in 10 randomly selected plants from each plot at 5, 10 and 15 days after spray. The % deadheart, % white ear, % reduction over control and increase in yield over control were calculated (Kumar, 2018). The economics like cost of cultivation, net returns and cost benefit ratio in different treatments were calculated based on the yield data and market price of barnyard millet using the formula given by Sidar et al. (2017). The experiment was carried out using RBD with each treatment replicated thrice. The data collected from each plot were processed to arcsine and

Table 1. Efficacy of insecticides against *S. inferens* and effect on yield of barnyard millet

Trt. No.	Insecticides	Dosage (a.i./ha)	PTC	First spray (% incidence)			Second spray (% incidence)			Percentage incidence (pooled mean)	Cumulative % reduction over control	Yield (q/ ha)	Gross return (Rs.)	C:B Ratio
				5 DAS	10 DAS	15 DAS	5 DAS	10 DAS	15 DAS					
T_1	Cartap hydro-chloride 4% G	750 g a.i./ha	18.93 (25.78)	5.56 (13.63)^{a}	4.51 (12.26)^{b}	3.49 (10.76)^{abc}	6.12 (14.31)^{cd}	6.05 (14.23)^{cd}	5.89 (14.04)^{c}	5.27 (13.26)^{d}	86.66	7.95 (2.82)^{d}	45315	1:2.49
T_2	Chlorantraniliprole 18.5% SC	30 ml/ha	18.88 (25.74)	5.13 (13.08)^{a}	4.17 (11.78)^{ab}	3.14 (10.20)^{abc}	4.93 (12.82)^{bc}	4.95 (12.86)^{bc}	4.47 (12.20)^{b}	4.46 (12.19)^{c}	88.71	8.83 (2.97)^{c}	50331	1:3.31
T_3	Flubendiamide 20% WG	25 g a.i./ha	18.44 (25.42)	4.45 (12.18)^{ab}	3.51 (10.79)^{ab}	2.62 (9.31)^{ab}	3.98 (11.51)^{ab}	3.95 (11.46)^{ab}	3.88 (11.36)^{ab}	3.73 (11.13)^{b}	90.56	8.91 (2.98)^{b}	50787	1:3.42
T_4	Emamectin benzoate 5% SG	9.5 g a.i./ha	19.56 (26.24)	5.97 (14.14)^{b}	4.56 (12.32)^{b}	3.75 (11.16)^{bc}	6.76 (15.07)^{c}	6.71 (15.01)^{d}	6.53 (14.80)^{c}	5.71 (13.82)^{d}	85.55	7.81 (2.79)^{de}	44517	1:2.78
T_5	Spinetoram 11.7% SC	50 g a.i./ha	18.06 (25.14)	3.47 (10.73)^{a}	2.70 (9.46)^{a}	2.19 (8.50)^{a}	3.19 (10.29)^{a}	3.14 (10.21)^{a}	3.03 (10.03)^{a}	2.95 (9.89)^{a}	92.63	9.57 (2.84)^{a}	54549	1:3.08
T_6	Standard check - Phorate 10 G	1 kg a.i./ha	17.87 (25.00)	9.19 (17.64)^{c}	6.48 (14.74)^{c}	4.47 (12.20)^{c}	8.18 (16.61)^{d}	7.52 (15.91)^{d}	7.29 (15.66)^{c}	7.28 (15.65)^{e}	81.57	7.57 (2.75)^{e}	43149	1:2.84
T_7	Untreated check	-	18.85 (25.72)	26.64 (31.06)^{d}	34.31 (35.84)^{d}	42.34 (40.58)^{d}	43.48 (41.24)^{e}	44.85 (42.03)^{e}	45.47 (42.39)^{d}	39.51 (38.93)^{f}	-	5.84 (2.42)^{f}	33288	1:2.60
	SEd		NS	0.94	1.07	1.20	1.09	0.86	0.82	0.47		0.020		
	CD (p=0.05%)			2.06	2.34	2.62	2.37	1.87	2.40	1.02		0.044		

Value in the parentheses are square root transformations; In a column, means followed by same letter are not significantly different at P = 0.05 as per LSD; Selling price of barnyard millet – Rs. 5700/q; Cost of cultivation excluding cost of insecticides – Rs. 12800, PTC- Pretreatment count.

square root data transformation. The data were analyzed using AGRES software to differentiate the transformed mean values using Fisher's Least Significant Difference (LSD, p=0.05) (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

One day before first spray the pretreatment count on deadheart damage ranged from 17.87 to 19.56% (Table 1). Five days after spraying spinetoram 11.7SC (3.47) recorded the lowest deadhearts followed by flubendiamide 20WG (4.45). The maximum damage was recorded in phorate 10G (9.19). On 10 days after spray, the lowest deadheart damage was in spinetoram 11.7SC (2.70) followed by flubendiamide 20WG (3.51). The maximum damage was in emamectin benzoate 5SG (4.56) and phorate 10G (6.48). On 15 days after spray spinetoram 11.7SC (2.19) recorded the least damage followed by flubendiamide 20WG (2.62) which were statistically on par. In second spray, on 5 days after spray the least white ear damage (3.19) was in spinetoram 11.7SC followed by flubendiamide 20WG (3.98) and chlorantraniliprole 18.5SC (4.93) which were significantly different. Emamectin benzoate 5SG (6.76) and phorate 10G (8.18) showed maximum white ear which were statistically on par. The data collected 10 days after spray revealed that spinetoram 11.7SC (3.14) led to the lowest white ear damage followed by flubendiamide 20WG (3.95) and chlorantraniliprole 18.5SC (4.95). The maximum white ears war with emamectin benzoate 5SG (6.71) and phorate 10G (7.52). At 15 days after spray also, spinetoram 11.7SC (3.03) showed the lowest white ear damage followed by flubendiamide 20WG (3.88). The treatment phorate 10G recorded the highest damage of 7.29%.

The cumulative white ear (damage) reduction over control was calculated with pooled mean. Spinetoram 11.7SC (92.63) gave maximum reduction followed by flubendiamide 20WG (90.56), chlorantraniliprole 18.5SC (88.71), cartap hydrochloride 4G (86.66) and emamectin benzoate 5SG (85.55). The least reduction (81.57%) was recorded in phorate 10 G. The non-effectiveness of granules might be due to profuse tillering of the crop. The cost of cultivation except plant protection chemicals was Rs.12800. More yield was obtained with spinetoram 11.7% SC (9.57 q/ ha) followed by flubendiamide 20% WG (8.91 q/ ha). Emamectin benzoate 5% SG (7.81 q/ ha) and phorate 10 G (7.57 q/ ha) led to the least yield. The % increase in yield over control was more in spinetoram 11.7% SC (63.87) and low in phorate 10 G (29.62). The gross

and net return were calculated based on the price of barnyard millet grains (One quintal = Rs. 5700). The cost benefit ratio was maximum in flubendiamide 20% WG (1:3.42) followed by chlorantraniliprole 18.5% SC (1:3.31), spinetoram 11.7% SC (1:3.08) and phorate 10 G (1:2.84). Less CBR was recorded in emamectin benzoate 5% SG (1:2.78) and cartap hydrochloride 4% G (1:2.49).

Previous studies found that cartap hydrochloride 4G was the most effective against *S. inferens* in finger millet (Sasmal, 2018), Spinosad 45SC recorded highest % yield increase (Deole et al. 2017) in maize. Sahu and Deole (2017) found emamectin benzoate as the most effective. It is concluded that spinetoram 11.7SC and flubendiamide 20WG are the superior ones and can be recommended against *S. inferens* with maximum cost benefit ratio.

ACKNOWLEDGEMENTS

The authors thank the Department of Agricultural Entomology, Agricultural College and Research Institute, Madurai for providing facilities.

REFERENCES

Changmei S, Dorothy J. 2014. Millet- the frugal grain. International Journal of Scientific Research and Reviews 3(4): 75-90.

Deole S, Dubey V K, Rana D K and Gauraha R. 2017. Evaluation of newer insecticides against pink stem borer: Major constraint insect pest of maize in Raipur, Chhattisgarh. Journal of Plant Development Sciences 9(4): 335-339.

Gahukar R, Reddy V P. 2019. Management of economically important insect pests of millet. Journal of Integrated Pest Management 10(1): 1-10.

Gomashe S S. 2017. Barnyard millet: Present status and future thrust areas: biology and genetic improvement. Millets and Sorghum 134: 184-198.

Gomez K A, Gomez A A. 1984. Statistical procedures for agricultural research. 2nd edition, John Wiley and Sons, New York: 680.

Kumar R. 2018. Assessment of different insecticides against maize stem borer infestation. International Journal of Current Microbiology and Applied Sciences 7: 790-800.

Reddy M, Babu T R, Reddy D D R, Sreeramalu M. 2003. Determination of economic injury and threshold levels for pink borer *Sesamia inferens* (Walker) in maize *Zea mays* L. International Pest Control 45(5): 260-263.

Renganathan V G, Vanniarajan C, Karthikeyan A, Ramalingam J. 2020. Barnyard millet for food and nutritional security: Current status and future research direction. Frontiers in Genetics 11: 1-21.

Santhosh H B, Sekhar J C, Rakshit S, Gadag R N, Sain D. 2008. Detection of epistatic interaction for susceptibility towards pink stem borer (*Sesamia inferens* Walker) in maize (*Zea mays* L.). Indian Journal of Genetics and Breeding 72(3): 284-289.

Sahu N, Deole S. 2017. Bio-rational insecticides against pink stem borer, *Sesamia inferens* Walker of maize. Journal of Applied Zoological Research 28(2): 209-215.

Sasmal A. 2018. Management of pink stem borer (*Sesamia inferens* walker) in finger millet (*Eleusine coracana* Gaertn.). Journal of Entomology and Zoology Studies 6(5): 491-495.

Sidar Y K, Deole S, Gajbhiye R K, Nirmal A. 2017. To evaluate the bio-efficacy of granular insecticide molecules against pink stem borer. Journal of Entomology and Zoology Studies 5(2): 1114-1120.

(Manuscript Received: February, 2021 ; Revised: April, 2021;
Accepted: April, 2021; Online Published: July, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21017

Indian Journal of Entomology 84(1): 129-131 (2022) DoI.: 10.55446/IJE.2021.334

FEEDING EFFICIENCY OF PREDATORY SPIDERS ON *MYZUS PERSICAE* (SULZER)

Anusha M*, Kusal Roy and Asim Kumar Maiti

Department of Agricultural Entomology, Bidhan Chandra Krishi Vishwavidyalaya,
Nadia 741252, West Bengal, India
*Email: anushamohankumar0@gmail.com (corresponding author)

The present study focused on the feeding efficiency of predatory spiders on aphid *Myzus persicae* (Sulzer). Under laboratory conditions, tetragnathid spiders showed significantly higher consumption rate followed by oxyopids and the least was observed with salticids and linyphiids. A significantly high overall consumption of prey by tetragnathid, oxyopid, salticid and linyphiid spiders was noticed with the treatment @ 10 prey (aphids)/ spider. These results indicate that even if the prey density increased, the consumption rate did not increase. In vitro survivability of lycosid and phalangiid group of spiders was merely 2 days, whereas spiders of other families survived 7-14 days.

Key words: Predators, spiders, *Myzus persicae*, cabbage, prey, prey density, consumption rate, generalist predators, tetragnathids, oxyopids, salticids, linyphiids, survivability

India is in second position in the world in the production of cabbage *Brassica oleraceae* var. *capitata* L, but its productivity is far lower (FAOSTAT, 2019), and pests and diseases are the constraints. Aphids alone cause 9-96% reduction of yield (Singh and Sharma, 2012), and diamond back moth may cause 52% yield loss (Krishnamoorthy, 2004). Indiscriminate use of insecticides results in development of resistance and resurgence of insect pests, outbreak of secondary pests and decline in population of natural enemies, and also contamination. A possible alternative to pesticides in the development of an IPM strategy against insect pests is biological conservation and augmentation of natural enemies.

Exploring new predators within various classes of phylum Arthropoda is important. Raworth et al. (1984) opined these predators and parasites have been the major determining factor. Cosmopolitan and solitary braconid parasitoid wasp *Diaeretiella rapae* (Mclntosh) and specialist cecidomyiid predator, *Aphidoletes aphidimyza* (Rond.) contribute immensely in controlling aphids during mid and heading stage of crop growth. However, generalist predators like spiders, coccinellids, rove beetles and chrysopids help prevent increase of aphids in the early stages of crop growth. Active spider predators tend to congregate in prey rich sites and affect indirectly by catching and killing without consuming it or trapping prey in abandoned webs (Gavish-Regev et al., 2009). Hence the present study evaluated the feeding efficiency of various predatory spiders on *Myzus persicae* (Sulzer) under laboratory conditions.

MATERIALS AND METHODS

Predatory spiders belonging to six families viz., Salticidae, Oxyopidae, Lycosidae, Tetragnathidae, Linyphiidae and Phalangiidae were found feeding on insect pests of cabbage. These were collected from the Jaguli Instruction Farm, Bidhan Chandra Krishi Vishwavidyalaya, Mohanpur, Nadia, West Bengal during 2019-20 during January-February. The dry pitfall trap and hand collection methods were followed. *Myzus persicae* aphids were collected manually using camel hair brush (size 0) from these fields. The spiders were maintained in vials individually at 25± 2°C, 70±10% RH, and 10 hr of darkness. These were starved for 48 hr to minimize the differences in individual hunger levels. Thereafter, these were introduced individually into petri plates with *M. persicae* nymphs and apterous adults, at three density levels i.e. 5, 10 and 15. The predatory spiders were assigned to these treatments randomly along with an untreated control treatment without spiders. The treatments were replicated thrice. After 48 hr, the number of preys consumed were counted from the surviving aphids, and mortality by non-predator factor was considered based on mean number of aphids surviving in the control treatment. Therefore, mean number of aphids consumed by each spider was standardized by using the equation given by Gavish-Regev et al. (2009). The ANOVA of factorial completely randomized design for two factors was done and the critical difference (CD, p= 0.05) was worked out using OPSTAT software. Tukey's HSD test was conducted using R-studio to find the difference between families.

RESULTS AND DISCUSSION

Predatory spiders belonging to six families viz. Lycosidae (wolf spider), Oxyopidae (lynx spider), Salticidae (jumping spider), Tetragnathidae (long jawed spider), Linyphiidae (sheet weavers) and Phalangiidae were found feeding on insect pests of cabbage. Feeding efficiency of lycosid and phalangiid spiders could not be studied under laboratory conditions, because the spiders died within 24 hr of capture, while others survived for 7-14 days. In control, the live prey was 5± 0, 9.67± 0.65 and 13.67± 1.72 at 5, 10 and 15 aphids/ spider prey density, respectively. These results reflect both the birth and non-predator inflicted mortality of aphids. This value was used to standardize the number of aphids in the other treatments. After 48 hr of introduction of spiders into prey containing petri plates, at prey density of 5 aphids/ spider, lowest feeding efficiency (4.67± 0.65) was noticed with salticids and linyphiids, followed by tetragnathids (4 ± 1.96). In contrast, maximum feeding efficiency (3.33± 1.72) was observed with oxyopids. However, at 10 and 15 aphids/spider density few aphids (1.72± 0.67) survived when tetragnathids were released. Least number of aphids (6.55± 1.78) was consumed by salticids at 10 and at 15 aphids/ spider, and by linyphiids (15.73± 0.71) (Table 1). Tukey's HSD test (p=0.05) revealed a significant mean difference of 3.55, 4.51 and 5.08 between feeding efficiency of tetragnathids vs oxyopids, salticids and linyphiids, respectively. No significant mean difference was observed between oxyopids, salticids, and linyphiids. These indicate a significant superiority of the tetragnathids as a promising predator of *M. persicae*. Low survival rate of aphid when tetragnathids were released indicates the better predation, showing its potential as biocontrol agent in cabbage.

The overall consumption of prey by oxyopids decreased as the prey density increased whereas, high consumption of prey by salticids and linyphiids was observed at density of 10 prey/ spider and low at density of 15 prey/ spider. The overall consumption of prey by tetragnathids was high at prey density of 10 aphids/ spider and low at prey density of 5 aphids/ spider. The combined (all spiders) prey survival rate at density of 5, 10 and 15 aphids/ spider were 83.32, 61.20 and 86.60%, respectively (Fig. 1). A significantly more overall consumption of prey by all families of spiders was noticed at 10 prey/ spider. These results indicated that even if the prey density increased, the consumption rate did not increase.

Table 1. Feeding efficiency of predatory spiders on aphids

Families	No. of aphids alive			Mean
	5 aphids/ spider	10 aphids/ spider	15 aphids/ spider	
Oxyopidae	3.33± 1.72	7.93± 0.67	12.80± 1.89	8.0
Salticidae	4.67± 0.65	6.55± 1.78	15.73± 1.43	9.0
Linyphiidae	4.67± 0.65	8.28± 2.02	15.73± 0.71	9.6
Tetragnathidae	4.00± 1.96	1.72± 0.67	7.68± 2.48	4.5
Control	5.00± 0.00	9.67± 0.65	13.67± 1.72	9.4
Mean	4.3	6.8	13.1	

Toft and Wise (1999) reported that aphids are the poor host to generalist predators, qualitatively. Hence, they prefer other food source for surviving. Mayntz and Toft (2001) reported that nutritionally balanced spiders consumed more aphids than imbalanced spiders. Availability of aphids as prey to ground spiders like lycosids and phalangiids is low and aphids are not the major component of their diet. These may be the reasons attributing to the poor survivability of lycosids and phalangiids under in vitro conditions. Sherawat and Butt (2014) found no significant difference between feeding efficiency and ability to catch prey with lycosids and oxyopids. They also stated that although aphid diet had no influence on growth and development of spiders, it helps to maintain predator population (linyphiids and lycosids) under starved conditions. Harwood et al. (2004), Gavish-Regev et al. (2009) and Khan (2013) found higher feeding efficiency in linyphiids and lycosids than other spiders, whereas in this study tetragnathids showed significant difference with other spiders. Butt and Xaaceph (2015) reported that as prey densities increased, total search time and search efficiency of oxyopids decreased but attack rate did not vary. They suggested that feeding strategy

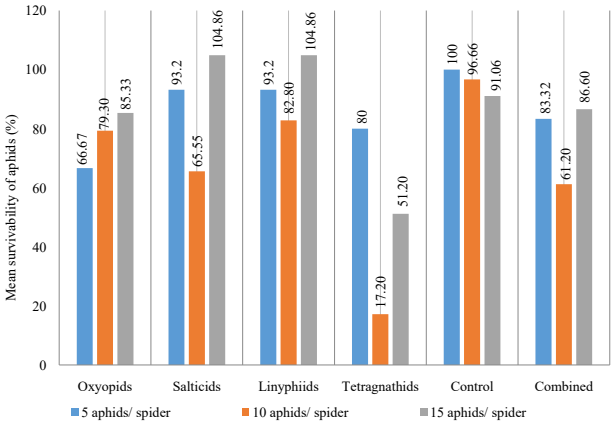


Fig. 1. Survival of aphids vs. prey density

was affected by prey density and habitat which is in comparison with the present study i.e., different level of prey density had no effect on feeding efficiency of spiders of various families.

An in vitro study can further be strengthened by rearing of the predatory spiders which may help in understanding the consumption behaviour and rate at various stages of spiders, difference between male and female in rate of consumption, and total feeding efficiency of prey during the entire life period. Apart from aphid, other insect pests such as lepidopteran larvae, whitefly, hoppers etc. can be adopted in feeding efficiency study. Combination or multiple pests can be given as prey which helps in determining the preference and behavioural changes in spiders. The present study brings our tetragnathids as a potential biocontrol agent of *M. persicae* in cabbage ecosystem. An increase in prey density did not impose any effect on consumption rate of predatory spiders. Survivability of lycosid and phalangiid group of spiders in captivity was merely 2 days, in contrast tetragnathids, oxyopids, salticids, and linyphiids could survive 7-14 days in captivity.

ACKNOWLEDGEMENTS

The authors acknowledge the Department of Agricultural Entomology, BCKV, Nadia for providing facilities.

REFERENCES

Butt A, Xaaceph M. 2015. Functional response of *Oxyopes javanus* (Araneidae: Oxyopidae) to *Sogotella furcifera* (Hemiptera: Delphacidae) in laboratory and mesocom. Pakistan Journal of Zoology 47(1): 89-95.

FAOSTAT 2019. Crops/ Regions/World list/Production Quantity (pick lists)- Cabbages and other brassicas, 2018. UN Food and Agriculture Organization, Corporate Statistical Database (FAOSTAT). 2019. Retrieved 18 October 2020.

Gavish-Regev E, Rotkopf R, Lubin Y, Coll M. 2009. Consumption of aphids by spiders and the effect of additional prey: Evidence from microcosm experiments. BioControl 54(3): 341-350.

Harwood J D, Sunderland K D, Symondson W O C. 2004. Prey selection by linyphiid spiders: molecular tracking of the effects of alternative prey on rates of aphid consumption in the field. Molecular Ecology 13: 3549-3560.

Khan A A. 2013. Evaluation of the biological control efficiency of four spiders using functional response experiments. The Bioscan 8(4): 1123-1128.

Krishnamoorthy A. 2004. Biological control of diamond back moth, *Plutella xylostella* (Linn.) and Indian scenario with reference to past and future strategies. Kirk A A, Bordat D (eds.). Proceedings. International symposium, 21-24 October, 2002, Montpellier, France, CIRAD. pp. 204-211.

Mayntz D, Toft S. 2001. Nutrient composition of the prey's diet affects growth and survivorship of a generalist predator. Oecologia 127: 207–213.

Raworth D A, Frazer B D, Gilbert N, Wellington W G. 1984. Population dynamics of the cabbage aphid, *Brevicoryne brassicae* (Homoptera: Aphididae) at Vancouver, British Columbia: Sampling methods and population trends. The Canadian Entomologist 116(06): 861-870.

Sherawat S M, Butt A. 2014. Role of hunting spiders in suppression of wheat aphid. Pakistan Journal of Zoology 46(2): 309-315

Singh Y P, Sharma K C. 2012. Integrated approach to manage the mustard aphid, *Lipaphis erysimis* (Kalt) (Homoptera: Aphididae) in oil seed Brassica crops- a review. Journal of Aphidology 2012(16): 77-88.

Toft S, Wise D H. 1999. Growth, development and survival of a generalist predator fed single- and mixed species diets of different quality. Oecologia 119: 191-197.

(Manuscript Received: February, 2021; Revised: April, 2021;
Accepted: April, 2021; Online Published: July, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21018

Indian Journal of Entomology 84(1): 132-133 (2022) DoI.: 10.55446/IJE.2021.335

RECORD OF *TELENOMUS CALIFORNICUS* ASHMEAD ON FALL ARMY WORM *SPODOPTERA FRUGIPERDA* (J E SMITH)

T K Nivetha and S Manisegaran*

Department of Agricultural Entomology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai 625104, Tamil Nadu, India
*Email: dr.profsmanisegaran@gmail.com (corresponding author)

ABSTRACT

***Telenomus californicus* Ashmead (Hymenoptera: Platygastridae), an egg parasitoid of *Spodoptera frugiperda* (J E Smith) is documented as a new record from Madurai in Tamil Nadu, India. This species has been reared from the field collections of parasitized eggs. The parasitoid was studied for its morphology and the species was distinguished by its dilated proximal four antennal segments.**

Key words: *Spodoptera frugiperda*, maize, Madurai, egg parasitoid, *Telenomus californicus*, Platygastridae, Hymenoptera, morphology, new record, description, diagnosis

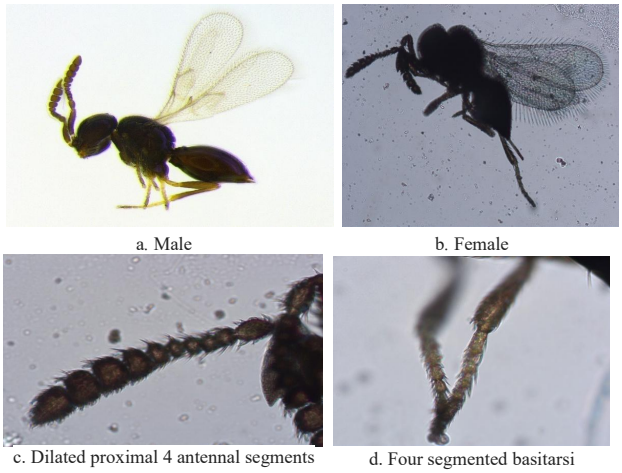
The fall army worm *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae) is a highly destructive pest of cereals, and is a native of the tropical and subtropical regions of North, Central and South America (Sparks, 1972). It was first reported in 2018 in India (Ganiger et al., 2018; Sharanabasappa et al.,2018). Following the invasion of *S. frugiperda* into India, emergency responses have been geared towards the use of insecticides (Dehmuki et al., 2020). The frequent application of insecticides is unsustainable due to insecticide resistance, increased production costs, and other hazards. Under these circumstances, biological control may offer an alternative. Parasitoids are natural enemies widely used to manage insect pests, when these are mass multiplied under laboratory condition and field released. *Telenomus* Haliday of subfamily Telenominae (Hymenoptera: Platygastridae) is a large cosmopolitan genus of egg parasitoids (Johnson, 1984). The hosts are mostly Lepidoptera and Hemiptera, but these are also known to attack dipteran and neuropteran eggs (Johnson, 1984; Johnson and Bin, 1982). Among parasitoids, egg parasitoids *Telenomus* spp., play a key role in the suppression of insect pests. *Telenomus remus* Nixon was identified as one of the natural egg parasitoids of *S. frugiperda* in Africa (Marc Kenis et al., 2019). The present study documents the occurrence of *Telenomus californicus* Ashmead reared from *S. frugiperda* eggs as a new record.

MATERIALS AND METHODS

During *S. frugiperda* surveys, parasitized egg masses were collected from maize fields of Agricultural College Research Institute, Madurai. The collections were reared under laboratory conditions. Adult parasitoids that emerged from egg masses were killed within 70-96% alcohol and stored in glass vials in 100% alcohol. Larvae from the non-parasitized eggs in the same egg mass were also reared until adult emergence to confirm the identity of the host. The samples of the egg parasitoids were sent to the Zoological Survey of India, Kolkata and got identified as *Telenomus californicus* and morphology details confirm this (Fig. 1a-d); it can be easily distinguished by its proximal four antennal segments dilated. Further, antennae ten segmented in female and eleven segmented in male. Tarsi four segmented with enlarged base tarsi. Male genitalia, however, provide fairly reliable characters.

RESULTS AND DISCUSSION

Altogether 22 species of *Telenomus* are known from India (Rajmohana, 2006; Rajmohana et al., 2013a,b). Now, *T. californicus* has been observed to occur as an egg parasitoid on *S. frugiperda*. *Telenomus* spp., are solitary egg parasitoids and only a few species that attack larger eggs of different insect orders are gregarious (Margaría et al., 2007). This study records a new gregarious *Telenomus* sp. that parasitizes the *S. frugiperda* eggs (Fig. 1). *Telenomus californicus* had been known as endoparasitoid of lepidopteran eggs from Brazil (Loiácono and Margaría 2002). Further, it had been known to parasitize the eggs of the satin moth *Leucoma salicis* L. (Burgess 1921; Burgess and Crossman 1927; Thompson, 1958). It had also been reported to be host specific on the eggs of Douglas-fir



a. Male b. Female

c. Dilated proximal 4 antennal segments d. Four segmented basitarsi

Fig. 1. *T. californicus*- adults, antennae, wings and legs

tussock moth *Orgyia pseudolsugata* (McDunnough) (Lepidoptera: Lymantriidae) (Torgersen and Rya 1981). The presence of *T. californicus* has important implications for the biological control of *S. frugiperda* in India.

ACKNOWLEDGEMENTS

The senior author is grateful to Dr (Mrs) Rajmohana K, Zoological Survey of India, Kolkata for identification of the egg parasitoid.

REFERENCES

Burgess A F. 1921. The satln moth *Leucoma salicis* Linnaeus an introduced enemy of poplars and willows USDA. Department Gircular no.167. 16 pp

Burgess A F, Crossman S S. 1927. The satln moth *Leucoma salicis* Linnaeus a recently introduced pest USDA. Department Bulletin No. 1469.

Deshmukh S, Pavithra H B, Kalleshwaraswamy C M, Shivanna B K, Maruthi M S, David Mota Sanchez. 2020. Field efficacy of insecticides for the control of invasive fall army worm *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), in the maize fields in India. Florida Entomologist 103: 221-227

Ganiger P C, Yeshwant H M, Muralimohan K, Vinay N, Kumar A R V, Chandrashekara K. 2018. Occurrence of the new invasive pest, fall army worm *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), in the maize fields of Karnataka, India. Current Science 115: 621-623.

Johnson N F, Bin F. 1982. Species of *Telenomus* (Hymoptera: Scelionidae), parasitoids of stalked eggs of Neuroptera (Chrysopidae and Berothidae). Redia 65: 189-206.

Johnson N F. 1984. Systematics of Nearctic *Telenomus*: classification and revisions of the *podisi* and *phymatae* species groups (Hymenoptera: Scelionidae). Bulletin of the Ohio Biological Survey 6: 1-113.

Loiácono M S, Margaría C B. 2002. Ceraphronoidea, Platygastroidea and Proctotrupoidea from Brazil (Hymenoptera).Neotropical Entomology 31(4): 551-560.

Kenis M, du Plessis H, Van den Berg J, Niango Ba M, Goergen G, Kwadjo K E, Baoua I, Tefera T, Buddie A, Cafà G, Offord L, Rwomushana I, Polaszek A. 2019. *Telenomus remus,* a candidate parasitoid for the biological control of *Spodoptera frugiperda* in Africa, is already present on the continent. Insects 10(4): 92.

Margaría C B, Gil-Santana H, Meira Marques O, Loiácono M S. 2007. Telenomus sp. (Hymenoptera: Scelionidae) egg parasitoid of *Caligo brasiliensis* (C. Felder, 1862) (Lepidoptera: Nymphalidae) in southern Brazil. Entomological News 118(5): 519-522.

Rajmohana K. 2006. A checklist of Scelionidae (Hymenoptera: Platygastroidea) from India. Zoos' Print Journal 21(12): 2506-2513.

Rajmohana K, Nisha M S. 2013a. *Telenomus oryzae* (Hymenoptera: Platygastridae), a new species of egg parasitoid of the Rice black bug, *Scotinophora* (Heteroptera: Pentatomidae) from India. Halteres 4: 79-86.

Rajmohana K, Srikumar K K, Bhat P S, Raviprasad T N, Jalali S K. 2013b. A new species of platygastrid *Telenomus cuspis* sp. nov. (Hymenoptera), egg parasitioid of tea mosquito bug from India, with notes on its bionomics and mtCo1 data. Oriental Insects 47(4): 226-232.

Sharanabasappa D, Kalleshwaraswamy C M, Asokan R, Mahadeva Swamy H M, Marutid M S, Pavithra H B, Hegde K, Navi S, Prabhu S T, Goergen G. 2018. First report of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), an alien invasive pest on maize in India. Pest Management in Horticultural Ecosystems 4: 23-29.

Sparks A N. 1972. A review of the biology of the fall armyworm. Florida Entomologist 2: 82–87.

Thompson W R. 1958. A catalogue of the parasites and predators of insect pests. Sect. 2. Pt. 5. Hosts of Hymenoptera, Lepidoptera and Streptsiptera. ClB : 698 pp.

Torgersen True R, Ryan R B. 1981. Field biology of *Telenomus californicus* Ashmead, an important egg parasite of Douglas-fir tussock moth. Annals of the Entomological Society of America 74(2): 185-186.

(Manuscript Received: February, 2021; Revised: April, 2021;
Accepted: April, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21019

Indian Journal of Entomology 84(1): 134-136 (2022) DoI.: 10.55446/IJE.2021.337

POPULATION DYNAMICS OF FALL ARMY WORM *SPODOPTERA FRUGIPERDA* (J E SMITH) ON MAIZE

P S Rajisha, N Muthukrishnan*, S Jeyarajan Nelson, R Jerlin[1] and R Karthikeyan[2]

Department of Agricultural Entomology; [1]Department of Seed Science and Technology;
[2]Department of Farm Management, Tamil Nadu Agricultural University,
Coimbatore 641003, Tamil Nadu, India
*Email: nmkrish@tnau.ac.in (corresponding author)

ABSTRACT

Population dynamics of the fall army worm (FAW) *Spodoptera frugiperda* on maize was carried out at the research field of Tamil Nadu Agricultural University, Coimbatore (kharif and rabi, 2018 and 2019). The results revealed that maximum FAW trap catches were obtained during 34th (7.6 moths/ trap) and 5th (7.8 moths/ trap) standard weeks (SW) of kharif and rabi seasons of 2018, respectively. During 2019, a more or less similar trend was observed with a maximum during 31st (7.2 moth/ trap) and 48th (8.2 moth/ trap) SW of kharif and rabi seasons, respectively. Correlation with weather factors indicated a significant negative correlation with evening relative humidity (RH) and significant positive correlation with morning RH during 2019-20. No significant effect of weather factors was observed during 2018-19 except for a significant positive correlation with evening RH and rainfall. The correlation between larval counts and pheromone trap catches were significantly positive with r-value of 0.55 and an R^2 value of 0.907 during 2018-19.

Key words: Maize, *Spodoptera frugiperda*, population dynamics, trap catches, temperature, relative humidity, rainfall, correlation and regression coefficients, pheromone trap, larval counts

The fall army worm (FAW) *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae) is the recent invasive polyphagous pest in India (Shylesha et al., 2018; Mallapur et al., 2018). Yield loss as high as 34% due to *S. frugiperda* had been reported (Cruz,1999; Williams and Davis,1990). Population dynamics/ fluctuations of any pest species are influenced by environmental factors such as temperature, rainfall/ precipitation and relative humidity (Prasad et al., 2008.). It has been proven that sex pheromone is a potential tool for monitoring of insect pest species and its management through mating disruption or male annihilation. Thus, developing an effective integrated management strategy for *S. frugiperda* in its new habitat (i.e., India), requires information on its population dynamics. Hence, this study on the influence of weather factors on the seasonal incidence of *S.frugiperda*.

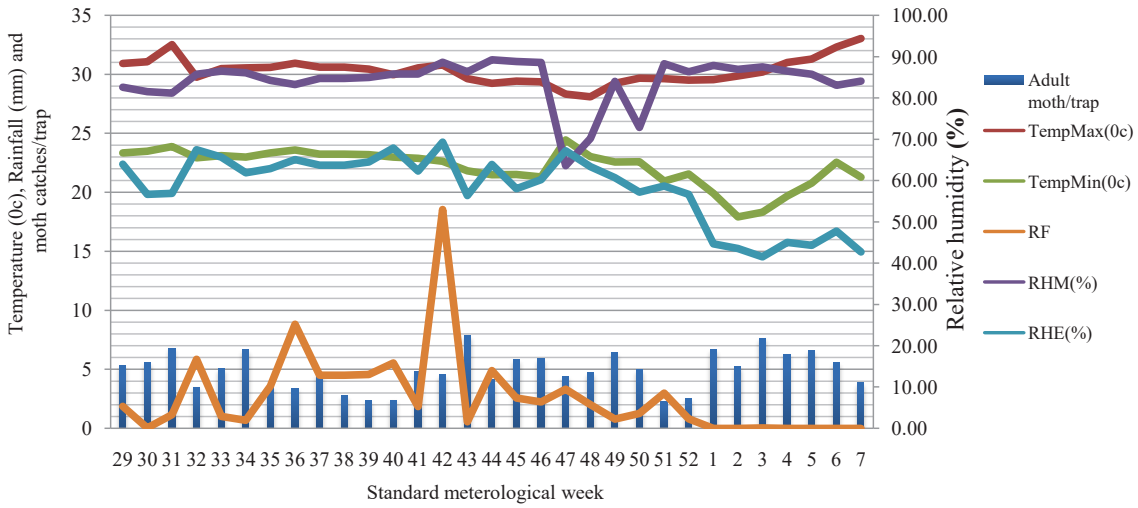
MATERIALS AND METHODS

Field experiments on maize (CO-H6) were conducted at the Research field of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu for two seasons (kharif and rabi) during 2018-19 and 2019-20 with standard maize cultivation practices under irrigated conditions. Funnel type pheromone traps and sex pheromone septa manufactured by Pheromone Chemicals (India) Pvt. Limited, Hyderabad were used for monitoring *S. frugiperda* moths @ 12.5 traps/ ha installed 10 days after sowing at a height of 2 m above ground level at three field sites. Pheromone traps were undisturbed with the activity of cultivation of crops. Septa and lure were changed periodically on exhaustion at 15 days interval throughout the season. Trap catches of moths were sorted and counted, and in males in which markings were not clear, genitalia were dissected to confirm the identity. To ascertain the relationship between moth catches and larval counts, fields were sampled from maize emergence until tasseling and silking stages. Data pertaining to the larval incidence was observed from 20 randomly selected plants following 'W' pattern in a zigzag manner at weekly intervals (Prasanna et al., 2018). All the open leaves and whorls of selected plants were observed thoroughly for larvae in a non-destructive manner to allow continuous collection over the crop cycle (VE: emergence, V1: first leaf collar to V(n): n^{th} leaf collar). Data on maximum and minimum temperature, morning and evening RH, rainfall (mm) were obtained from the Meteorological unit of Agroclimatic Research Centre, TNAU, Coimbatore. Weekly trap catches were recorded

as number of moths/ trap. Spearman's correlation analysis was performed to determine correlations between moth catches and weather data. Correlation and regression an analysis was done using SPSS 16.0 software. A one-way ANOVA was conducted to assess statistically significant differences in FAW density across maize development stages.

RESULTS AND DISCUSSION

Trap captures of *S. frugiperda* varied significantly in different weeks of growing season (kharif and rabi) in 2018 and 2019. Trap catch data indicate that the *S. frugiperda* survived year round in this location; in 2018, the incidence was maximum during 34th (7.6 moth/ trap) and 5th (7.8 moth/trap) standard weeks (SW) of kharif and rabi seasons, respectively (Fig. 1); during 2019, a more or less similar trend was observed with a maximum during 31st (7.2 moths/ trap) and 48th SW (8.2 moth/ trap), kharif and rabi seasons and the least during 44th (1.2 moth/ trap) and 6th SW (1.9 moth/ trap). Pooled data revealed that peak activity was during 43rd SW (7.85 moths/ trap). These results are in accordance with earlier results of Kumar et al. (2020) who observed its peak incidence in second fortnight of July 2019 and minimum in second fortnight of October during kharif season. Similarly, Nboyine et al. (2020) reported that the moth trap catches increased from July and peak was during August; thereafter moth catches declined significantly. During kharif 2018, the trap catches revealed a non significant positive correlation with maximum temperature (r=0.127), minimum temperature (r=0.073) and significant negative correlation with evening RH (r=-0.714) and rainfall (r=-0.763) while non significant negative correlation with morning RH. No significant impact of weather was noticed during rabi 2018 and about 81.3% and 26.2% variation in moth trap catches was due to all weather factors considered in multiple regression for both kharif and rabi seasons, respectively (Fig. 1). During kharif 2019, correlation coefficient with maximum temperature and morning RH were non-significant and positive (r=0.438 and 0.217) while with rainfall it was significant and positive (r=0.088). Multiple regression indicated that about 43.0 and 51.4% variation in trap catches is contributed by the weather factors. The pooled data revealed that maximum temperature (r = 0.61) and evening RH (r = 0.59) had significant correlation with trap catches during kharif season, while during rabi season all the weather



Correlation coefficients and regression- incidence of S. frugiperda vs. weather factors

Year		Max.Temp(°C)	Min.Temp(°C)	Mor. RH (%)	Eve. RH (%)	Rainfall (mm)
2018-19	Kharif	0.127	0.073	-0.493	-0.714*	-0.763*
(Moth trap catches)	$Y=37.892+(-0.934X_1)+(1.144X_2)+(-0.081X_3)+(-0.373X_4)+(-0.123X_5)+1.107$					$R^2=0.813$
	Rabi	-0.211	0.211	0.108	-0.241	-0.206
	$Y=26.698+(-1.123X_1)+(0.961X_2)+(0.078X_3)+(-0.272X_4)+(-0.297X_5)+2.098$					$R^2=0.262$
2019-20	Kharif	0.438	-0.115	0.217	-0.387*	0.088*
(Moth trap catches)	$Y=-18.218+(0.429X_1)+(-0.133X_2)+(0.268X_3)+(-0.148X_4)+(0.035X_5)+1.663$					$R^2=0.430$
	Rabi	0.340	-0.435	0.268*	-0.485*	-0.364*
	$Y=88.327+(2.849X_1)+(1.091X_2)+(0.106X_3)+(0.557X_4)+(0.087X_5)+1.472$					$R^2=0.514$

Fig. 1. Population dynamics of *S. frugiperda* on maize (pooled data, kharif and rabi, 2018, 2019)

parameters exhibited a nonsignificant correlation. Paul and Deole (2020) and Kumar et al. (2020) reported that larvae of *S. frugiperda* exhibited a significant negative correlation with total rainfall and RH, which are in conformity with this study. On the contrary Nboyine et al. (2020) reported that moth trap catches of *S. frugiperda* had a significant and positive correlation with rainfall (r=0.714).

There was no significant difference in *S. frugiperda* density across maize growth stages during 2018 and 2019. During early plant stages (V2-V3), first and second instar were predominant, and about two to three larvae/ plant were found while in V11-V12 maize growth stage *S. frugiperda* in late larval stage were more frequently observed in 2018 and a similar trend was also observed in 2019. *S. frugiperda* is known to prefer feeding in the vegetative stages of maize within whorl (Capinera, 2008) and the results from this study show that *S. frugiperda* larvae builds up until V8-V10 and then decreased from V11-V12. Murua et al. (2006) reported that *S. frugiperda* infestations displayed a plant age-dependent response with the VE– V3 stages being the most preferred stages. Bessera et al. (2002) and Granger et al. (2020) reported that the distribution of *S. frugiperda* larvae and eggs varied according to the phenological stage of the crop. Nboyine et al. (2019) with correlation studies indicated that weekly trap catches of *S. frugiperda* were linearly and positively correlated with larval counts in maize. It is concluded that understanding the population dynamics will be helpful in formulating IPM strategies against *S. frugiperda*.

ACKNOWLEDGEMENTS

The authors thank Dr N Chitra, Department of Agricultural Entomology, TNAU, Coimbatore for the support and manuscript correction. The financial support from the DST Inspire, Govt. of India is acknowledged.

REFERENCES

Beserra E B, Dias C T D S, Parra J R. 2002. Distribution and natural parasitism of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) eggs at different phenological stages of corn. Florida Entomologist 85(4): 588-593.

Capinera J L. 2008. Fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae). Encyclopedia of Entomology. Springer, The Netherlands. pp. 1409-1412.

Cruz I, Figueiredo M C, Oliveira A C, Vasconcelos C A. 1999. Damage of *Spodoptera frugiperda* (Smith) in different maize genotypes cultivated in soil under three levels of aluminium saturation. International Journal of Pest Management 45(4): 293-296.

Granger D L, Mfune T, Musesha M, Lowry A, Reynolds K, Buddie A, Cafa G, Offord L, Chipabika G, Dicke M, Kenis M. 2020. Factors influencing the occurrence of fall armyworm parasitoids in Zambia. Journal of Pest Science. pp.1-14.

Kumar N V, Yasodha P, Justin C G L 2020. Seasonal incidence of maize fall armyworm *Spodoptera frugiperda* (J.E Smith) (Noctuidae; Lepidoptera) in Perambalur district of Tamil Nadu, India. Journal of Entomology and Zooligy Studies 8(3): 1-4.

Murúa G, Ochoa M J, Coviella C. 2006. Population dynamics of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) and its parasitoids in northwestern Argentina. Florida Entomologist 89(2): 175-182.

Nboyine J A, Kusi F, Abdulai M, Badii B K, Zakaria M, Abdu G B, Haruna A, Seidu A, Osei V, Alhassan S, Yahaya A. 2019. A new pest, *Spodoptera frugiperda* (J.E. Smith) in tropical Africa: Its seasonal dynamics and damage in maize fields in northern Ghana. Crop Protection 127: 1-5.

Prasad T V, Gopal V N, Gedia V N. 2008. Seasonal abundance of *Sesbania* thrips *Caliothrips indicus* Bagnall in groundnut. Journal of Agrometeorology 1: 211-214.

Shylesha A N, Jalali S K, Gupta A, Varshney R, Venkatesan, T, Shetty P, Ojha R, Ganiger C P, Navik O, Subhaharan K, Bhaktha V N, Ballal C R. 2018. Studies on new invasive pest *Spodoptera frugiperda* (J.E Smith) (Lepidoptera: Noctuidae) and its natural enemies. Journal of Biological Control 32(3): 145-151.

Williams W P, Davis F M. 1990. Response of corn to artificial infestation with fall armyworm and southwestern corn borer larvae. Southwestern Entomologist 15(2): 163-166.

(Manuscript Received: February, 2021; Revised: April, 2021;
Accepted: April, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21047

Indian Journal of Entomology 84(1): 137-139 (2022) DoI.: 10.55446/IJE.2021.338

BIOLOGY OF PINK STEM BORER *SESAMIA INFERENS* WALKER ON BARNYARD MILLET *ECHINOCHLOA FRUMENTACEA*

M Roopika*, G Srinivasan and M Shanthi

Department of Agricultural Entomology,
Agricultural College and Research Institute, TNAU, Madurai 625104, Tamil Nadu, India
*Email: roobika1997@gmail.com (corresponding author)

ABSTRACT

Laboratory study was conducted to assess the biology of pink stem borer *Sesamia inferens* Walker on barnyard millet during February to April. The eggs were round and creamy white, and were laid inside the leaf sheath. The incubation period was 10.88± 0.41 days, and hatching % was 68.19± 1.16 and the larva had six instars. The weight of first, second, third, fourth, fifth and sixth instar were 0.21± 0.01, 6.86± 0.57, 36.29± 2.79, 63.75± 2.06, 135.97± 2.57 and 225.05± 4.65 mg, respectively; duration of these instars was 3.76± 0.23, 3.92± 0.17, 5.08± 0.21, 5.52± 0.28, 5.72± 0.23 and 6.68± 0.36 days, respectively. The total larval and prepupal duration were 30.68± 0.89 days and 1.48± 0.10 days, respectively, with a pupation of 86.4± 1.86% and pupal period of 9.96± 0.46 days. The pupal weights of males were 138.12± 3.05 mg and females were 196.63± 1.56 mg. The adult emergence was 84.4± 1.93%, with female being larger than males; with filiform antenna, while the had bipectinate antenna. The weight of male adult was 110.20± 4.73 mg and female adult was 189.30± 9.40 mg, and longevity was 4.92± 0.16 6.4± 0.21 days, in male and female, respectively. The fecundity ranged from 28 to 226 eggs/ female (118.4± 12.09) and the total lifecycle ranged from 41 to 63 days (51.2± 1.44 days) for male and from 47 to 70 days (58.12± 1.47 days) for female.

Key words: *Sesamia inferens*, *Echinochloa frumentacea*, egg, larva, pupa, adult, duration, weight, sex ratio, pupation, longevity, fecundity, lifecycle

Barnyard millet (*Echinochloa frumentacea)* which belongs to the family Poaceae, is a multi-purpose crop cultivated for both food and fodder (Gomashe, 2017). It is enriched with nutrients like proteins and dietary fibers. The grains are good source of carbohydrate and minerals like zinc and iron when compared to other major cereals (Renganathan et al*.,* 2020). Barnyard millet is ravaged by several insect pests like defoliators, stem borers and sap feeders. Among these, the pink stem borer *Sesamia inferens* Walker (Noctuidae: Lepidoptera) is a serious pest in barnyard millet (Gahukar and Reddy, 2019). In peninsular India, pink stem borer causes more damage throughout the year (Santhosh et al., 2008). Adults lay eggs inside the leaf sheath in clusters. After hatching, the larva bores into the stem and feeds inside. During panicle emergence, the infestation causes white chaffy panicles, termed as white ear (Reddy et al*.,* 2003). Concerned with the threat caused by pink stem borer, this study on its biology was carried out.

MATERIALS AND METHODS

The biology study on *S. inferens* was conducted in the Post Graduate Entomology Laboratory, Agricultural College and Research Institute, Madurai (9.9699°N, 78.2040°E). The larval and pupal samples were collected from barnyard millet fields of Madurai district. These were mass cultured in barnyard millet stem following Singh and Kular (2015a). For studying the biology, in each stage 25 individuals were selected with three replications. The duration in various developmental stages was recorded in egg, larval, pupal and adult. The % hatchability, egg duration, larval duration, larval weight, % pupation, pupal duration, % adult emergence, sex ratio and adult longevity were recorded by observing each stage as per the methodology suggested by Chaudhari et al. (2018). The eggs were allowed to hatch and the duration and the hatchability % were noted, and for the incubation period, these were kept in petri plates until they turn to black head stage. These petri plates were provided with moist cotton to avoid drying, and eggs hatched was counted regularly to know the hatchability%. The newly emerged larva were provided with soft stems as a food supplements and in later stages they were provided with matured stem cuttings. By regular observation of moulted skin or head capsule, the changes in the instars were recorded. The weight and duration of each instar were recorded regularly, and pupation % was noted from the larvae transformed into pupa, along with weight and duration. The adult emergence % was observed from the adults

emerged, along with number of male and female, and sex ratio and their duration worked out. The weight of both male and female adults was also recorded. The number of eggs laid was counted to know the fecundity. By adding the duration of different stages, the total duration of lifecycle was calculated. The data collected were analysed using descriptive statistics (Sharma et al*.,* 2017).

RESULTS AND DISCUSSION

The eggs of pink stem borer were round and creamy white and laid inside the leaf sheath. The fecundity was 118.4± 12.09 and the incubation period was 10.88± 0.41 days. Prior to hatching, the eggs turned black and the hatching % was 68.19± 1.16 (Table 1). This is in accordance with Sharma et al. (2017) who studied its biology in maize genotypes. The larval duration was 30.68± 0.89 days, with six instars. Post- hatching, the tiny and soft first instar larva started scrapping the leaf sheath. The first instar lasted for 3.76± 0.23 days, and weighed 0.21± 0.01 mg; the second was seen with duration of 3.92± 0.17 days, and made small bore holes in the stem and fed on inner contents of stem, and weighing 6.86± 0.57 mg. The third instar larva fed inside the stem and duration and weight was 5.08± 0.21 days and 36.29± 2.79 mg, respectively. The fourth instar weight was 63.75± 2.06 mg and the duration was 5.52± 0.28 days. The fifth instar lasted for 5.72± 0.23 days, and weighed 135.97± 2.57 mg; the final instar was large stout and pinkish, weighing from 185.61 to 253.37 mg and lasted for 6.68± 0.36 days. The infested crop showed deadheart symptom during tillering stage and white ear symptom during reproductive stage in accordance with Chaudhari et al. (2018); this study reported that the instars lasted for 4.04± 0.84, 3.44± 1.16, 4.96± 0.79, 5.56± 1.04, 6.00± 0.82 and 7.44± 1.19 days, respectively and also confirmed that the pupation takes place inside the stem.

Upon completion of six instars, the larva entered into prepupal stage which lasted 1.48± 0.10 days, with pupation being 86.4± 1.86%, and pupal duration was 9.96± 0.46 days. The male pupal weight was 138.12± 3.05 mg and female was 196.63± 1.56 mg. Total developmental period was 48.8± 1.56 days. Similarly, Singh and Kular (2015b) in wheat reported that the pupal duration was 36.05± 0.36 days for male and 37.78± 0.17 days for female. The adult emergence was 84.4± 1.93%., with female larger than the male; female had filiform antenna while in male it was bipectinate. The number of males emerged was 10.2± 0.36, and in female it was 11.0± 0.37, while these weighed 110.20± 4.73 and 189.30± 9.40 mg, in male and female, respectively; longevity of male was 4.92± 0.16 and in female, it was 6.4± 0.21 days. Total lifecycle lasted for 51.2± 1.44 days for male and 58.12± 1.47 days for female. These results are in consonance with those of Singh and Kular (2015b).

Table 1. Biology of *S. inferens* reared on barnyard millet stem

S. No.	Parameters	Mean± S.E.
1.	Fecundity (no.)	118.4 ± 12.09
2.	Incubation period (days)	10.88± 0.41
3.	Egg hatching (%)	68.19± 1.16
4.	Larval period (days)	30.68± 0.89
	I	3.76± 0.23
	II	3.92± 0.17
	III	5.08± 0.21
	IV	5.52± 0.28
	V	5.72± 0.23
	VI	6.68± 0.36
5.	Larval weight (mg)	
	I	0.21± 0.01
	II	6.86± 0.57
	III	36.29± 2.79
	IV	63.75± 2.06
	V	135.97± 2.57
	VI	222.05± 4.65
6.	Pre-pupal period (days)	1.48± 0.10
7.	Pupation (%)	86.4± 1.86
8.	Male pupal weight (mg)	138.12± 3.05
9.	Female pupal weight (mg)	196.63± 1.56
10.	Pupal period (days)	9.96± 0.46
11.	Adult emergence (%)	84.4± 1.93
12.	Adults emerged (No.)	10.2± 0.36
	Male	
	Female	11.0± 0.37
13.	Adult weight (mg)	
	Male	110.20± 4.73
	Female	189.30± 9.40
14.	Adult longevity (days)	
	Male	4.92± 0.16
	Female	6.4± 0.21
15.	Total developmental period (days)	
	Male	51.2± 1.44
	Female	58.12± 1.47
16.	Male female ratio	1: 1.08

Mean± SE (n=20); SE - Standard error

REFERENCES

Changmei S, Dorothy J. 2014. Millet- the frugal grain. International Journal of Scientific Research and Reviews 3(4): 75-90.

Chaudhari N S, Patel A A, Deb S, Patel P S. 2018. Biology of pink stem borer, *Sesamia inferens* (Walker) on wheat. An International e Journal 7 (2): 133-147.

Gahukar R, Reddy V P. 2019. Management of economically important insect pests of millet. Journal of Integrated Pest Management 10(1): 1-10.

Gomashe S S. 2017. Barnyard millet: Present status and future thrust areas: Biology and genetic improvement. Millets and Sorghum 134: 184–198.

Gomez K A, Gomez A A. 1984. Statistical procedures for agricultural research. 2nd edition, John Wiley and Sons, New York: 680.

Reddy M, Babu T R, Reddy D D R, Sreeramalu M. 2003. Determination of economic injury and threshold levels for pink borer *Sesamia inferens* (Walker) in maize *Zea mays* L. International pest control 45(5): 260-263.

Renganathan V G, Vanniarajan C, Karthikeyan A, Ramalingam J. 2020. Barnyard millet for food and nutritional security: Current status and future research direction. Frontiers in Genetics 11: 1-21.

Santhosh H B, Sekhar J C, Rakshit S, Gadag R N, Sain D. 2008. Detection of epistatic interaction for susceptibility towards pink stem borer (*Sesamia inferens* Walker) in maize (*Zea mays* L.). Indian Journal of Genetics and Breeding 72(3): 284-289.

Sharma H, Jaglan M S, Yadav S S. 2017. Biology of pink stem borer, *Sesamia inferens* (Walker) on maize, *Zea mays*. Journal of Applied and Natural Science 9 (4): 1994-2003.

Singh B, Kular J S. 2015a. Influence of abiotic factors on population dynamics of pink stem borer, *Sesamia inferens* Walker in rice-wheat cropping system of India. Journal of Wheat Research 7 (2): 23-28.

Singh B, Kular J S. 2015b. Notes on the bionomics of the pink stem borer, *Sesamia inferens* Walker (Lepidoptera: Noctuidae): an upcoming pest of wheat in India.*Acta* Phytopathologica et Entomologica Hungarica 50 (2): 239-259.

(Manuscript Received: March, 2021; Revised: May, 2021;
Accepted: May, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21054

Indian Journal of Entomology 84(1): 140-144 (2022) DoI.: 10.55446/IJE.2021.299

EVALUATION OF SOME IPM MODULES AGAINST RED ANT *DORYLUS ORIENTALIS* WESTWOOD IN POTATO

ELANGBAM BIDYARANI DEVI*, BADAL BHATTACHARYYA AND SUDHANSU BHAGAWATI

Department of Entomology, Assam Agricultural University, Jorhat 785013, Assam, India
*Email: bidyaranielangbam@gmail.com (corresponding author)

ABSTRACT

Field experiments were conducted at Charaibahi village, Jorhat, Assam during 2015-17 to evaluate six ecofriendly IPM modules against red ants *Dorylus orientalis* Westwood in potato. Among the modules evaluated, Module-II (pre sowing treatment of mustard oil cake @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3% and soil drenching with neem oil @ 5 ml/ lit after 1st and 2nd earthing up (25 and 60 DAS) recorded the lowest tuber damage both in weight (8.65%) and number (10.70%) basis and found at par with the recommended package of practices (RPP) (application of malathion 5% dust @ 40 kg/ ha+ mustard oil cake @ 150 kg/ ha in the soil after 1st and 2nd earthing up) recording 8.18 and 10.20% tuber damage, respectively. The same module also recorded highest tuber yield (119.37 q/ ha) which was at par with the RPP (120.12 q/ ha). The maximum benefit cost ratio (1.41) was recorded in RPP followed by Module-II (1.33) and Module-VI (1.26). The untreated control plot registered a very high level of tuber damage (25.93 and 28.70 on weight and number basis, respectively) having maximum population of red ants (3.95 numbers/ m^2) with a tuber yield of 89.91 q/ ha.

Key words: *Dorylus orientalis*, IPM modules, incidence, tuber damage, panchagavya, neem oil, mustard oil cake, wood ash, malathion, soil drenching, earthing up, yield, cost benefit

Potato (*Solanum tuberosum* L.) is an important cash crop and a staple food item of Indian diet. India is the second largest producer of potato contributing to approximately12% of global production. As per the third advance estimate for 2018-19 (NHB), India produced 53.02 million tonnes of potatoes (Anon., 2018). Favourable subtropical climatic conditions of Assam also allows extensive potato cultivation both in the plains and hills with a production of 1072780 tonnes (Anon., 2017). Potato crop is attacked by many insect pests right from sowing of tubers to harvesting and storage causing potential yield loss. Among the various insect pests of potato, red ants *Dorylus orientalis* Westwood has long been considered as a major pest both in the plains and hills (Fletcher, 1914) causing extensive damage by making minute holes (2-3 mm diameter) to the underground tubers. Highest infestation is recorded at the time of harvesting which reduces tuber quality as well as market price makes them unfit for human consumption (Bhandari, 2011). In severe cases, the tuber infestation may reach up to 50-90% (Roonwal, 1976 and Chowdhury, 1997). Limited literature available regarding management practices for red ants and available literature is biased toward insecticide based treatments including some of them are banned in our neighbouring country like Sri Lanka (Fernando and Manickavasagar, 1958) and Assam (Anon., 1965; Rahman, 1967). Despite being a pest of potato, concerted efforts for the ecofriendly IPM measures of red ants is still in infancy. Moreover, the North Eastern region is also tagged as "Organic hub of India" and hence the adoption of chemocentric agriculture cannot be overlooked. Considering the above facts, field experiments were carried out to evaluate some IPM management modules against red ants in potato.

MATERIALS AND METHODS

The experiments were conducted in highly red ant endemic areas in the farmer's field of Charaibahi, Jorhat, Assam during 2015-17 to evaluate the effectiveness of six IPM modules in comparison with recommended package of practices and untreated control. The details of different modules are: i) Module-I: Pre sowing treatment of MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3%; ii) Module-II: Pre sowing treatment of MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3% and soil drenching with neem oil @ 5 ml/ l after 1st and 2nd earthing up (25 and 60 DAS); iii) Module-III: Pre sowing treatment of MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3% and soil drenching with jatropha oil @ 5 ml/

lit after 1st and 2nd earthing up (25 and 60 DAS); iv) Module-IV: Pre sowing treatment of MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3% and soil drenching with pongamia oil @ 5 ml/ lit after 1st and 2nd earthing up (25 and 60 DAS); v) Module-V: Pre sowing treatment of MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3% and soil drenching with castor oil @ 5 ml/ lit after 1st and 2nd earthing up (25 and 60 DAS); vi) Module-VI: Pre sowing treatment of MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3% and soil drenching with sesamum oil @ 5 ml/ lit after 1st and 2nd earthing up (25 and 60 DAS); vii) RPP: Application of malathion 5% dust @ 40 kg/ ha+ mustard oil cake @ 150 kg/ ha in the soil after 1st and 2nd earthing up (25 and 60 DAS); and viii) Untreated control. The potato crop (variety: Kufri Jyoti) was grown by following all the recommended package and practices of Assam. The experiment was conducted in randomized block design with 3 replications with plot size of 4x 3 m^2. The efficacy of each module was assessed on the basis of tuber damage (weight and number basis), number of red ants/ m^2 at the time of harvest (30 cm depth of soil) and tuber yield (q/ ha). The cost benefit ratio was also computed from the total expenditure and net return. The data on tuber damage (weight and number basis) were subjected to angular transformation and data on number of red ants/ m^2 and tuber yield were analysed by ANOVA (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The effect of IPM modules evaluated against *D. orientalis* based on tuber damage (weight and number basis), red ant incidence, tuber yield and benefit cost ratio are presented in Table 1. Experimental results revealed that all the evaluated modules were statistically superior over untreated control. Among the IPM modules, Module-II (pre sowing treatment of MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3% and soil drenching with neem oil @ 5 ml/ l after 1st and 2nd earthing up (25 and 60 DAS) led to the least tuber damage on weight basis (8.65%) and this treatment was at par with RPP (8.18%). The next best treatment was Module-VI (pre sowing treatment of MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3% and soil drenching with sesamum oil @ 5 ml/ l after 1st and 2nd earthing up (25 and 60 DAS) recording 12.38% on weight basis followed by Module-III (pre sowing treatment of MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3% and soil drenching with jatropha oil @ 5 ml/ l after 1st and 2nd earthing up (25 and 60 DAS) (14.79%) and Module-IV (pre sowing treatment of MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3% and soil drenching with pongamia oil @ 5 ml/ l after 1st and 2nd earthing up (25 and 60 DAS) (16.92%). Module-V (pre sowing treatment of MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3% and soil drenching with castor oil @ 5 ml/ l after 1st and 2nd earthing up (25 & 60 DAS) recorded 18.43% and Module-I (pre sowing treatment of MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3%) registered 20.65% tuber damage on weight basis, respectively. The maximum tuber damage on weight basis was observed in untreated control (25.93%).

When tuber damage was assessed on number basis, the % infestation followed the same trend as observed in weight basis. Module-II led to the least values (10.70%) which was found to be at par with RPP (10.20%). The plot treated with Module-VI recorded 14.60% tuber damage followed by Module-III (16.89%). Module-IV (18.63%), Module-V (21.16%) and Module-I (23.57%) registered tuber damage. The untreated control plots recorded 28.70% tuber damage. As regards to tuber yield, maximum yield was obtained from Module-II (119.37 q/ ha) and was found to be at par with RPP (120.12 q/ ha). This treatment was followed by Module-VI (114.67 q/ ha), Module-III (111.41 q/ ha) and Module-IV (108.24 q/ ha). Module-V registered tuber yield of 105.83 q/ ha and Module-I (94.91 q/ ha), respectively. The tuber yield recorded in untreated control plots was 89.91 q/ ha. While considering the red ant incidence in different treatments, it was found to range from 2.37 to 3.95 at the time of harvesting. However, among all the six IPM modules evaluated, least number of ants/ m^2 was with Module-II (2.47). The highest B: C ratio (1.41) was recorded in RPP followed by Module-II (1.33) and Module-VI (1.26), respectively.

The present findings are in agreement with Borah (1994) who in potato fields at Diphu, Assam during 1992-94 found that soil drenching with malathion 50EC @ 0.1% was very effective in reducing infestation caused by *D. orientalis*. Application of chlorpyriphos 20EC @ 5ml/ l of water thrice around the root zone starting from 45 days after sowing at 10 days interval registered the least tuber infestation (17.28 and 10.68% reduction) with (62.77 and 56.60% reduction) closely followed by 3 times application of carbaryl 85 WP @ 3 gm/ l of water (20.14 and 13.73% reduction) with (85.77 and 81.71% reduction) (Dash et al., 2013). Bhattacharyya et al. (2014) also observed that soil drenching with chlorpyriphos 20EC @ 0.06% was

Table 1. Efficacy of ecofriendly IPM modules against red ant *D. orientalis* in potato (2015-17)

Modules	Pre-sowing treatment	Soil drenching	Tuber damage (%) on weight basis	Tuber damage (%) on number basis	Tuber yield (q/ ha)	Ant counts No./ m^2	BCR
Module-I	MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3%	-	20.65 (27.02)	23.57 (29.04)	94.91	3.36	1.04
Module-II	MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3%	Soil drenching with neem oil @ 5 ml/ lit after 1st & 2nd earthing up (25 & 60 DAS)	8.65 (17.05)	10.70 (19.06)	119.37	2.47	1.33
Module-III	MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3%	Soil drenching with jatropha oil @ 5 ml/ lit after 1st & 2nd earthing up (25 & 60 DAS)	14.79 (22.59)	16.89 (24.24)	111.41	2.70	1.22
Module-IV	MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3%	Soil drenching with pongamia oil @ 5 ml/ lit after 1st & 2nd earthing up (25 & 60 DAS)	16.92 (24.27)	18.63 (25.54)	108.24	2.82	1.18
Module-V	MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3%	Soil drenching with castor oil @ 5 ml/ lit after 1st & 2nd earthing up (25 & 60 DAS)	18.43 (25.41)	21.16 (27.36)	105.83	3.07	1.16
Module-VI	MOC @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3%	Soil drenching with sesamum oil @ 5 ml/ lit after 1st & 2nd earthing up (25 & 60 DAS)	12.38 (20.56)	14.60 (22.44)	114.67	2.60	1.26
RPP	Malathion 5% dust @ 40 kg/ ha+ mustard oil cake @ 150 kg/ ha in the soil after 1st & 2nd earthing up (25 & 60 DAS)		8.18 (16.55)	10.20 (18.58)	120.12	2.37	1.41
Control	-		25.93 (30.60)	28.70 (32.39)	89.91	3.95	-
S.Ed (±)			0.24	0.30	0.43	-	-
CD (p=0.05)			0.52	0.66	0.93	-	-

*RPP- Recommended package of practices.\; Figures in parentheses angular transformed values

found to be the best with least tuber damage (6.81 and 7.28% on weight and number basis) and maximum tuber yield (123.38 q/ ha) followed by the application of banana trap @ 350-400 numbers/ ha mixed with malathion 5% dust recording 8.68 and 8.94% tuber damage on weight and number basis, respectively; this gave a tuber yield of 119.33 q/ ha. Saikia and Debnath (2017) reported that combined application of malathion 5% dust @ 40 kg/ ha and MOC @ 150 kg/ ha followed by chlorpyriphos 20 EC @ 5 ml/ l and carbofuran 3 G @ 25 kg/ ha were the best in Cachar district, Assam.

The present study brings out the very good efficacy of panchagavya, for the organic cultivation, as it has been invariably included in all the modules evaluated herein. The efficacy might be due to the fact that it acts as potential biopesticide and bioenhancer as reported earlier (Pathak and Ram, 2013; Golakiya et al., 2019). Panchagavya being a mixed culture of naturally occurring, beneficial microbes mostly lactic acid bacteria (*Lactobacillus*), yeast (*Saccharomyces*), actinomyces (*Streptomyces*), photosynthetic bacteria (*Rhodopseudomonas*) and certain fungi (*Aspergillus*) promoted the growth and yield of different crops and registered higher B:C ratio (Shailaja et al., 2014). Boomiraj et al. (2004) reported that panchagavya was effective against leafhopper (*Amrasca biguttula biguttula*) and whitefly (*Bemisia tabaci*) in okra. Panchagavya+ Neem Seed Kernel Extract (NSKE) proved as best in managing *Spodoptera litura* larvae followed by panchagavya+ *Vitex nigundo* and calotropis in groundnut and soybean (Bharathi, 2005). Neelakanth (2006) noted that panchagavya+ cow urine in combination with NSKE proved next best over spinosad in controlling *Plutella xylostella* in cabbage. While studying the effect of panchagavya against 9 insect pests in teak, Kumar et al. (2015) recorded that 7 and 5% diluted panchagavya application was found to be more effective.

The superiority of neem oil in reducing various soil insect pests is known- Nwilene et al. (2008) observed that neem seed oil can be effective control against termites on rice fields and can also be used as alternatives to persistent pesticides. Similarly, Devi and Mohandas (1982) and Pereira and Wohlgemuth (1983) reported that neem oil at 1% and 0.8% applied on red gram and cowpea respectively, acted as a good protectant against *Callosobruchus chinensis*. Ali et al. (1983) observed that neem oil @ 0.5% on gram seed as most effective against *C. chinensis*. Verma et al. (1983) found oil and cakes of neem, castor and mustard to be effective in reducing the fecundity, egg hatching and adult emergence in *Sitotroga cerealella*. Kumari et al. (1990) reported that neem oil at 1% as the highly effective against *C. chinensis*. In all the tested management modules against *D. orientalis*, two important components *viz*., mustard oil cake and wood ash were also included which might have contributed in reducing the infestation. The efficacy of the mustard oil cake may be attributed to essential oils that acts as repellent against *Agrotis ipsilon* (Isman et al., 2000). The results clearly indicate that among the modules evaluated, Module-II (pre sowing treatment of mustard oil cake @ 150 kg/ ha+ wood ash 150 kg/ ha+ panchagavya @ 3% and soil drenching with neem oil @ 5 ml/ lit after 1st and 2nd earthing up (25 and 60 DAS) led to the least tuber damage both in weight and number basis. The tuber yield and benefit cost ratio were also more. Therefore, Module-II may be recommended for application against the *D. orientalis* infestation in potato.

REFERENCES

Ali S I, Singh O P, Mishra U S. 1983. Effectiveness of plant oils against pulse beetle, *Callosobruchus chinensis* Linnaeus. Indian Journal of Entomology 45: 6-9.

Anonymous. 1965. Control of soil insects of potato. Annual Report (1964-65). Entomology Division, Department of Agriculture, Government of Assam.

Anonymous. 2017. https://www.potatopro.com/assam/potato-statistics.

Anonymous. 2018. National Horticulture Board. Area and production of horticultural crops for 2018-19 (3rd Advance Estimates), Ministry of Agriculture and Farmers Welfare, Government of India.

Bhandari M R. 2011. Assessment of red ant organic management options in potato field of Dhading. Nepal. Nepalese Journal of Agricultural Sciences 9: 90-94.

Bharathi S M. 2005. Role of organics and indigenous components against *Spodoptera litura* (Fab.) in groundnut and soybean. M Sc Thesis, University of Agricultural Sciences, Dharwad.

Bhattacharyya B, Bhuyan U, Pujari D. 2014. Management of red ant, *Dorylus orientalis* (Hymenoptera: Formicidae) in potato. Journal of Entomological Research 38(4): 265-267.

Boomiraj K, Christopher Louduraj A, Pannesrselvam S, Somasundram E, Singaram P. 2004. Insect incidence in bhendi as influenced by application of organic manure, panchagavya and herbal leaf extract spray. Proceedings. National seminar. Operational methodology and packages of practice in organic farming. 7th-9th October. Bangalore. pp. 141-143.

Borah R K. 1994. Efficacy of some insecticides and plant materials against red ant, *Dorylus orientalis* (Westwood) on potato. Journal of Agricultural Science Society of North East India 7(1): 41-44.

Chowdhury H M. 1997. Effects of irrigation and liming on the incidence of soil insect pests on potato. M Sc Thesis. Assam Agricultural University, Jorhat, Assam, India.

Dash C K, Hassan K, Pramanik M E A, Rashid M H, Choudhury A

R. 2013. Development of management strategies against red ant (*Dorylus orientalis* Westwood) of potato. Universal Journal of Plant Science 1(3): 74-77.

Devi D A, Mohandas N. 1982. Relative efficacy of some antifeedants and deterrents against insect pests of stored paddy. Entomon 7: 261-264.

Fernando H E, Manickavasagar P. 1958. Investigation on potato insects and their control with special reference to *Dorylus orientalis*. Tropical Agriculture 114(2): 127-139.

Fletcher T B. 1914. Some south indian insects and other animals of importance. Madras. 274 pp.

Golakiya P D, Kaswala A R, Dubey P K, Sisodiyaan R R, Neethu T M. 2019. Panchagavya-Cow-based bio-enhancers and botanicals for organic farming. International Journal of Chemical Studies 7(3): 2741-2746.

Gomez K A, Gomez A A. 1984. Statistical procedures for agricultural research, Edn 2, Wiley-Interscience, John Wiley & Sons, New York. 680 pp.

Isman M B, Katan J, Aharonson N, Cohen E, Rubin B, Mathews G A. 2000. Plant essential oils for pest and disease management. Crop Protection 19(8-10): 603-608.

Kumar S M, Bharath M, Josmin Laali Nisha L L, Basavaraju H. 2015. Field efficacy of panchagavya on insect pests recorded during the study in *Tectona grandis*. International Journal of Research in Agriculture and Forestry 2(7): 1-8.

Kumari K, Sinha M M, Mehto D N, Hammed S F. 1990. Effect of some vegetable oils as protectants against *Callosobruchus chinensis.* Bulletin of Technology 28: 58-60.

Neelakanth, I S. 2006. Role of biorationals in the management of diamond back moth, *Plutella xylostella* L. in cabbage ecosystem. M Sc Thesis, University of Agricultural Sciences, Dharwad.

Nwilene F E, Agunbiade T A, Togola M A, Youm O. 2008. Efficacy of traditional practices and botanicals for the control of termites in rice at Ikenne, south west Nigeria. International Journal of Tropical Insect Science 28(1): 37-44.

Pathak R M, Ram R A. 2013. Bio-enhancers-a potential to improve soil fertility, plant health in organic production in horticultural crops. Progressive Horticulture 45(2): 237-254.

Pereira J, Wohlgemuth R. 1983. Neem, *Azadirachta indica* (Adrien-Henri de Jussieu) of West African origin as a protectant of stored maize. Journal of Applied Entomology 94: 208-214.

Rahman A. 1967. Studies on the efficacy of some chlorinated insecticides in controlling soil insects of potato with special reference to *Dorylus orientalis* Westw. M Sc (Ag) Thesis. Dibrugarh University, Assam Agricultural College, Jorhat.

Roonwal M L. 1976. Plant pest status of root eating ants. *Dorylus orientalis* with notes on taxonomy, distribution and habits (Insects: Hymenoptera). The Journal of the Bombay Natural History Society 72: 305-313.

Saikia N, Deb Nath K. 2017. Efficacy of various pesticides against red ant, (*Dorylus orientalis*, Westwood) of potato. Journal of Applied and Natural Science 9(4): 2350-2352.

Shailaja B, Mishra I, Gampala S, Singh V J, Swathi K. 2014. Panchagavya-an ecofriendly insecticide and organic growth promoter of plants. International Journal of Advanced Research 2(11): 22-26.

Verma S P, Singh B, Singh Y P. 1983. Studies on the comparative efficacy of certain grain protectants against *Sitotroga cerealella* (Oliver). Bulletin of Technology 21: 37-42.

(Manuscript Received: September, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20350

Indian Journal of Entomology 84(1): 145-148 (2022) DoI.:10.55446/IJE.2021.298

FIELD EFFICACY OF INSECTICIDES AGAINST OKRA SHOOT AND FRUIT BORER *EARIAS VITELLA* (F.)

Ram Kumar* and P P Singh

Department of Entomology, Dr. Rajendra Prasad Central Agricultural University,
Pusa 848125, Samastipur, Bihar, India
*Email: rk440659@gmail.com (corresponding author)

ABSTRACT

A field experiment was carried out during kharif 2018 and 2019 to evaluate the efficacy of insecticides against okra shoot and fruit borer *Earias vitella* (F.). Out of nine insecticides, profenophos 50EC @ 500g a.i./ ha at fortnightly interval was found to the best giving maximum protection (2.55% shoot and 5.69% fruit damage) followed by spinosad 45SC @ 50g a.i./ ha and thiamethoxam 25WG @ 25g a.i./ ha. Amongst the botanicals used, Yam Bean Seed Extract- YBSE (5%) was found to be better. Application of profenophos 50EC (@ 500 g a.i./ha) led to maximum fruit yield (152.9 q/ ha) while the neem oil 3% yielded the least (131.1 q/ ha). Among the plant products, YBSE (5%) yielded maximum (136.2 q/ ha). The benefit-cost ratio was at its maximum (12.78:1) with profenophos 50EC, and it was closely followed by acetamiprid 20SP (11.57:1) and thiamethoxam 25WG (10.11:1).

Key words: *Earias vitella*, spinosad, thiamethoxam, acetamiprid, deltamethrin, profenophos, neem oil, yam bean seed extract, neem seed kernel extract, benefit cost ratio, shoot damage, fruit damage

Okra (*Abelmoschus esculentus* L.) is an important vegetable crop (Singh et al., 2008), and in India, it is grown extensively during kharif and summer seasons (Raghuraman and Birth, 2011). Similar to other vegetable crops, okra is also ravaged by an array of biotic and abiotic factors. Out of biotic constraints insect pests are the most crucial, and according to Srinivasa and Rajendran (2003) nearly, 72 insect species have been recorded on okra. Besides, it also harbours insect vectors that transmit many diseases (Showkat et al., 2010). Among these, the shoot and fruit borer *Earias vitella* (F.) is the most prominent and it adversely affects yield, and loss varies up to 35% (Krishnaiah, 1980) while Bhawan (1984) recorded 76% yield loss. Although, several non-chemical control strategies are developed under IPM, still farmers trust on synthetic insecticides because of their rapid response. The indiscriminate use of non-recommended insecticides in under or over doses is known, with the regular use of conventional insecticides causing development of insecticide resistance (Kranthi et al., 2002), pest resurgence, secondary pest outbreaks and pesticide residue problems. In addition, it also affects beneficial insects, animals and human. Hence, there is always a need to assess the efficacy of insecticides. Therefore, the present study to evaluate the efficacy of few synthetic and botanicals insecticides against *E. vitella* in okra.

MATERIALS AND METHODS

Field experiment was conducted at the Research Farm of T C A Dholi, Muzaffarpur (Bihar) during kharif, 2018 and 2019. The experiment was laid out in randomized block design with nine treatments and three replications. Kashi Pragati okra variety was grown following all the recommended package of practices. The insecticides evaluated include: T_1 - Spinosad 45SC @ 50 g a.i./ ha, T_2 - Thiamethoxam 25WG @ 25 g a.i./ ha, T_3 - Acetamiprid 20SP @ 20 g a.i. /ha, T_4 - Deltamethrin 2.8EC @ 15 g a.i./ ha, T_5 - Profenophos 50EC @ 500 g a.i./ ha, T_6 - Neem oil 3%, T_7 - NSKE 5%, T_8 - Yam bean seed extract (5%) and T_9 - Untreated control. The crop was sown on 13th June 2018 and 15th June 2019 in a plot size of 3x 2 m with a row spacing of 50x 20 cm. All the treatments were applied thrice at fortnightly intervals starting after one month of sowing. The mean % shoot and fruit infestation (weight basis) was recorded a day before spraying and 7 days after each spray. The extent of shoot infestation was determined by formula of Rakshith and Kumar (2017). After picking infested and healthy fruits were sorted out and weight of infested as well as total harvested fruits was recorded, from which % fruit damage was worked out as per Sujayanand et al. (2014). Yield data was recorded on the basis of healthy fruits at each picking. The additional yield over untreated control was also calculated for

Table 1. Efficacy of synthetic and some biorational insecticides against *E. vittella* on okra (Pooled data, 2018 and 2019, kharif)

Treatments	Mean % shoot damage at 1 DBS	Mean % shoot damage at 7 days after each spray			Cumulative mean	Mean % fruit damage at 1 DBS	Mean % fruit damage at 7 days after each spray			Cumulative mean
		1st spray	2nd spray	3rd spray			1st spray	2nd spray	3rd spray	
T_1 – Spinosad (45 SC) @ 50g a.i./ ha	4.50 (12.22)	2.84 (9.68)	3.69 (11.07)	1.13 (6.05)	2.94 (9.86)	5.22 (13.15)	-	5.54 (13.59)	8.57 (17.00)	6.64 (14.91)
T_2 – Thiamethoxam (25 WG) @ 25g a.i./ ha	4.39 (12.09)	3.28 (10.43)	3.97 (11.47)	1.37 (6.71)	3.32 (10.48)	5.21 (13.18)	-	6.52 (14.78)	9.66 (18.09)	7.46 (15.84)
T_3 – Acetamiprid (20 SP) @ 20g a.i./ ha	4.28 (11.93)	3.65 (11.00)	4.44 (12.15)	1.65 (7.38)	3.73 (11.13)	5.18 (13.14)	-	7.09 (15.43)	10.28 (18.66)	7.95 (16.36)
T_4 – Deltamethrin (2.8 EC) @ 15g a.i./ha	4.65 (12.43)	3.92 (11.39)	5.83 (13.90)	1.97 (8.05)	4.44 (12.13)	5.08 (13.02)	-	9.01 (17.44)	11.22 (18.55)	9.05 (17.49)
T_5 – Profenophos (50 EC) @ 500g a.i./ ha	4.37 (12.05)	2.54 (9.15)	3.05 (10.05)	1.05 (5.85)	2.55 (9.17)	5.21 (13.19)	-	4.59 (12.35)	7.25 (15.57)	5.69 (13.78)
T_6 – Neem oil 3%	4.53 (12.27)	4.79 (12.63)	8.10 (16.53)	2.31 (8.74)	5.76 (13.88)	4.98 (12.88)	-	12.84 (20.98)	22.67 (28.41)	15.34 (23.03)
T_7 – NSKE 5%	4.26 (11.90)	4.45 (12.16)	7.43 (15.80)	2.25 (8.62)	5.35 (13.36)	5.10 (13.05)	-	12.05 (20.30)	21.55 (27.67)	14.59 (22.44)
T_8 – YBSE 5%	4.55 (12.31)	4.21 (11.83)	7.02 (15.35)	2.14 (8.41)	5.07 (13.00)	5.33 (13.33)	-	11.48 (19.77)	20.65 (26.96)	14.03 (21.96)
T_9 – Untreated control	4.34 (12.02)	8.37 (16.80)	10.42 (18.82)	2.86 (9.74)	8.42 (16.86)	5.16 (13.11)	-	14.14 (22.07)	29.73 (33.02)	18.62 (25.54)
S.Em (±)	(0.30)	(0.32)	(0.47)	(0.37)	(0.36)	(0.39)	-	(0.51)	(0.80)	(0.58)
CD (p=0.05)	N/S	(0.96)	(1.43)	(1.11)	(1.09)	N/S	-	(1.55)	(2.41)	(1.76)
CV (%)	8.45	9.04	11.25	9.63	9.77	10.10	-	9.97	11.47	10.31

DBS – Days before spray; #Figures in parentheses the values of angular transformation; NSKE-neem seed kernel extract; YBSE-yam bean seed extract

assessing the yield performance. Ultimately, the benefit cost ratio (BCR) was calculated on the basis of prevailing market price of okra, insecticides and spraying cost.

RESULTS AND DISCUSSION

The data in Table 1 reveals that on cumulative mean basis the shoot damage ranged from 2.55 to 8.42% with minimum in profenophos 50EC and maximum in untreated control. Out of botanicals used, YBSE (5%) was found to eb the most effective (5.07%) which was statistically at par with NSKE 5% (5.35%) and neem oil 3% (5.76%). Katti and Surpur (2015) evaluated the efficacy of flubendiamide 480SC against *E. vitella* at different doses and concluded that flubendiamide 480SC @ 60 g a.i./ ha was found superior, followed by flubendiamide 480SC @ 48 g a.i/ ha at Raichur, Karnataka. Rahman et al. (2013) found the least shoot damage in Ecofuran (5G) treated plot, while it was 17.29% to 19.78% with neem leaf extract. On cumulative mean basis, the fruit damage was minimum (5.69%) in profenophos 50EC @ 500 g a.i./ ha with respect to untreated control (18.62%). Among the plant products, YBSE 5% was the most promising (14.03%) and was statistically on par with NSKE 5% and neem oil 3%. Misra et al. (2002) and Ghosh et al. (2012) found profenophos 50EC is effective. The present findings are also in accordance with the findings of Birth and Raghuraman (2011) on spinosad 45SC; Verma (2018), Kodandaram et al. (2017), Chowdary et al. (2010) and Tripathi and Maurya (2011) corroborate with the present results.

The data given in Fig. 1 reveal that three rounds of profenophos 50EC (@ 500 g a.i./ ha) gave maximum fruit yield (152.9 q/ ha). Among the plant products, YBSE 5% was the best (136.2 q/ ha). These data are in agreement with those of Chowdhary et al. (2010) on rynaxypar 20 SC, followed by spinosad 45 SC. However, Gadekar et al. (2016) observed maximum yield with thiamethoxam (0.005%) followed by acetamiprid and acephate. The reports of Lal and Sinha (2005), Singh et al. (2008), Birth and Raghuraman (2011), Raghuraman and Birth (2011), Sarkar and Roy (2015) and Kalmath and Mahantesh (2016) also broadly corroborate with the present results. The benefit-cost ratios, when computed revealed that it was maxiumum (12.78:1) in case of profenophos 50EC closely followed by acetamiprid 20SP (11.57:1). Gadekar et al. (2016) also reported that acetamiprid registered the highest B: C ratio (47.67) followed by thiamethoxam and acephate. In contrast, Sakthivel et al. (2007) observed that NSKE gave maximum B: C ratio among the botanicals.

REFERENCES

Bhawan S. 1984. Studies on the extent of loss and economics of pest management in okra. Tropical Pest Management 29: 363-370.

Birth A, Raghuraman M. 2011. Impact of emamectin benzoate on fruit and shoot borer, *Earias vittella* (Fabricius) in okra. Indian Journal of Entomology 73(1): 42-44.

Chowdary L R, Bheemanna M, Kumar L R. 2010. Field efficacy of

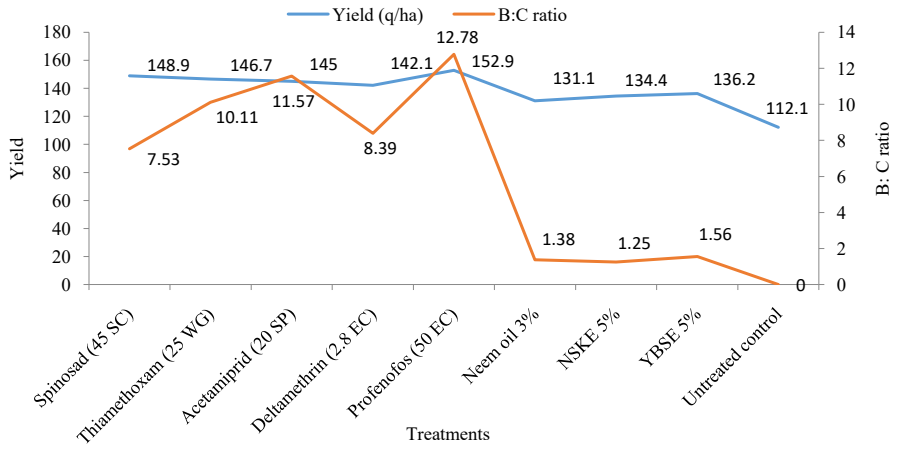


Fig. 1. Yield and economics of synthetic and biorational insecticides in okra (Pooled data, 2018 and 2019, kharif)

Selling price of okra: Rs. 1250.00/ q, Cost of insecticides viz. spinosad (45% SC) = Rs. 23571/ litre, thiamethoxam (25% WG) = 5600/ kg, acetamiprid (20% SP) = Rs. 2500/ litre, deltamethrin (2.8% EC) = Rs. 2280/ litre, profenofos (50% EC) = Rs. 930/ litre, neem oil (3%) = Rs. 400/ litre, and yam bean seeds extract (YBSE) 5% = Rs. 300/ kg, neem seed kernel extract (NSKE) 5% = Rs. 320/ litre, respectively. No. of labourers per ha/ spray = 3, (for 3 sprays 9 labours/ ha) = Rs. 2772/-, wages of each labour = Rs. 308/ day.

rynaxypyr (Coragen) 20 SC against fruit and shoot borer, *Earias vittella* (Fab.) in okra. International Journal of Plant Protection 3(2): 316-318.

Gadekar S D, Acharya V S, Keshav M, Singh V. 2016. Evaluation of some insecticides and botanicals against major sucking pests of okra. Journal of Experimental Zoology, India 19(1): 543-548.

Ghosh S K, Tanmoy M, Supriya B, Chakraborty K. 2012. Field evaluation of cultivars and bio-efficacy of insecticides against pest complex of ladys finger [*Abelmoaschus esculentus* (L.) Moench]. Journal of Applied Zoological Researches 23(2): 117-124.

Kalmath B. Mahantesh K. 2016. Bio-efficacy of dinotefuran 20 SG against sucking pests of okra. Journal of Experimental Zoology, India 19(1): 321-325.

Katti P, Surpur S. 2015. Field bioefficacy of flubendiamide 480 SC against okra fruit and shoot borer, *Earias vitella* (Fab.) during Rabi season, 2012-13. International Journal of Plant Protection 8(2): 319-323.

Kodandaram M H, Halder J, Singh N, Rai A B. 2017. Pest management modules against major insect pests of okra. Pesticide Research Journal. 29(2): 153-157.

Kranthi K R, Jadhav D R, Kranthi S, Wanjari R R, Ali S S, Russell D A. 2002. Insecticide resistance in five major insect pests of cotton in India. Crop Protection 21: 449-460.

Krishnaiah K. 1980. Methodology for assessing crop losses due to pests of vegetables. Assessment crop due to pests and diseases. Govindu H C et al. USA Tech Series No 33: 259-267.

Lal O P, Sinha S R. 2005. Impact of imidacloprid seed treatment along with some insecticidal sprayings against insect pests of okra. Indian Journal of Entomology 76(4): 73(1): 328-333.

Misra H P, Dash D D, Mahapatra D. 2002. Efficacy of some insecticides against okra fruit borer, *Earias* spp. and leafroller, *Sylepta derogata* Fab. Annals of Plant Protection Sciences 10(1): 51-54.

Raghuraman M, Birth A. 2011. Field efficacy of imidacloprid on okra sucking pest complex. Indian Journal of Entomology 73(1): 76-79.

Rahman M M, Uddin M M, Shahjahan M. 2013. Management of okra shoot and fruit borer, *Earias vittella* (Fabricius) using chemical and botanical insecticides for different okra varieties. International Research Journal of Applied Life Sciences 2(1): 1-9.

Rakshith K A, Kumar A. 2017. Field efficacy of selected insecticides and neem products against shoot and fruit borer, *Earias vittella* (F.) on okra, *Abelmoschus esculentus* (L.) Moench. International Journal of Current Microbiology and Applied Sciences 6(8): 122-128.

Sakthivel T, Alice J, Sujeetha R P, Nadaranjan L. 2007. Efficacy of Phytochemicals against the sucking pests of okra, *Abelmoschus esculentus* (L) Monech. Asian Journal of Bio-science 2(2): 140-142.

Sarkar P, Roy D. 2015. Positioning IPM compatible pre-mix formulation of cartap hydrochloride 50SP+buprofezin 10EC (KCB-2010) to combat chewing and sucking pests of okra. Journal of Crop and Weed 11(2): 172-180.

Showkat A, Bhagat R M, Ishtiyaq A, Amit K. 2010. Pest complex and their succession on okra, *Abelmoschus esculentus* (L.) Moench. Haryana Journal of Horticultural Sciences 39(1/2): 169-171.

Singh S, Choudhary D P, Sharma H C, Mahla R S, Mathur Y S, Ahuja D B. 2008. Effect of insecticidal modules against jassid and shoot and fruit borer in okra. Indian journal of Entomology 70(3): 197-199.

Srinivasa R, Rajendran R. 2003. Joint action potential of neem with other plant extracts against the leaf hopper *Amrasca devastance* (Distant) on okra. Pest Management and Economic Zoology 10: 131-136.

Sujayanand G K S, Sharma R K, Shankarganesh K. 2014. Impact of intercrops and border crops on pest incidence in okra. Indian Journal of Horticulture 73(2): 219-223.

Tripathi M K, Maurya T N. 2011. Efficacy of synthetic, botanical and bio-pesticides for management of *Earias vitella* in okra. Journal of Experimental Zoology, India 14(2): 595-596.

Verma K D. 2018. Efficacy of indoxacarb and combinations with cypermethrin for management of *Earias vitella* of okra. HortFlora Research Spectrum 7(1): 81-83.

(Manuscript Received: September, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20349

Indian Journal of Entomology 84(1): 149-151 (2022) DoI.: 10.55446/IJE.2021.296

GENOME SIZE ESTIMATION OF POTATO APHID *MACROSIPHUM EUPHORBIAE* USING FLOW CYTOMETRY

Kailash Chandra Naga*, Hemant B Kardile, Rahul K Tiwari, Subhash S[1], Gaurav Verma, Sanjeev Sharma and Anuj Bhatnagar[1]

ICAR-Central Potato Research Institute, Shimla 171001, Himachal Pradesh, India
[1]ICAR-Central Potato Research Station, Modipuram 250110, Uttar Pradesh, India
*Email: kailashnaga3j@gmail.com (corresponding author)

ABSTRACT

Potato aphid *Macrosiphum euphorbiae* (Thomas) (Hemiptera: Aphididae) is colonizing species and vector for many economically important potato viruses. There is dearth of genomic information about this economically important aphid species. Hence, to get insight into the genomic architecture, genome size was determined using flow cytometry. The estimated size of *M. euphorbiae* was 0.53 pg or 519.4 Mbp. The genome size of *M. euphorbiae* is approximately 2.9, 2.2 and 1.9x larger than that of *Drosophila melanogaster,* honey bee (*Apis mellifera*) and mosquito *Anopheles gambiae,* respectively. The generated genome size information will provide the foundation for futuristic genomic research on *M. euphorbiae.*

Key words: *Macrosiphum euphorbiae*, potato, flow cytometry, feulgen densitometry, genome size, mtCOI, *Drosophila melanogaster*, *Apis mellifera*, *Anopheles gambiae*

Potato aphid *Macrosiphum euphorbiae* (Thomas) (Hemiptera: Aphididae) is one of the colonizing aphid species on potato and vector of many economically important potato viruses (Fox et al., 2017; Xu and Gray, 2020). A number of virus diseases are spread by *M. euphorbiae*, among them *Potato Leaf Roll Virus* and *Potato Virus Y* are the predominant. They have complex lifecycles, comprising of both sexual and asexual (parthenogenetic) modes of reproduction. In addition to that it has been found that an aphid establishes complex relationships with their host plant and produce effectors that modulate host defense responses. The unusual biology of aphids makes them ideal models for the study of several biological processes that are not readily studied in other genetic model systems. In recent years, few studies have generated the genomic and transcriptomic data of aphid species (Czosnek and Ghanim, 2016; Teixeira et al., 2018; Chen et al., 2019) that has created genomic information which is now becoming useful for better understanding of aphid species. Being an important pest of potato with complex biology, *M. euphorbiae* has been studied at transcriptome level for identification of virus responsive genes and inhabiting plant viruses (Teixeira et al., 2018). Similar type of functional genomics studies are expected in near future. Hence, basic information about its genome size is crucial for various fields of research like evolutionary changes and taxonomic studies (Kron et al., 2007). Previously genome size of *M. euphorbiae* was estimated to 0.40 pg using feulgen densitometry however, this method of genome size estimation has various drawbacks (Goldstein, 1981; Hardie et al., 2002). From last couple of years, flow cytometry has emerged as a significant method for DNA content analysis, as it is fast, convenient, and reliable. The determination of nuclear DNA amounts is performed with high precision using 1 to 5 % coefficients of variation (CV) in DNA peaks (Doležel et al., 2007). In this study, flow cytometry has been used for *M. euphorbiae* genome size estimation using external standard method.

MATERIALS AND METHODS

Adults of *M. euphorbia*e were collected from rose (*Rosa* spp.) plant grown in institute garden (CPRI, Shimla) at Shimla ($31^0$5'14"N $77^0$11'6" E). Single parthenogenetic female was used to establish aphid colony on potato host and aphids from such colony was used for identification and genome estimation. Adults were collected in Falcon tubes (50 ml) for molecular identification as well as flow cytometry analysis. Species level identification was carried out by sequencing the Mitochondrial Cytochrome Oxidase-I (mtCOI) region using universal primer LCO1490/HCO2198 (Forward: 5′-GGTCAACAAATCATAAAGATATTG-3′; Reverse: 5′-TAAACTTCAGGGTGACCAAAAAATCA-3′) (Folmer et al., 1994). DNA of aphid was isolated using blood and tissue kit (Qiagen) following the

manufacturer guidelines and quantified using NanoDrop 2000/2000c spectrophotometer (Thermo Fisher Scientific). The PCR reaction consist of 10 µl Emerald Amp GT master mix (2x), 1 µM of each forward and reverse primer, 1 µl of DNA templet (50 ng/ µl) and the final volume of reaction was setup as 20 µl with nuclease free H_2O. PCR was performed at 94^0C for 4 min as initial denaturation, 35 cycles of 94^0C for 30 sec, 50^0C for 45 sec, 72^0C for 1 min and a final extension was given with 72^0C for 7 minutes. The visualization of PCR product was performed with 1% agarose gel and Qiaquick gel extraction kit (Qiagen) was used for purification. The PCR product after purification was cloned in ptz57R/T vector (thermos fisher scientific). Five positive clones were sequenced using genetic analyzer 3500 (ABI). Partial mtCOI sequences of *M. euphorbiae* were aligned in clustalW followed by construction of phylogenetic tree using Neighbor-Joining method (Saitou and Nei, 1987).

The samples for flow cytometry analysis were prepared as per the methodology given by the Doležel et al. (2007) with few modifications. About 10 adults *M. euphorbiae* were taken in 15 ml falcon and immersed in 1 ml of (modified hypopropidium iodide) HPI buffer. Tissues were homogenized in the 1 ml of modified HPI buffer (Krishnan et al., 1975) using the surgical blade. The homogenate was filtered through the 40-micron filters and incubated on ice under dark conditions with occasional shaking. Samples were analyzed on flow cytometer (BD FACS Canto II) by external standard method using chicken erythrocyte nuclei (CEN) (BD Biosciences, Cat No. 349523) as the external reference standard; and in three technical replicates, Data were recorded using the BD Facs Diva software. The genome size was estimated using the formula: 2C=2.5 x mean position of sample nuclei peak/ 2C mean position of CEN nuclei peak

RESULTS AND DISCUSSION

The collected aphids were identified as *M. euphorbiae* based on multiple sequence alignment with reference sequence (Fig. 1). The mtCOI sequence reveals 100% similarity with reference sequences (Accessions no. MT651328.1, KY323034.1, KY323033.1 etc.) at NCBI database and one representative mtCOI sequence of *M. euphorbiae* has been submitted at NCBI vide accession no. MT821481. Mean peak position of G_0G_1 cells was 13,784 and mean position of 2C peak of CEN was 63948 (Fig. 2). Based on this mean position, nuclear DNA content for *M. euphorbiae* was estimated to be 0.53 pg and in terms of base pairs it was estimated to be 519.4 Mbp. The estimated genome size slightly varied with previous reports, earlier it was estimated to be 0.40 pg using scanning micro-densitometry (Finston et al., 1995). It is reported that DNA amount has direct influence on duration of mitotic cycle and cell size, such phenotypic effects are called as 'nucleotypic' effects (Bennett, 1972) which denote the physico-mechanical properties of the nucleus, and it is assumed these can be attributed for slightly varied results. Many other factors can also affect genome size, such as accessory chromosomes fixation, polyploidy (Uozu et al., 1997; Ullmann et al., 2005), size of inrons (Moriyama et al., 1998), transposable elements (Sanmiguel and Bennetzen, 1998; Vieira et al., 2002) and microsatellite presence (Warner and Noor, 2000) which needs to be instigated at cytological level. The genome size of *M. euphorbiae* (519.4 Megabase) is approximately 2.9x greater than that of *D. melanogaster* (176 Megabase) (Adams et al., 2000), 2.2x higher than that of honey

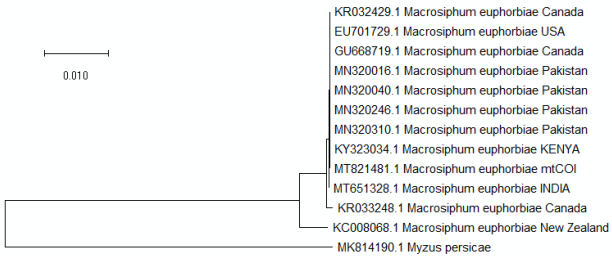


Fig. 1. Phylogenetic analysis of *M. euphorbiae* with reference sequences from NCBI. Multiple sequence alignment by clustal W followed by phylogenic tree construction using Neighbor-Joining method with 1000 bootstrap value

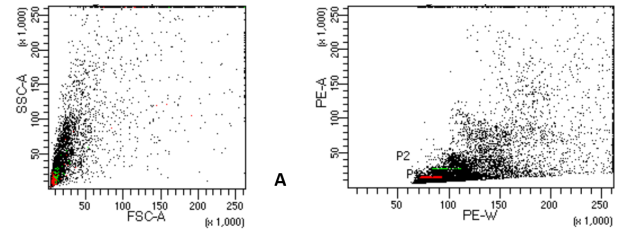


Fig. 2. The dot plot and bar graph of flow analysis; B, PI-fluorescence histogram of G0/G1 and G2/M cells of M. euphorbiae.

bee (*Apis mellifera*) (234.7 Megabase) (Ardila-Garcia et al., 2010), 1.9x higher than that of mosquito *Anopheles gambiae* (264Megabase) (Holt et al., 2002), 1.4x that of the aphid *M. persicae* (Finston et al., 1995) and about equal in size of the *Bombyx mori* (508 Megabase) (Rasch, 1974). The flow cytometry-based determination of genome size of *M. euphorbiae* could serve foundation for whole-genome sequencing and shape sequence integrity.

REFERENCES

Adams M D, Celniker S E, Holt R A, Evans C A, Gocayne J D, Amanatides P G, Scherer S E, Li P W, Hoskins R A, Galle R F, George R A, Lewis S E, Richards S, Ashburner M, Henderson S N, Sutton G G, Wortman J R, Yandell M D, Zhang Q,… Craig Venter J. 2000. The genome sequence of *Drosophila melanogaster*. Science 287(5461): 2185-2195.

Ardila-Garcia A M, Umphrey G J, Gregory T R. 2010. An expansion of the genome size dataset for the insect order Hymenoptera, with a first test of parasitism and eusociality as possible constraints. Insect Molecular Biology 19(3): 337-346.

Bennett M D. 1972. Nuclear DNA content and minimum generation time in herbaceous plants. Proceedings of the Royal Society of London. Series B. Biological sciences 181(63): 109-135.

Chen W, Shakir S, Bigham M, Richter A, Fei Z, Jander G. 2019. Genome sequence of the corn leaf aphid (*Rhopalosiphum maidis* Fitch). GigaScience 8(4): 1-12.

Czosnek H, Ghanim M. 2016. Management of insect pests to agriculture: Lessons learned from deciphering their genome, transcriptome and proteome. In: Management of Insect Pests to Agriculture: Lessons Learned from Deciphering Their Genome, Transcriptome and Proteome. Springer International Publishing, Switzerland. 290 pp.

Doležel J, Greilhuber J, Suda J. 2007. Estimation of nuclear DNA content in plants using flow cytometry. Nature Protocols 2(9): 2233-2244.

Finston T L, Hebert P D N, Foottit R B. 1995. Genome size variation in aphids. Insect Biochemistry and Molecular Biology 25(2): 189-196.

Folmer O, Black M, Hoeh W, Lutz R, Vrijenhoek R. 1994. DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3(5): 294-299.

Fox A, Collins L E, Macarthur R, Blackburn L F, Northing P. 2017. New aphid vectors and efficiency of transmission of *Potato Virus A* and strains of *Potato Virus Y* in the UK. Plant Pathology 66(2): 325-335.

Goldstein D J. 1981. Errors in microdensitometry. The Histochemical Journal 13(2): 251-267.

Hardie D C, Gregory T R, Hebert P D N. 2002. From pixels to picograms: A beginners' guide to genome quantification by Feulgen image analysis densitometry. Journal of Histochemistry and Cytochemistry 50(6): 735-749.

Holt R A, Mani Subramanian G, Halpern A, Sutton G G, Charlab R, Nusskern D R, Wincker P, Clark A G, Ribeiro J M C, Wides R, Salzberg S L, Loftus B, Yandell M, Majoros W H, Rusch D B, Lai Z, Kraft C L, Abril J F, Anthouard V, … Hoffman S L. 2002. The genome sequence of the malaria mosquito *Anopheles gambiae*. Science 298(5591): 129-149.

Kron P, Suda J, Husband B C. 2007. Applications of Flow Cytometry to Evolutionary and Population Biology. Annual Review of Ecology, Evolution, and Systematics 38: 847-876.

Moriyama E N, Petrov D A, Hartl D L. 1998. Genome size and intron size in *Drosophila.* Molecular biology and evolution 15(6): 770-773.

Rasch E M. 1974. The DNA content of sperm and hemocyte nuclei of the silkworm*, Bombyx mori* L. Chromosoma 45(1): 1-26.

Saitou N, Nei M. 1987. The neighbor-joining method: a new method for reconstructing phylogenetic trees. Molecular Biology and Evolution 4(4): 406-425.

Sanmiguel P, Bennetzen J L. 1998. Evidence that a recent increase in maize genome size was caused by the massive amplification of intergene retrotransposons. Annals of Botany 82: 37-44.

Teixeira M A, Sela N, Atamian H S, Bao E, Chaudhary R, MacWilliams J, He J, Mantelin S, Girke T, Kaloshian I. 2018. Sequence analysis of the potato aphid *Macrosiphum euphorbiae* transcriptome identified two new viruses. Plos One 13(3).

Ullmann A J, Lima C M R, Guerrero F D, Piesman J, Black W C. 2005. Genome size and organization in the blacklegged tick, *Ixodes scapularis* and the Southern cattle tick, *Boophilus microplus.* Insect Molecular Biology 14(2): 217-222.

Uozu S, Ikehashi H, Ohmido N, Ohtsubo H, Ohtsubo E, Fukui K. 1997. Repetitive sequences: Cause for variation in genome size and chromosome morphology in the genus *Oryza*. Plant Molecular Biology 35(6): 791-799.

Vieira C, Nardon C, Arpin C, Lepetit D, Biémont C. 2002. Evolution of genome size in *Drosophila*. Is the invader's genome being invaded by transposable elements?. Molecular Biology and Evolution 19(7): 1154-1161.

Warner R D, Noor M A F. 2000. High frequency of microsatellites in *Drosophila pseudoobscura*. Genes and Genetic Systems 75(2): 115-118.

Xu Y, Gray S M. 2020. Aphids and their transmitted potato viruses: A continuous challenges in potato crops. Journal of Integrative Agriculture 19(2): 367-375.

(Manuscript Received: September, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20340

Indian Journal of Entomology 84(1): 152-155 (2022) DoI.: 10.55446/IJE.2021.293

EFFICACY OF ACARICIDES AGAINST PHYTOPHAGOUS MITES IN APPLE

Joginder Singh

Dr Y S Parmar University of Horticulture and Forestry, Horticulture Research Station, Seobagh, Kullu 175138, Himachal Pradesh, India
Email: drjsverma@yahoo.com

ABSTRACT

Efficacy studies were conducted during June-July in 2017 in Kullu Valley of Himachal Pradesh against the phytophagous mites *Panonychus ulmi* (Koch) and *Tetranychus urticae* Koch in apple orchards. Four acaricides were evaluated at different doses. After seven days of spray, maximum efficacy was obtained from fenazaquin @ 0.20 ml/ l (0.50 mites/ leaf) which was at par with other test concentrations of fenazaquin @ 0.15, 0.25ml/ l, hexythiazox @ 0.5, 1.0 ml/ l, etoxazole @ 0.25, 0.4, 0.55 ml/ l and abamectin @ 0.5, 0.6 ml/ l. In 14 and 21days post-treatment observations, though the mite incidence increased gradually in all the treatments, all concentrations of hexythiazox, fenazaquin and etoxazole were found significantly superior. After 28 days of spray, maximum efficacy was again with fenazaquin @ 0.25 ml/ l which was at par with hexythiazox (0.5, 1.0 ml/ l), etoxazole (0.25, 0.4, 0.55 ml/ l) and these were significantly superior. Fenazaquin was found extremely toxic to the natural enemies.

Key words: Apple, *Panonychus ulmi*, *Tetranychus urticae*, abamectin, etoxazole, fenazaquin, hexythiazox, propargite, efficacy, predators, safety

Apple is the main cash crop of temperate regions in the Himalayan states. This crop is attacked by many insects and non-insect pests, of which the mites are the most serious causing substantial loss. Mites attack a diverse group of crops including various fruit, vegetable, ornamental and field crops. The two major mite pests of apple in north western Himalayas are the European red mite *Panonychus ulmi* (Koch) and two spotted spider mite *Tetranychus urticae* (Koch). In nature, phytophagous mites are kept under check by different predators such as predatory mites, *Chrysoperla* larvae, *Stethorus* beetles and predatory thrips etc. Khajuria and Sharma (1996) reported the phytoseiid mite *Amblyseius fallacis* (Garman) to suppress mites in apple. Phytoseiid mites are an important component of IPM by virtue of their ability to feed on alternate prey and survive at low prey mite densities (Overmeer, 1985). Indiscriminate use of pesticides has often been attributed for mite outbreaks. Although, many acaricides are being recommended for their effective management (Marshall and Pree, 1991; Khajuria and Sharma, 2001; Khajuria et al., 2006), with the passage of time many of these acaricides become obsolete either due to ban on their use or their non-production. Also, there are reports of resistance development (Croft et al., 1987). Besides, predator activity is also adversely affected to a larger extent due to their regular exposure to chemicals being applied to manage phytophagous mites. Therefore, newer molecules against phytophagous mites should be evaluated regularly under field conditions. Keeping this in view, efficacy of some acaricides were tested during 2017 along with their safety to natural enemies in apple orchards.

MATERIALS AND METHODS

Field trials were laid out in apple orchards at the Horticultural Research Station, Seobagh in Kullu. The trials were laid out in completely randomized block design on 15-20 years old trees CV. Red Chief. There were 15 treatments each replicated four times with single tree serving as a replication. Four acaricides viz., abamectin, etoxazole, fenazaquin and hexythiazox at different concentrations were evaluated and compared with standard propargite and the untreated control (Table 1). Spraying was done with a high-volume sprayer in the third or last week of June. The pretreatment counts of mites were taken a day before spray and post-treatment counts at 7, 14, 21 and 28 days after the spray (DAS). A sample of 20 mature leaves each from outer and middle part of the canopy was taken randomly from each replication in a treatment. These leaf samples were then passed through a mite-brushing machine and number of live mites/ leaves was counted under a stereozoom microscope. Only motile stages of mites were taken into consideration. Data on number of natural enemies viz., *Chrysoperla* larvae, phytoseiid mites, *Stethorus* beetles and predatory thrips were also observed to evaluate the

Table 1. Efficacy of acaricides against phytophagous mites and the natural enemies in apple

Treatments	Dose (ml/ l)	No. of mites/ leaf					No. of natural enemies/ leaf				
		Pre count	7 DAT	14 DAT	21 DAT	28 DAT	Pre count	7 DAT	14 DAT	21 DAT	28 DAT
Abamectin 1.9EC	0.3	20.03 (4.55)	10.43 (3.37)^{c}	14.28 (3.89)^{e}	26.40 (5.20)^{f}	34.73 (5.94)^{c}	3.78 (2.18)	2.53 (1.87)^{h}	2.83 (1.96)^{d}	4.13 (2.26)^{f}	3.25 (2.05)^{de}
Abamectin 1.9EC	0.4	27.55 (5.27)	10.13 (3.15)^{c}	14.53 (3.75)^{e}	20.88 (4.49)^{ef}	25.03 (5.04)^{bc}	3.15 (2.04)	1.30 (1.51)^{def}	1.75 (1.66)^{bc}	2.78 (1.94)^{e}	2.20 (1.78)^{bcd}
Abamectin 1.9EC	0.5	28.40 (5.32)	4.33 (2.16)^{ab}	6.00 (2.64)^{cd}	14.60 (3.67)^{cde}	21.48 (4.58)^{b}	3.38 (2.09)	0.85 (1.36)^{bcde}	1.15 (1.46)^{ab}	2.23 (1.80)^{de}	1.15 (1.46)^{a}
Abamectin 1.9EC	0.6	27.85 (5.26)	3.23 (1.97)^{ab}	4.30 (2.21)^{abcd}	11.15 (3.31)^{bcde}	16.60 (4.10)^{b}	2.93 (1.98)	0.35 (1.16)^{a}	0.55 (1.24)^{a}	1.80 (1.67)^{cd}	1.00 (1.41)^{a}
Etoxazole 10SC	0.1	27.38 (5.30)	7.78 (2.89)^{bc}	8.83 (3.04)^{de}	8.25 (2.92)^{abcd}	16.80 (4.18)^{b}	3.63 (2.15)	2.40 (1.84)^{gh}	2.28 (1.81)^{cd}	2.33 (1.82)^{de}	2.63 (1.90)^{cd}
Etoxazole 10SC	0.25	24.20 (5.00)	2.30 (1.77)^{a}	3.60 (2.12)^{abcd}	5.60 (2.52)^{abc}	8.20 (2.99)^{a}	3.45 (2.11)	1.78 (1.66)^{fg}	2.05 (1.75)^{cd}	2.10 (1.76)^{de}	2.15 (1.77)^{bcd}
Etoxazole 10SC	0.4	27.80 (5.25)	1.60 (1.59)^{a}	2.28 (1.78)^{abc}	3.25 (2.03)^{ab}	6.15 (2.66)^{a}	3.55 (2.13)	1.33 (1.52)^{ef}	1.68 (1.63)^{bc}	1.75 (1.65)^{bcd}	1.88 (1.69)^{abc}
Etoxazole 10SC	0.55	24.88 (5.07)	1.33 (1.51)^{a}	1.78 (1.65)^{abc}	2.88 (1.94)^{a}	4.55 (2.34)^{a}	3.68 (2.14)	0.75 (1.32)^{abc}	0.88 (1.37)^{a}	1.00 (1.41)^{a}	1.20 (1.48)^{a}
Fenazaquin 20SC	0.15	20.73 (4.64)	0.90 (1.37)^{a}	4.63 (2.32)^{bcd}	12.23 (3.58)^{cde}	20.18 (4.58)^{b}	2.53 (1.87)	0.58 (1.25)^{ab}	0.80 (1.33)^{a}	1.20 (1.48)^{abc}	1.63 (1.61)^{ab}
Fenazaquin 20SC	0.20	20.53 (4.63)	0.50 (1.20)^{a}	2.33 (1.82)^{abc}	7.73 (2.91)^{abcd}	16.33 (4.14)^{b}	2.68 (1.91)	0.40 (1.18)^{ab}	1.00 (1.40)^{a}	1.15 (1.45)^{abc}	1.08 (1.43)^{a}
Fenazaquin 20SC	0.25	25.03 (5.09)	0.60 (1.24)^{a}	1.55 (1.55)^{abc}	2.30 (1.79)^{a}	3.70 (2.13)^{a}	2.33 (1.81)	0.45 (1.20)^{ab}	0.85 (1.34)^{a}	1.10 (1.44)^{ab}	1.13 (1.44)^{a}
Hexythiazox 5.45EC	0.5	36.35 (5.95)	1.10 (1.44)^{a}	0.35 (1.16)^{a}	2.58 (1.88)^{a}	7.00 (2.82)^{a}	3.25 (2.06)	0.78 (1.33)^{abcd}	0.55 (1.24)^{a}	1.15 (1.46)^{abc}	1.50 (1.58)^{ab}
Hexythiazox 5.45EC	1.0	34.43 (5.84)	0.80 (1.31)^{a}	0.55 (1.23)^{ab}	2.03 (1.72)^{a}	6.23 (2.63)^{a}	3.50 (2.11)	0.60 (1.26)^{ab}	0.68 (1.29)^{a}	0.90 (1.38)^{a}	1.20 (1.48)^{a}
Propargite 57EC	1.0	41.38 (6.40)	8.25 (2.93)^{bc}	11.70 (3.48)^{e}	13.55 (3.76)^{cde}	25.68 (5.12)^{bc}	3.25 (2.05)	1.13 (1.46)^{cde}	1.90 (1.70)^{c}	1.73 (1.65)^{bcd}	3.00 (1.99)^{de}
Control	water spray only	28.73 (5.39)	51.18 (7.12)^{d}	88.75 (9.34)^{f}	93.13 (9.61)^{g}	116.15 (10.80)^{d}	3.93 (2.21)	3.63 (2.15)^{i}	3.95 (2.21)^{e}	4.00 (2.22)^{f}	4.13 (2.24)^{e}
CD (p = 0.05)		NS	0.96	1.14	1.33	1.07	NS	0.18	0.23	0.22	0.28

*Figures in parentheses √ (n+1) transformed values *Each replicate consisted of 20 leaves; *Means followed by the common letter do not differ significantly at p = 0.05; *DAT = Days After Treatment

safety/ toxicity of acaricides. The data was analyzed statistically after √ (n+1) transformation.

RESULTS AND DISCUSSION

The data revealed significant reduction in mite incidence after 7 DAS in all the treatments (Table 1). Fenazaquin (all concentrations), hexythiazox (both concentrations) and etoxazole (0.25, 0.4 and 0.55 ml/ l) were more effective followed by abamectin (0.6 and 0.5ml/ l), while etoxazole (0.1ml/ l), propargite (1.0ml/ l) and abamectin (0.3 and 0.4ml/ l) were less effective; the least mite count of 0.50 mites/ leaf was observed in fenazaquin @ 0.20 ml/ l, however, it was found at par with fenazaquin @ 0.15, 0.25 ml/ l (0.90, 0.60 mites/ leaf), hexythiazox @ 0.5, 1.0 ml/ l (1.10, 0.80 mites/ leaf), etoxazole @ 0.25, 0.4, 0.55 ml/ l (2.30, 1.60, 1.33 mites/ leaf) and abamectin @ 0.5, 0.6 ml/ l (4.33, 3.23 mites/ leaf). Fourteen DAS, both the concentrations of hexythiazox (0.35, 0.55 mites/ leaf), fenazaquin @ 0.20, 0.25ml/ l (2.33, 1.55 mites/ leaf), etoxazole @ 0.4, 0.55ml/ l (2.28, 1.78 mites/ leaf) retained their efficacy, whereas fenazaquin @ 0.15ml/ l (4.63 mites/ leaf), etoxazole @ 0.1, 0.25 ml/ l (8.83, 3.60 mites/ leaf) and all the concentrations of abamectin (4.30 to 14.28 mites/ leaf) were less effective; after 21 DAS, hexythiazox (both concentrations), fenazaquin (0.25ml/ l), etoxazole (0.4 and 0.55 ml/ l) retained effectiveness (2.03 to 3.25 mites/ leaf); and after 28 DAS, although all the acaricides showed an increase in incidence still higher doses of fenazaquin and etoxazole (3.70, 4.55 mites/ leaf) were superior.

These results are in confirmation with Rana and Bhardwaj (2004) on fenazaquin who reported it as highly effective and persistent against European red mite *Panonychus ulmi* on apple. Reddy et al. (2014) found abamectin and fenazaquin as superior against two spotted spider mite infesting cucumber under laboratory and green house conditions. Alfred and Ramaraju (2018) reported hexythiazox 5.45EC as very effective against *Oligonychus coffeae* in tea. Wang et al. (2018) ranked eight acaricides, from highest average efficacy at the recommended dosage to lowest as etoxazole > bifenazate > fenpyroximate > propargite > spirodiclofen > pyridaben > hexythiazox > chlorfenapyr against two spotted spider mites on greenhouse strawberries. Propargite was found moderately toxic against phytophagous mites of fruit trees (Laffi and Raboni, 1995; Khajuria and Sharma, 2010). Different natural enemies viz., *Chrysoperla* larvae, phytoseiid mites, *Stethorus* beetles and predatory thrips were observed during the study. Data on the toxicity at different concentrations against the natural enemies indicated their significant higher mortality in all the acaricidal treatments (Table 1); fenazaquin and hexythiazox recorded higher toxicity, while most others were found to be moderately toxic. High toxicity of fenazaquin observed in this study, receives support from Kim and Seo (2001) who reported it to be very toxic to adult females and immatures of *Amblyseius womersleyi*. They also found that etoxazole did not seriously affect the survival and reproduction of adult female predators but caused high mortality rates in eggs and larvae of *A.womersleyi*. Moderate toxicity of hexythiazox observed now receive support from Hoy and Ouyang (1986) who reported it to be safer against phytoseiid predator *Metaseiulus occidentalis* (Nesbitt), whereas moderate toxicity of propargite corroborate the earlier reports of Croft (1975) and Khajuria and Sharma (2010).

REFERENCES

Alfred Daniel J, Ramaraju K. 2018. Evaluation of hexythiazox 5.45 EC against red spider mite *Oligonychus coffeae nietner* on tea. Journal of Entomological Research 42(4): 579-583

Croft B A, Hoyt S C, Westigard P H. 1987. Spider mite management on pome fruits, revisited: organotin and resistance management. Journal of Economic Entomology 80: 304-311.

Croft B A. 1975. Integrated control of apple mites. Michigan State University, Co-operative Extension Service, USA. Extension Bulletin No. E-825. 16 pp.

Hoy M A, Ouyang Y L. 1986. Selectivity of the acaricides clofentezine and hexythiazox to the predator *Metaseiulus occidentalis* (Acari: Tetranychidae). Journal of Economic Entomology 79: 1377-1380.

Khajuria D R, Sharma J P. 1996. Outbreak of phytophagous mites on apple in Kullu valley. Indian Journal of Plant Protection 24(1,2): 134-138.

Khajuria D R, Sharma J P. 2001. Bio efficacy of various pesticides against the European red mite, *Panonychus ulmi* (Koch), on apple. Pest Management and Economic Zoology 9(1): 89-92.

Khajuria D R, Dubey J K, Gupta D. 2006. Management of phytophagous mites with selective acaricides on apple and sensitivity of phytoseiid mites to acaricides. Pest Management and Economic Zoology 14(1&2): 1-9.

Khajuria D R. 2009. Predatory complex of phytophagous mites and their role in integrated pest management in apple orchard. Journal of Biopesticides 2(2): 141-144.

Khajuria D R, Sharma J P. 2010. Bio-efficacy of various acaricides against the phytophagous mites on apple and their sensitivity to the phytoseiid mites. Pest Management and Economic Zoology 18(1/ 2): 116-121.

Kim S S, Seo S G. 2001. Relative toxicity of some acaricides to the predatory mite, *Amblyseius womersleyi* and the two spotted spider mite, *Tetranychus urticae* (Acari: Phytoseiidae, Tetranychidae). Applied Entomology and Zoology 36(4): 509-514.

Laffi F, Raboni F. 1995. New acaricides effective against red spider mite of fruit trees. Informatore Agrario 51(4-7): 60-64.

Marshall D B, Pree D J. 1995. Effect of miticides on the life stages

of the European red mite, *Panonychus ulmi* (Koch) (Acari: Tetranychidae). Canadian Entomologist 123 (1): 77-87.

Overmeer W P J. 1985. Alternative prey and other food resources. Helle W, Sabelis M W (eds.). Spider mites, their biology, natural enemies and control. Vol. 1B. Elsevier, Amsterdam. 131-140 pp.

Rana V K, Bhardwaj S P. 2004. Bioefficacy of acaricides against European red mite, *Panonychus ulmi* on apple (*Malus domestica*). Indian Journal of Agricultural Sciences 74(11): 628-630.

Reddy D S, Nagaraj R, Pushpalatha M, Chowdary R. 2014. Comparative evaluation of noel acaricides against two spotted spider mite, *Tetranychus urticae* Koch. Infesting cucumber (*Cucumis sativus*) under laboratory and green house conditions. The Bioscan 9(3): 1001-1005.

Wang Z, Cang T, Wu S, Wang X, Qi P, Wang X, Zhao X. 2018. Screening for suitable chemical acaricides against two-spotted spider mites, *Tetranychus urticae*, on greenhouse strawberries in China. Ecotoxicology and Environmental Safety 163: 63-68.

(Manuscript Received: September, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20339

Indian Journal of Entomology 84(1): 156-159 (2022) DoI.: 10.55446/IJE.2021.291

CONTROL OF *LUPROPS TRISTIS* F. DURING ITS DORMANCY WITH INSECT GROWTH REGULATORS

Binsha P and Sabu K Thomas

P G and Research Department of Zoology, St. Joseph's College (Autonomous),
Devagiri, Kozhikode 673008, Kerala, India
Email: binshababuraj05@gmail.com (corresponding author)

ABSTRACT

Hypersensitive and neurotoxic side effects of permethrin compounds and possibility of buildup of insecticide resistance against pyrethroid insecticides in darkling beetle *Luprops tristis* F. (Coleoptera: Tenebrionidae), a home-invading nuisance pest necessitates efficacy studies on other class of insecticidal compounds with more target specific action and less mammalian toxicity. The baseline dose- response bioassays conducted on *L. tristis* during their dormancy phase with three insect growth regulators (IGRs), fenoxycarb, diflubenzuron and 20-hydroxyecdysone (20E) revealed interesting results. Mortality (LC_{50} and LC_{90}), fecundity and egg hatchability were estimated by exposing dormant beetles to a range of concentrations. These data revealed that their LC_{50} values are within the permissible mammalian toxicity level. The capacity to reduce fecundity and hatchability of eggs (progeny production) together makes fenoxycarb a safer alternative to other pesticides in tackling *L. tristis*.

Key words: *Luprops tristis*, insect growth regulator, fenoxycarb, diflubenzuron, dormancy, 20-hydroxyecdysone (20E), bioassay, aggregated beetles, mortality, fecundity, egg hatchability

Massive home invasion of litter-dwelling Mupli beetle *Luprops tristis* (F.) (Coleoptera: Tenebrionidae), in the range of 500,000 to over 4 million/ residential building following summer showers, and their aggregation and prolonged stay in a state of dormancy are a regular event in rubber plantation belts in south India (Sabu et al., 2008). Litter stands of monoculture rubber plantations during non-rainy season are the feeding and breeding habitats for *L. tristis*. Rain-soaked litter stands during the monsoon period induce annual migrations of Mupli beetles to tile-roofed and palm-frond thatched residential buildings and other over-wintering quarters in the vicinity of rubber plantations (Vinod and Sabu, 2010). Following home invasion, clusters of these beetles crawl inside living areas, fall off from the ceilings into beds and food, and when disturbed by picking them off the walls or when they are squeezed, release an odorous secretion that causes skin irritation and eye inflammation (Sabu et al., 2008; John et al., 2010). Subsequently, they congregate in attics and gaps between palm fronds in thatched sheds and remain dormant during the 8-9 months in wet monsoon period (Sabu and Vinod, 2010).

Attempts to control the beetles with physical and mechanical means were all ineffective and failed for various reasons. Dormancy period of *L. tristis* is the most convenient time for their control as the home-invaded beetles in a specific locality, aggregate and enter into 8-9 months long dormancy in the attics of specific buildings and knocking down the home-invaded dormant beetles with permethrin-based compounds is the recommended methodology for *L. tristis* control (Aswathi et al., 2013). However, hypersensitive and neurotoxic side effects of permethrin compounds (Vijverberg and Bercken, 1990) and possibility of buildup of insecticide resistance against pyrethroid insecticides necessitates efficacy studies on *L. tristis* with other class of compounds having more target specific action and less mammalian toxicity. It leads to the present effort to analyze the utility of Insect growth regulators (IGRs). Insect growth regulators adversely interfere with the growth and development of insects (Dhadialla et al., 2005). Insect growth regulators are grouped under three categories: (i) Juvenile hormones (JHs) and their analogues, (ii) Ecdysone agonists and (iii) Chitin synthesis inhibitors (CSIs) based on their mode of action (Wing and Aller 1990). Juvenile hormone, fenoxycarb; Chitin synthesis inhibitor, diflubenzuron and Ecdysone agonist, 20- Hydroxyecdysone (20E) are effective against tenebrionid beetles especially against *Alphitobius diaperinus* Panzer which colonizes poultry and grain storage houses (Grenier and Grenier 1992; Singh and Johnson 2013). It is hypothesized that the

above three insect growth regulators (IGRs) which were effective against *A. diaperinus* with similar habits of aggregaion will be effective against *L. tristis*. Results will provide baseline data on the susceptibility of dormant *L. tristis* to the tested IGRs, which can be used as reference points for application of the compounds to the aggregated dormant beetles in residential areas.

MATERIALS AND METHODS

Aggregated dormant beetles were collected from a residential building near to 15 years old 5- ha rubber plantation (*Hevea brasiliensis* [Wild.ex ADR. De Jus] Muell. Arg. Of RRII 105 clone) from Kodenchery, Kozhikode, Kerala (11.4719^{0}N,75.96899^{0}E) by third week of August 2018. Collected beetles were maintained in laboratory by providing the cultural setup for dormancy (Sabu et al., 2008). Three insect growth regulators viz., a juvenile hormone analog (JHA), fenoxycarb (98%); a chitin synthesis inhibitor (CSI), diflubenzuron (99%); and the molting hormone, 20-hydroxyecdysone (20E) (98%) (Sigma Aldrich Laborchemikalien GmbH) were assayed. Stock solutions of 1000 ppm concentration of fenoxycarb, diflubenzuron and 20E were made by dissolving them in acetone. Serial dilutions of stock solutions were done to achieve five different concentrations-- of IGRs such as 0.01 ppm, 0.1 ppm, 1 ppm, 10 ppm and 100 ppm. Collected dormant beetles were exposed to selected concentration of three IGRs following the filter paper bioassay method (Tomberlin et al., 2002; Sheppard and Hinkle, 1987). Experimental setup containing Whatman No.1 filter paper (30 cm^2) placed in PVC vials (Tarsons; 5.5 × 4.5 cm; 50 ml capacity) for each concentration of the IGR was used. One ml of specific concentration of IGR was applied to the filter paper placed in individual vial with a micropipette for getting concentrations 3.33 mg/ cm^2, 0.33 mg/ cm^2, 0.03 mg/ cm^2, 0.003 mg/ cm^2 and 0.0003 mg/ cm^2. Filter paper wetted with acetone alone served as control.

Dormant adult beetles in stock culture were sexed based on sternal notch methodology (Vinod et al., 2008) and five mating pairs were transferred into each labeled vial. Six replicates were kept for each concentration of each IGR in experimental set up and three replicates were maintained for control in each set up. Beetles were observed at 24 hrs interval to record their mortality to fix the acute toxicity of each IGR tested. Towards the end of their dormancy period each mating pair of live beetles was transferred into post dormancy cultural set ups (Sabu et al., 2008). At the end of their post-dormancy period, egg lying was noted. Fecundity and % of egg hatchability were recorded. PROBIT analysis was used to determine lethal concentrations (LC) values and respective 95% confidence limits (Finney 1971, Robertson et al., 2007). All significance levels of variation in fecundity and % egg hatchability among the tested concentrations were subjected to two-way ANOVA and pair wise differences with Tukeys- Kramer Post hoc testes (t-tests). Significance was determined at $p < 0.05$. Analyses were done with Minitab software for Windows (Minitab 2010).

RESULTS AND DISCUSSION

Lowest LC_{50} and LC_{90} values were recorded for fenoxycarb compared to 20E and diflubenzuron. LC_{90} concentrations obtained for fenoxycarb, diflubenzuron and 20E were $2.30x10^7$ ppm, $1.63x10^{25}$ ppm and $1.12x10^{13}$ ppm and LC_{50} concentrations were $8.1x10^3$ ppm, $1.14x10^{13}$ ppm and $6.29x10^5$ ppm respectively. For all the compounds, LC_{90} values were higher than mammalian toxicity levels. LC_{50} values of 20E and diflubenzuron, were higher than mammalian toxicity levels (LD_{50} of 20E for mammals > 6000 ppm; LD_{50} of diflubenzuron for mammals > 4640 ppm, (Fischer and Hall 1992, Dinan and Lafont 2006) and LC_{50} value of fenoxycarb was lower than mammalian toxicity level (LD_{50} for mammals >10000 ppm) (Sullivan 2000). Hence, though with the lowest LC_{50} value compared to other two compounds, lower mammalian toxicity level of fenoxycarb makes it as the safer IGR than 20E and diflubenzuron for direct killing of dormant *L. tristis* aggregated inside residential buildings.

Fecundity of dormant beetles treated with five tested concentrations of fenoxycarb, diflubenzuron and 20E were lower than that of untreated control beetles ($p < 0.05$). Fecundity of beetles treated with fenoxycarb, diflubenzuron and 20E did not vary for all treatments ($p > 0.05$) except for 100 ppm concentration treatment with diflubenzuron. Diflubenzuron at 100 ppm concentration recorded the lowest fecundity (24.67 ± 1.03) which was 40% lower than the fecundity recorded with untreated control and 13.4% and 15.5 % lower than the fecundity with fenoxycarb and 20E respectively. Hatchability of eggs laid by dormant beetles treated with fenoxycarb, diflubenzuron and 20E were different at 100 ppm and 10 ppm concentrations ($p< 0.05$) and not different for other concentrations. Lowest hatchability rate of eggs (19.67± 0.81) was observed in beetles exposed to 100 ppm concentration of diflubenzuron. When cumulative effect on progeny reduction (by combining

Table 1. Mortality, fecundity and egg hatchability of *L. tristis* as influenced by the IGRs

IGR	% mortality				
	100 ppm	10 ppm	1 ppm	0.1 ppm	0.01ppm
FXB	65	56.66	55	53.33	50
DFB	53.33	51.22	50	50	46.67
20E	60	55	55	50	50
Control	42				
			Fecundity		
FXB a	28.50± 1.87a	35.33± 1.86a	38.17± 1.47a	38.50± 2.16a	39.5± 1.38a
DFB a	24.67± 1.03	36.83± 1.47a	38.50± 1.37a	38.67± 1.03a	38.17± 2.93a
20E a	29.16± 1.47a	35.50± 1.97a	36.50± 1.64a	37.5± 1.05a	41.50± 2.17a
Control	40.83± 2.36				
			Egg hatchability		
FXB a	24.17±1.94	30.67± 1.03	33.83± 1.94	34.33± 2.33	34.17± 0.75
DFB b	19.67± 0.81	33.50± 1.04	35.67± 1.75a	36.67± 1.21a	35.83± 2.64
20E	27.33± 0.82	34.33± 2.25	34.83± 0.98a	36.00± 0.89a	40.5± 2.95
Control ab	36.5± 2.07				

Means in same column with similar letter (s) not significantly different (p> 0.05); values transformed to % for analysis, but actual values given here; FXB-fenoxycarb; DFB-Diflubenzuron; ZOE-Zohydroxy ecdyscre

both reduction in fecundity and hatchability rate of eggs laid) in the next life cycle stage, the post dormant phase alone is considered, diflubenzuron at 100 ppm with 47% reduction in progeny production was more effective than the 100 ppm concentrations of fenoxycarb and 20E with 33.80% and 25.12% reduction in progeny production.

Comparing the effects of three tested IGRs on dormant beetles, none of the three compounds was effective enough to control *L. tristis* by causing higher mortality of adults or significant reduction in progeny production with the permissible limits.
As fenoxycarb can bring down the population number of *L. tristis* substantially by causing 50% mortality of dormant beetles and later by causing 33.5% reduction in the progeny production in the surviving dormant beetles (during post dormancy phase after their return to the litter field after 5 months from application), collectively, it leads to a gradual 83.5% fall in the population of *L. tristis*, fenoxycarb is better than the other two tested IGRs and is a safer alternative to pesticides in controlling home invaded *L. tristis* and repeated applications in successive years can bring down the *L. tristis* populations.

ACKNOWLEDGEMENTS

Financial assistance provided by the Department of Science and Technology - INSPIRE and laboratory infrastructure facilities provided by DST- FIST, Government of India are gratefully acknowledged.

REFERENCES

Aswathi P, Sabu K T. 2013. Control of the Mupli Beetle, *Luprops tristis* (Coleoptera: Tenebrionidae), and Dormancy phase-related variation in insecticide susceptibility. Journal of Agricultural and Urban Entomology 29: 76-84.

Dhadialla T S, Retnakaran A, Smagghe G. 2005. Insect growth and development disrupting Insecticides. 6: 55-116.

Dhadialla T S, Glenn R, Carlson, Le D P. 1998. New Insecticides with Ecdysteroidal and Juvenile Hormone activity. Annual Review of Entomology 43: 545-569.

Dinan L, Lafont R. 2006. Effects and application of arthropod steroid hormones (ecdysteroids) in mammals. Journal of Endocrinology 191: 1-8.

Edwards J P, Menn J J. 1981. The use of juvenoids in insect pest management. 6: 185-214.

Finney D J. 1971. Probit analysis, 3rd ed. Cambridge University Press, Cambridge, U.K.

Fischer S A, Hall L W. 1992. Environmental concentrations and aquatic toxicity data on diflubenzuron (Dimilin). Critical Reviews in Toxicology 22(1): 45-79.

Grenier S, Grenier A M. 1992. Fenoxycarb, a fairly new insect growth regulator: a review of its effects on insects. Annals of Applied Biology 122: 369-403.

Minitab Inc. 2010. MINITAB Statistical software, Release 16 for Windows. Minitab, Inc., State College, Pennsylvania.

Robertson J L, Russell R M, Preisler H K, Savin N E. 2007. Bioassays with Arthropods, 2nd ed. CRC Press, Boca Raton, Florida. 224.

Sabu K T, Vinod K V, Joby M C. 2008. Life history, aggregation, and dormancy of the rubber plantation litter beetle, *Luprops tristis*, from the rubber plantations of moist Southwestern Ghats. Journal of Insect Science 8(1): 1-17.

Shepperd D C, Hinkle N C. 1987. A field procedure using disposable materials to evaluate horn fly insecticide resistance. Journal of Agricultural and Urban Entomology l4(1): 87-89.

Singh N, Johnson T D. 2013. Baseline Responses of *Alphitobius diaperinus* (Coleoptera: Tenebrionidae) to Insect Growth Regulators. Journal of Agricultural and Urban Entomology 29: 35-54.

Sullivan J. 2000. Environmental fate of fenoxycarb. Environmental monitoring fate reviews. Environmental Monitoring Branch, Department of Pesticide Regulation, California EPA, Sacramento, CA, USA.

Tomberlin J K, Sheppard D C, Joyce A J. 2002. Susceptibility of black soldier fly (Diptera; Stratiomyidae) larvae and adults to four insecticides. Jornal of Economic Entomology 95: 598- 602.

Vijverberg H P M, Bercken J V. 1990. Neurotoxicological Effects and the Mode of Action of Pyrethroid Insecticides. Critical Reviews in Toxicology 21(2): 105-126.

Vinod K V, Sabu K T. 2010. Dormancy-inducing factors of rubber litter beetle, *Luprops tristis* (Coleoptera: Tenebrionidae). Journal of Insect Science 17: 47-51.

Vinod K V, T K Sabu, T M Benny. 2008. Sex determination of the live rubber plantation litter beetle, *Luprops tristis*: a novel method. Journal of Insect Science 8:17.

Wing H D, Aller H E. 1990. Ecdysteroid agonists as novel insect regulators. In: Pesticides and alternatives (ed. J.E. Casida) 251-257.

(Manuscript Received: September, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20337

Indian Journal of Entomology 84(1): 160-163 (2022) DoI.: 10.55446/IJE.2021.290

EVALUATION OF ENTOMOPATHOGENIC FUNGI AGAINST *BEMISIA TABACI* (GENNADIUS) IN CAPSICUM UNDER PROTECTED CULTIVATION

B Ramanujam*, Krishna Japur and B Poornesha

ICAR-National Bureau of Agricultural Insect Resources (NBAIR), H A Farm Post, Hebbal, Bellary Road, Bengaluru 560024, Karnataka, India
*Email: bonamramanujam58@gmail.com (corresponding author)

ABSTRACT

Effect of indigenous isolates of *Beauveria bassiana*, *Metarhizium anisopliae* and *Lecanicillum lecanii* were tested for two years during 2012 and 2013 on *Bemisia tabaci* infesting capsicum under protected cultivation. Among the ten isolates tested, NBAIR-Vl8 isolate of *L. lecanii*, NBAIR-Bb5a and NBAIR-Bb9 isolates of *B. bassiana* showed significant suppression of *Bemisia tabaci* (Genn.) with reduction of 73.15, 71.84 and 63.10% respectively. The yields were also superior in these treatments.

Key words: *Bemisia tabaci*, entomopathogenic fungi, Capsicum, protected cultivation, *Beauveria bassiana*, *Metarhizium anisopliae, Lecanicillum lecanii*, indigenous isolates, NBAIR- V18, NBAIR- Bb5a, NBAIR- Bb9

Bell pepper (*Capsicum annuum* L) is one of the most popular and highly remunerative vegetable and is intensively cultivated in Karnataka, Tamil Nadu, Maharashtra, Himachal Pradesh and hilly areas of Uttar Pradesh. Capsicum cultivation under protected conditions is gaining popularity in periurban production system because of easy access to urban markets. Various biotic, abiotic and physiological factors are encountered by the farmers which resulted in low productivity and poor quality produce. Sucking pests, especially whitefly *Bemisia tabaci* (Genn.) (Hemiptera: Aleyrodidae) is considered a serious problem on capsicum crop in polyhouse cultivation, as they multiply in large numbers and cause significant crop loss under controlled conditions of temperature and humidity. It is a serious threat to crop production not only by direct damage but also by transmitting several plant viruses (Oliveira et al., 2001; Jones, 2003). *B. tabaci* is among the most devastating and widespread pest of a broad range of greenhouse and field crops worldwide. *B. tabaci* attacks more than 500 species of plants (Greathead, 1986) from 63 plant families (Mound and Halsey, 1978). Now-a-days whiteflies show resistance to insecticides due to indiscriminate use, and this causes many non-target effects (Sharma, 2009). Among biocontrol agents, entomopathogenic fungi possess the unique ability to infect their host directly through the integument. Moreover, they play a role in their natural mortality (Lacey et al., 1996). These can be easily mass multiplied, formulated and applied in the field using simple spraying techniques. Since favourable conditions of moderate temperature and humidity are maintained in polyhouse, the applied entomopathogenic fungi can multiply rapidly and give better control. The present study was taken up to develop a safe and environmental friendly control measure for capsicum whitefly under protected cultivation using entomopathogenic fungi.

MATERIALS AND METHODS

Four isolates of *Beauveria bassiana* (NBAIR Bb-5a, Bb-36, Bb-68 and Bb-9), three isolates of *Metarhizium anisopliae* (NBAIR Ma-42, Ma-41 and Ma-6) and three isolates of *Lecanicillium* spp (NBAIR Vl-8, Vl-12 and Vl-32) from ICAR-NBAIR culture repository were used for this experiment. Fungal isolates were grown on sterilized broken rice grains (100 grams) taken in polypropylene bags for 15days at 26± 1°C after inoculation with 4day-old shaker cultures grown on Sabouraud's Dextrose Yeast extract broth (SDYB) medium. Sporulated rice grains were dried aseptically at room temperature of 26-30°C for two days and the spores were harvested using 300µm sieve. Oil formulations were prepared using harvested spore dust, sterilized liquid paraffin oil, glycerol and Tween 80 with spore load of 1x 10^8 spores/ml. The trials were conducted under polyhouse conditions at ICAR-NBAIR, Yelahanka Farm, Bengaluru, India during July-October in 2012 and 2013 using capsicum variety Indira. The experiment was laid out in randomized block design (RBD) with three replications with a plot size of 1.2x 2 m and spacing of 60x 30 cm containing 30 plants. All agronomic practices were followed as per the package of practices of University of Horticultural Sciences

Table 1. Effect of entomopathogenic fungi on incidence of whitefly *B. tabaci* and yield in capsicum

Sl. No.	Isolate	2012				2013				Pooled				
		No. of whiteflies/ plant	% reduction over control	Yield (kg)/ Plant	Yield t/ ha	No. of whiteflies/ plant	% reduction over control	Yield (kg)/ Plant	Yield t/ ha	No. of whiteflies/ plant	% reduction over control	Yield (kg)/ Plant	Yield t/ ha	C:B ratio
1	Bb-5a	7.12^{a} (2.76)	66.67	2.18^{ab} (1.64)	104.9	6.98^{a} (2.73)	75.12	2.42^{a} (1.71)	118.1	7.05^{a} (2.66)	71.84	2.30^{ab} (1.67)	111.5	3.25
2	Bb-36	16.96^{bc} (4.18)	20.60	1.82^{cde} (1.52)	85.1	20.18^{b} (4.55)	30.24	1.94^{de} (1.56)	91.7	18.57^{bc} (4.37)	25.42	1.88^{de} (1.54)	88.4	2.46
3	Bb-68	14.11^{ab} (3.82)	34.09	1.98^{bc} (1.57)	93.9	17.36^{b} (4.23)	38.27	1.78^{ef} (1.51)	82.9	15.73^{b} (4.03)	36.18	1.88^{de} (1.54)	88.4	2.46
4	Bb-9	8.39^{ab} (2.98)	60.73	2.12^{ab} (1.62)	101.6	9.71^{ab} (3.20)	65.47	2.38^{ab} (1.70)	115.9	9.05^{ab} (3.09)	63.10	2.25^{ab} (1.66)	108.8	3.14
5	Ma-42	19.41^{bc} (4.46)	9.13	2.01^{bc} (1.58)	95.6	19.98^{b} (4.53)	28.95	1.86^{ef} (1.54)	87.3	19.70^{bc} (4.49)	19.04	1.94^{cd} (1.56)	91.4	2.56
6	Ma-41	15.84^{bc} (4.04)	25.85	1.62^{de} (1.46)	74.1	12.53^{ab} (3.61)	55.45	2.19^{bc} (1.64)	105.5	14.78^{b} (3.91)	40.65	1.91^{cd} (1.55)	89.8	2.51
7	Ma-6	17.19^{bc} (4.21)	19.53	1.52^{def} (1.42)	68.6	16.23^{b} (4.09)	42.29	1.92^{de} (1.56)	90.6	16.71^{b} (4.15)	30.91	1.72^{ef} (1.49)	79.6	2.16
8	Vl-8	6.18^{a} (2.58)	71.17	2.36^{a} (1.69)	114.8	6.47^{a} (2.64)	77.00	2.56^{a} (1.75)	125.8	6.33^{a} (2.50)	73.15	2.46^{a} (1.72)	120.3	3.53
9	Vl-12	16.78^{bc} (4.16)	21.45	1.48^{f} (1.41)	66.4	15.16^{b} (3.96)	46.09	2.09^{cd} (1.61)	100.0	15.97^{b} (4.06)	33.77	1.79^{def} (1.51)	83.2	2.29
10	Vl-32	16.42^{bc} (4.11)	23.17	1.86^{cd} (1.54)	87.3	13.19^{ab} (3.70)	53.10	2.37^{ab} (1.69)	115.4	14.81^{b} (3.91)	38.14	2.12^{bc} (1.62)	101.3	2.89
11	Control	21.36^{c} (4.68)	-	1.58^{def} (1.44)	71.9	28.12^{c} (5.35)	-	1.68^{f} (1.48)	77.4	24.74^{c} (5.02)	--	1.63^{f} (1.46)	74.7	2.00
CD (p=0.05%)		6.96	-	-	-	7.66	-	-	-	7.87	--	--	--	

Note: Means followed by the similar letters in the columns are not significantly different at (p=0.05) by DMRT; C:B - Cost Benefit ratio

(UHS), Bagalkot, Karnataka, India (Horticultural crops-package of practices, 2012). The foliar sprays of oil formulations of entomopathogenic fungi @ the dose 1x 10^8 cfu/ ml were imposed thrice at 15 days intervals as soon as *B. tabaci* incidence was noticed and the experiment was repeated for two consecutive years. The pre and post count observations on *B. tabaci* incidence were recorded on three leaves/ plant (lower, medium and upper part) at each spray. The data were statistically analysed using SPSS v16 software. The treatment-wise yield of capsicum/ plant were also recorded separately and converted to / ha basis. The cost benefit ratio was calculated for the pooled data based on the formula- BC Ratio =NR/CC where NR- net returns, and CC- cost of cultivation.

RESULTS AND DISCUSSION

The incidence of *B. tabaci* got significantly reduced in all the treatments with entomopathogenic fungi (EPF) during both years as shown in Table 1. During 2012, the incidence ranged from 6.18 to 19.41/ plant in all EPF treated plots as compared to 21.36 whiteflies /plant in the untreated control. Among the ten isolates tested, Vl-8 isolate of *L. muscarium*, Bb-5a and Bb-9 isolates of *B. bassiana* showed the least whitefly incidence (6.18, 7.12 and 8.39 whiteflies/ plant) with reduction of 71.17, 66.67 and 60.73%, respectively over control and were on par with each other. Similarly, during 2013, the least incidence was in the plots treated with Vl-8 isolate of *L. muscarium*, Bb-5a and Bb-9 isolates of *B. bassiana* (6.47, 6.98 and 9.71 whiteflies/ plant) with reduction of 77.0, 75.12 and 65.47%, respectively and at par with each other. The pooled data indicated that Vl-8 isolate of *L. muscarium*, Bb-5a and Bb-9 isolates of *B. bassiana* were superior with reduction of 73.15, 71.84 and 63.1%, respectively which were at par with each other. Singh and Joshi (2020) reported that three foliar applications of *L. lecanii* bioformulation @ 10 and 12 g/ l at 10 days interval showed 60-61% reduction of whitefly in capsicum. Cuthbertson and Walters (2005) demonstrated that the application of *L. muscarium* (Mycotal, Koppert Biological Systems Ltd., UK) resulted in a significant increase in the mortality of sweet potato whitefly *B. tabaci* under glasshouse cultivation. Flores et al., 2015 reported 51.5, 43.5 and 34.6% mortality of *B. tabaci* adults in beans with *B. bassiana*, *M. anisopliae* and *I. fumosorosea* respectively. *L. lecanii* was found most virulent among the fungal isolates tested against *B. tabaci* in tomato crop under greenhouse conditions (Abdel-Raheem and Lamya, 2016). In the present study, *L. muscarium* (Vl-8 isolate) and *B. bassiana* isolates (Bb-5a and Bb-9) showed 63-73% reduction in incidence.

Pooled data of yield revealed significantly higher yields of 120.3, 111.5 and 108.8 t/ ha in the treatments with Vl-8 isolate of *L. muscarium*, Bb-5a and Bb-9 isolates of *B. bassiana*, respectively and were on par with each other. The cost benefit ratio was found highest (3.53) in *L. muscarium* (ICAR-NBAIR-Vl-8) treatment, followed by *B. bassiana* (ICAR-NBAIR-Bb5a) treatment (3.25) and (ICAR-NBAIR-Bb9) treatment (3.14) and the rest of the treatments showed C:B ratio in the range of 2.0-2.56 (Table 1). Sreedhara et al. (2013) reported C:B ratio of 3.92 with chemical insecticide treatment for capsicum pest management under protected conditions, while Rath and Ghosal (2015) observed C:B ratio of 2.98 and 0.80 in chemical insecticide treatment in capsicum under greenhouse and open field conditions, respectively. In the present study, the cost benefit ratio was found 3.14-3.53 in the treatments with *L. muscarium* (Vl-8) and *B. bassiana* (Bb-5a and Bb-9 isolates). *Bemisia tabaci* infestation has been observed regularly in capsicum under protected cultivation in Karnataka, Tamil Nadu, Maharashtra, and Himachal Pradesh in spite of repeated use of insecticides. The results of the present study provide a safe and cost-effective control strategy for capsicum whitefly management. Three rounds of foliar sprays of oil formulations of *L. muscarium* (Vl-8)/*B. bassiana* (Bb-5a/Bb-9) at 15 days intervals @ the dose 1x10^8 cfu/ ml at the initial incidence was found effective.

ACKNOWLEDGEMENTS

The authors thank the Director, ICAR-National Bureau of Agricultural Insect Resources, Bengaluru, Karnataka, India for the support.

REFERENCES

Abdel-Raheem M A, Lamya A A K. 2016. Virulence of three entomopathogenic fungi against whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) in tomato crop. Journal of Entomology 14: 155-159.

Cuthbertson A G S, Walters K F A. 2005. Pathogenicity of the entomopathogenic fungus, *Lecanicillium muscarium*, against the sweet potato whitefly *Bemisia tabaci* under laboratory and glasshouse conditions. Mycopathologia 160: 315-319.

Greathead A H. 1986. Host plants. *Bemisia tabaci*- a literature survey on the cotton whitefly with an annotated bibliography. M J W Cock (ed.). CAB International Institute of Biological Control, Ascot, UK. Chapter 3, pp. 17-25.

Flores M, Pucheta D, Rodriguez N, Torre M, Ramos L. 2012. Mycoinsecticide effects of *Beauveria bassiana*, *Metarhizium anisopliae*, and *Isaria fumosorosea* on the whitefly *Bemisia tabaci* (Homoptera: Aleyrodidae) in different strata of bean. African Journal of Microbiology Research 6: 7246-7252.

Horticultural crops-package of practices. 2012. Package of practice (POP) by University of Horticultural Sciences (UHS), Bagalkot (India) pp. 57-70 (Kannada).

Jones D R. 2003. Plant viruses transmitted by whiteflies. European Journal of Plant Pathology 109: 195-219

Lacey L A, Fransen J J, Carruthers R I. 1996. Global distribution of naturally occurring fungi of *Bemisia*, their biologies and use as biological control agents. Gerling D, Mayer R T (eds.), *Bemisia* 1995: Taxonomy, biology, damage, control and management. Intercept, Andover, UK. pp. 356-456.

Mound L A, Halsey S H. 1978. *Bemisia tabaci* (Gennadius). Whitefly of the world, a systematic catalog of the Aleyrodidae (Homoptera) with host plant and natural enemy data. British Museum (Natural History) and John Wiley and Sons, Chichester, New York, Brisbane, Toronto. pp.118-124.

Oliveira M R V, Henneberry T J, Anderson P. 2001. History current status and collaborative research projects for *Bemisia tabaci*. Crop Protection 20: 709-723.

Rath J R, Ghosal M K. 2015. Comparative study on yield and cost of cultivation of capsicum in a greenhouse and open field condition in warm and humid climate of India. International Journal of Tropical Agriculture.33(1): 81-85.

Sharma H C. 2009. Applications of biotechnology in pest management and ecological sustainability. CRC Press/ Taylor and Francis, Boca Raton, Florida, USA. 526 pp.

Singh H, Joshi N. 2020. Management of the aphid, *Myzus persicae* (Sulzer) and the whitefly, *Bemisia tabaci* (Gennadius), using biorational on capsicum under protected cultivation in India. Egyptian Journal of Biological Pest Control 30: 67.

Sreedhara D S, Kerutagi M G, Basavaraja H, Kunnal L B, Dodamani M T. 2013. Economics of capsicum production under protected conditions in Northern Karnataka. Karnataka Journal of Agricultural Sciences 26(2): 217-219.

(Manuscript Received: September, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: August, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20335

Indian Journal of Entomology 84(1): 164-167 (2022) DoI.: 10.55446/IJE.2021.288

MANAGEMENT OF CORIANDER APHID *HYADAPHIS CORIANDRI* (DAS) WITH SAFER INSECTICIDES

Dinesh Swami*, B L Jat and S K Dotasara

Department of Entomology, SKN College of Agriculture,
Jobner, Jaipur 303329, Rajasthan, India
(Sri Karan Narendra Agriculture University, Jobner)
*Email: dswami6559@gmail.com (corresponding author)

ABSTRACT

A field experiment on the relative efficacy of botanicals, biopesticides and insecticides against aphid *Hyadaphis coriandri* (Das) on coriander was conducted in 2015-16 and 2016-17. The results revealed that dimethoate 30EC was the most effective followed by acephate 75SP and cartap hydrochloride 50SP. The dhatura leaf and karanj seed extracts were found to be the least effective. The biopesticides *Beauveria bassiana*, *Verticillium lecanii*, *Metarhizium anisopliae*, azadirachtin 20EC, NSE and neem oil were found moderately effective.

Key words: *Hyadaphis coriandri*, coriander, botanicals, biopesticides, dimethoate, acephate, cartap hydrochloride, dhatura leaf extract, karanj seed extract, azadirachtin

Coriander (*Coriandrum sativum* L.) is one of the important seed spice and winter crop in India, with Rajasthan and Gujarat states together contributing >80% of production (Anonymous, 2016). Insect pests are one of the major limiting factors for higher quality production of coriander. Among the various insect pests, the coriander aphid *Hyadaphis coriandri* (Das) had been reported as a regular and major pest in Rajasthan and other parts of the country (Pareek et al., 2013; Meena et al., 2017). The safer insecticides mainly botanicals, microbials and pro-insecticides, overcome the problems like insecticide resistance, environmental pollution and insecticide residues. A pro-insecticide is a substance which is inactive in its original form but is transformed into an active state by a plant, animal or microorganism. Classical pesticides can be modified to yield pro-pesticides retaining their insecticidal activity but lowering mammalian toxicity and acquiring plant-systemic properties (Fukuto, 2004). The application of fungal pathogens like *Verticillium lecanii*, *Beauveria bassiana* and *Metarhizium anisopliae* and botanicals like *Azadirachta indica* oil and *Pongmia pinnata* karanj oil effectively control aphids (Kant et al., 2013; Chaudhary et al., 2015; Meena et al., 2016). The present study evaluates such safer insecticides against *H. coriandri*.

MATERIALS AND METHODS

The field experiment was laid out in a randomized block design (RBD) with twelve treatments and replicated thrice. The coriander variety RCr-41 recommended for this region was used and the plot size was 3.0 x 2.0 m, keeping row to row and plant to plant spacing of 30 and 10 cm, respectively. The crop was sown on 30th October and 2nd November in 2015-16 and 2016-17, respectively. The treatments included were azadirachtin 1500 ppm (5ml/ l), Neem Seed Kernel Extract (NSKE- 5.0%), neem oil (1.0%), Karanj Seed Extract (KSE- 5.0%), dhatura leaf extract (DLE- 5.0%), *Beauveria bassiana* 1.15 WP (1g/ l), *Verticillium lecanii* 1.15 WP (1g/ l), *Metarhizium anisopliae* 1.15 WP (1g/ l), acephate 75SP (0.05%), cartap hydrochloride 50SP (0.03%), dimethoate 30EC (0.03%) and untreated control. To prepare 5% NSKE and KSE, coarse powder of 30 kg seeds of neem and karanj were tied in a muslin cloth separately and immersed in 50 l of water overnight and the complete extract was separated by squeezing the cloth containing the crushed seeds. The cloth containing the crushed seed was again dipped in 50 l of water and squeezed again. In this way 100 l of solution was obtained, and to this 500 l of water was added to prepare 5% solution. Before using the solution, 200 gm khadi soap was added and the fresh material was used. To prepare dhatura leaf extract, 100 g fresh leaves of dhatura was washed with sterilized with distilled water and ground/ minced/ powdered in 100 ml distilled water. The macerate was filtered through double layered cheese cloth and centrifuged at 3500 rpm for 20 min. The supernatant was filtered through Whatman's filter paper No. 42. The extract (100%) thus obtained was

utilized (Jayadevi et al. 2003). Two foliar sprays of all the insecticides were given at an interval of 15 days, with spraying done using knapsack sprayer. First spray was done when the pest incidence crossed ETL and second was done at 15 days interval. The aphids on three inflorescence/ umbels from each tagged plants were counted. Pretreatment count was recorded one day before the application of insecticides, and post treatment data after 1, 3, 7 and 15 days. Similar observations were made after the second application. The data obtained were used to estimate the % reduction in incidence following Henderson and Tilton (1955). The data were statistically analysed by transforming the % reduction into angular transformation values (Bliss, 1937). To determine the most effective and economical treatment, the net profit and benefit cost ratio was worked out by taking the expenditure on the individual insecticidal treatment and the corresponding yield into account.

RESULTS AND DISCUSSION

The pooled data as given in Table 1 indicate that diamethoate 30EC proved to be the most effective insecticidal treatment against aphid *H. coriandri* (96.07 and 94.28% reduction after three days in first and second insecticidal application, respectively); these were at par with acephate 75SP and cartap hydrochloride 50SP. The findings of Sachan et al. (2010) support the present findings on dimethoate 30EC and acephate 75SP as highly effective. Gupta and Pathak (2009) reported cartap hydrochloride (0.1%) as highly effective. The entomopathogenic fungi and neem products viz., *M.anisopliae*, *B.bassiana, V. lecanii,* azadiractin 20EC, NSKE and neem oil were moderately effective (66.93-53.93% reduction in first, and 79.98- 57.86% reduction in second application, respectively), after three days of insecticide application. Kant et al. (2013) observed that *M. anisopliae*, *B. bassiana* and *V. lecanii* are effective. Meena et al. (2016) found that biopesticides and Choudhary et al. (2015) the neem oil, azadirachtin and NSKE as moderately effective. The karanj seed and dhatura leaf extracts stood at the lower order of efficacy, with 37.15 and 37.68% reduction in incidence after three days of application after first and 47.02 and 43.64% in second sprays, respectively. Meena et al. (2016)

Table 1. Efficacy of insecticides against *H. coriandri* on coriander (Pooled, 2015-16, 2016-17)

Insecticides	Conc. (%)/ dosage	% reduction in aphid population days after spray									
		First spray					Second spray				
		One	Three	Seven	Fifteen	Mean	One	Three	Seven	Fifteen	Mean
Azadirachtin 20 EC	5 ml/l	50.02* (45.01)**	60.45 (50.03)	60.28 (50.93)	19.28 (26.05)	47.51 (43.57)	46.30 (42.88)	61.18 (51.46)	62.98 (52.52)	87.57 (69.38)	64.51 (53.43)
Neem seed extract	5.0%	46.39 (42.93)	55.93 (48.41)	59.19 (50.30)	18.28 (25.31)	44.95 (42.10)	46.50 (42.99)	60.39 (51.00)	58.43 (49.85)	84.58 (66.88)	62.47 (52.22)
Neem oil	1.0%	44.45 (41.81)	53.93 (47.25)	55.58 (48.20)	14.64 (22.50)	42.15 (40.48)	44.04 (41.58)	57.86 (49.52)	56.09 (48.50)	84.28 (66.64)	60.57 (51.10)
Karanj seed extract	5.0%	28.03 (31.97)	37.15 (37.55)	44.86 (42..05)	12.15 (20.40)	30.55 (33.55)	27.09 (31.36)	47.02 (43.29)	44.90 (42.07)	73.28 (58.87)	48.08 (43.90)
Dhatura leaf extract	5.0%	24.75 (29.83)	37.68 (37.87)	42.85 (40.89)	10.86 (19.24)	29.04 (32.61)	26.65 (31.08)	43.64 (41.35)	41.60 (40.16)	73.60 (59.08)	46.37 (42.92)
Beauveria bassiana	1g/l	52.26 (46.30)	63.01 (52.54)	81.67 (64.65)	46.40 (42.94)	60.84 (51.26)	50.50 (45.29)	75.46 (60.31)	83.90 (66.34)	91.83 (73.39)	75.42 (60.28)
Verticillium lecanii	1g/l	47.23 (43.41)	62.30 (52.12)	79.77 (63.27)	48.13 (43.93)	59.36 (50.39)	51.70 (45.97)	76.34 (60.89)	83.45 (65.99)	91.69 (73.25)	75.79 (60.53)
Metarhizium anisopliae	1g/l	50.95 (45.54)	66.93 (54.90)	84.83 (67.08)	56.02 (48.46)	64.69 (53.54)	51.35 (45.77)	79.98 (63.42)	85.13 (67.32)	93.57 (75.31)	77.51 (61.69)
Acephate 75 SP	0.05%	72.38 (58.29)	94.00 (75.82)	81.80 (64.75)	75.43 (60.29)	80.90 (64.09)	70.90 (57.35)	90.06 (71.62)	93.63 (75.38)	98.36 (82.64)	88.24 (69.94)
Cartap hydrochloride 50 SP	0.03%	70.61 (57.17)	89.81 (71.38)	74.12 (59.42)	71.46 (57.71)	76.50 (61.00)	66.16 (54.43)	88.22 (69.93)	93.73 (75.50)	96.49 (79.20)	86.15 (68.15)
Dimethoate 30 EC	0.03%	77.90 (61.96)	96.07 (78.57)	87.07 (68.93)	78.00 (62.03)	84.76 (67.02)	78.76 (62.56)	94.28 (76.16)	96.81 (79.71)	98.73 (83.53)	92.15 (73.73)
Untreated 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)
SEm±		1.36	2.07	1.21	1.29	1.30	1.65	2.31	1.27	1.23	1.95
CD (p= 0.05%)		4.95	5.90	4.58	4.78	4.76	5.31	6.26	4.69	4.63	5.66

*Mean of three replications, **figures in parentheses angular transformed values.

Table 2. Economics of insecticides on coriander (Pooled 2015-16, 2016-17)

S.No.	Insecticides	Conc. (%) / dosage (ml or g)	Yield (q ha^{-1})	Increase in yield over control (q ha^{-1})	Return of increase yield (Rs ha^{-1})*	Total cost of expenditure (Rs ha^{-1})**	Net profit (Rs ha^{-1})	Benefit cost ratio
1.	Azadirachtin 20EC	5 ml/l	9.65	2.45	12862	4284	8578	2.00
2.	Neem seed extract	5.0%	9.35	2.15	11287	1636	9651	5.90
3.	Neem oil	1.0%	9.25	2.05	10762	1707	9055	5.30
4.	Karanj seed extract	5.0%	9.05	1.85	9712	1636	8076	4.94
5.	Dhatura leaf extract	5.0%	8.90	1.70	8925	1636	7289	4.46
6.	*Beauveria bassiana*	1g/l	10.00	2.80	14700	2637	12063	4.57
7.	*Verticillium lecanii*	1g/l	10.25	3.05	16012	2997	13015	4.34
8.	*Metarhizium anisopliae*	1g/l	10.40	3.20	16800	2097	14703	7.01
9.	Acephate 75SP	0.05%	12.45	5.25	27562	1727	25835	14.96
10.	Cartap hydrochloride 50SP	0.03%	11.65	4.45	23362	2091	21271	10.17
11.	Dimethoate 30EC	0.03%	12.85	5.65	29662	1857	27805	14.97
12.	Untreated control	-	7.20	-	-	-	-	-

*Cost of coriander seed calculated at Rs. 5250.00 q^{-1}; **It includes cost of insecticides and labour charges

evaluated the relative efficacy of botanicals and found that the karanj seed (10ml/ l) and dhatura leaf extracts (10 ml/ l) were the least effective. These observations corroborate with the present findings.

Table 2 reveals that the maximum net profit of Rs. 27805 was obtained with dimethoate 30EC followed by acephate 75SP (Rs.25835) and cartap hydrochloride 50SP (Rs. 21271). The minimum net profit of Rs.7289 was observed in plots treated with dhatura leaf extract followed by karanj seed extract (Rs. 8076), azadirachtin 20 EC (Rs. 8578) and neem oil (Rs. 9055). These results corroborate with those of Pareek (2009) with net profit obtained with dimethoate 30EC and acephate 75SP. The maximum benefit cost ratio (14.97) was obtained with dimethoate 30EC followed by acephate 50SP (14.96), and it was less with azadirachtin 20EC, *V. lecanii* and dhatura leaf extract. The present findings also confirm with those of Lekha and Jat (2004) who reported the highest benefit cost ratio with phosphamidon 85SL followed by dimethoate 30EC and acephate 75SP. Jat et al. (2009) recorded the maximum benefit cost ratio with dimethoate 30EC followed by acephate 75SP and the least with NSKE and neem oil.

ACNOWLEDGEMENTS

The senior author thanks the Dean, SKN College of Agriculture, Jobner (Sri Karan Narendra Agriculture University, Jobner) Jaipur, Rajasthan for providing facilities and to the ICAR for the Senior Research Fellowship during his Ph D.

REFERENCES

Anonymous. 2016. Vital agriculture statistics, 2015-16, Directorate of Agriculture, Rajasthan (Statistics cell), Jaipur.

Bliss C I. 1937. Angles corresponding to percentage. Plant Protection, No.12 Leningrad.

Chaudhary H R, Ali M, Verma P, Ram B, Jadon C. 2015. Management of coriander aphid, *Hyadaphis coriandri* (Das) under soybean–coriander cropping system. International Journal of Seed Spices 5(1): 98-99.

Fukuto T R. 2004. Pro-pesticides. P S Magee, G K Kohn, J J Men (eds.). Pesticides synthesis through rational approaches. ACS Symp. Ser. 255. American Chemical Society, Washington, DC, USA. pp. 87-102.

Gupta M P, Pathak R K. 2009. Comparative efficacy of neem products and insecticides against the incidence of coriander aphid, *Hyadaphis coriandri* (Das). Indian Journal of Agricultural Science 29(1): 69-71.

Henderson C F, Tilton E W. 1955. Tests with acaricides against brown wheat mite, *Petrobia latens* (Muller). Journal of Economic Entomology 48: 157-161.

Jat B L, Choudhary R K, Kumawat K C. 2009. Bioefficacy and economics of newer insecticides and neem products against aphid, *Hyadaphis coriandri* (Das) on fennel. Indian Journal of Entomology 71(2): 133-136.

Jayadevi H C, Sumithrama N, Nagaraja D N, Kumar A R V. 2003. Field evaluation of aqueous extracts of *Gnidia glauca* and *Lobelia nicotianaefolia* leaves for the management of diamond back moth in cabbage. Pest Management in Horticultural Ecosystems 9: 41-47.

Kant K, Ramanujam B, Tyagi S K, Sharma Y K, Meena S S, Mishra B K, Vishal M K, Meena S R. 2013. Management of fennel aphid, *Hyadaphis coriandri* (Das) through biorational approaches. Annals of Plant Protection Sciences 21(1): 21-23.

Lekha, Jat B L. 2004. Evaluation of some insecticides against aphid, *Hyadaphis coriandri* (Das) on coriander. Indian Journal of Applied Entomology 18(1): 32-35.

Meena N K, Lal G, Meena R S, Harisha C B, Meena S R. 2017. Pest

scenario of coriander (*Coriandrum sativum* L.) and population dynamics in semi-arid region of Rajasthan. International Journal of Tropical Agriculture 35(4): 779-783.

Meena N K, Singh Balraj, Lal G, Kant K, Meena R D. 2016. Sustainable management of aphid in coriander (*Coriandrum sativum* L.) through botanicals and bio-pesticides. International Journal of Seed Spices 6(1): 25-31.

Pareek R K, Sharma A, Kumawat K C. 2013. Seasonal abundance of insect pests and their major natural enemies in coriander, *Coriander sativum* (Linn.). Indian Journal of Applied Entomology 27(1): 21-26.

Pareek R K. 2009. Eco-friendly management of insect pest complex of coriander with special reference to aphid, *Hyadaphis coriandri* (Das) under semi-arid conditions. Ph D. Thesis, Submitted to Rajasthan Agricultural University, Bikaner.

Sachan S K, Singh C V, Singh H. 2010. Efficacy of botanical and chemical insecticides against coriander aphid, *Hyadaphis coriandri* (Das). Progressive Agriculture 10(2): 389-390.

(Manuscript Received: September, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: July, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20332

Indian Journal of Entomology 84(1): 168-170 (2022) DoI No.: 10.55446/IJE.2021.249

POPULATION DYNAMICS OF MUSTARD APHID AND ITS NATURAL ENEMIES

Rahul Kumar, R S Singh and Neelam Yadav*

Department of Entomology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur 208002, Uttar Pradesh, India
Email: neelu.amogh@gmail.com (corresponding author)

ABSTRACT

A field experiment was conducted on mustard aphid *Lipaphis erysimi* Kalt. and its natural enemies to document its seasonal incidence over four varieties of mustard during rabi season at the Instructional Farm, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. The aphids appeared in first week of January at the flowering stage, which peaked during 7th standard week were 115.5-155.0, 98.01-121.0, 75.5-108.6 and 55.80-86.49, aphids/ plant on mustard variety Urvashi, Vardan, Varuna and Rohini, respectively. Correlation coefficients of incidence with weather factors have been worked out.

Key words: Mustard, *Lipaphis erysimi*, incidence, natural enemies, weather parameters, seasonal variation, varieties, correlation coefficients, population dynamics

Mustard is an important oilseed crop which is considered to be highly economic important crop for national and international trade. A number of insect-pests are found to be associated with rapeseed-mustard crops in India, which include mustard aphid, *Lipaphis erysimi* Kaltenbach (Homoptera: Aphididae), sawfly, *Athalia lugens* Klug (Hymenoptera: Tenthredinidae), painted bug, *Bagrada hilaris* Burmeister (Hemiptera: Pentatomidae), diamond back moth (*Plutella xylostella* Linnaeus), cabbage butterfly (*Pieris brassicae* Linnaeus), larger moth (*Crocidolomia binotalis* Zeller), green peach aphid (*Myzus persicae* Sulzer) etc. (Dhaliwal and Arora, 2006) but mustard aphid is very important among them which may alone prove as limiting factor in the production of mustard. However, this insect-pest can be managed through chemicals, which have been found detrimental for their natural enemies as well as to human health. Therefore, development of ecofriendly techniques in IPM are required and with this in view this study evaluates the seasonal incidence of these.

MATERIALS AND METHODS

Before sowing the mustard, the experimental fields were prepared by ploughing with the soil turning plough-followed by two ploughings with cultivator and levelled. The most popular varieties of Indian mustard in Uttar Pradesh like Varuna, Vardan, Rohini and Urvashi were selected. The trial was conducted in 2.8 x 5m^2 net plot size replicated thrice with split plot design, with 45 x 10 cm spacing. The occurrence of grubs and adult of species of C*occinella septempunctata* predators were recorded on selected plants at weekly intervals. To determine the population dynamics of aphid in relation to weather parameters, aphid incidence was recorded at weekly intervals on 10 randomly selected plants on 10 cm top shoots (Mathur and Singh, 1986b). The meteorological data was obtained from the Department of Agronomy of the University. The seed yield was recorded at harvest. The method for counts of aphids followed All India Co-ordinated Research Project on oilseeds and Bakhetia et al. (1989). The data were analysed for the correlation coefficients (p=0.05).

RESULTS AND DISCUSSION

The observations on aphid incidence and weather factors given in Table 1, Figs. 1 and 2 reveal that the aphid *L. erysimi* appeared in first week of January, and reached a peak of 115.5-155.0 aphids plant^{-1} on Urvashi, 98.01-121.0 on Vardan, 75.5-108.16 on Varuna, and 55.80-86.49 aphids plant^{-1} on Rohini varieties during 7th standard week in second week of February; and it was nil in the last week of February and first week of March during 2010-11 and 2011-12, respectively. The natural enemies of mustard aphid observed led to the observations on the coccinellid C*occinella septempunctata*. This appeared during second and third week of February and reached its peak mid-February when the aphid incidence was maximum. Srivastava et al. (1995) observed *L.* towards the end of December on flowering. Rohilla et al. (1996) studied the abundance of Aphidoidea on five rapeseed cultivars, and observed

Table 1. Seasonal incidence of *L.erysimi* on varieties of mustard

Varieties	2010-11 No. of aphids/ plant									2011-12 No. of aphids/ plant								
	SW-1	SW-2	SW-3	SW-4	SW-5	SW-6	SW-7	SW-8	SW-9	SW-1	SW-2	SW-3	SW-4	SW-5	SW-6	SW-7	SW-8	SW-9
Urvashi	2.50 (1.58)	5.95 (2.44)	13.76 (3.71)	21.07 (4.59)	31.02 (5.57)	68.06 (8.25)	115.5 (10.7)	65.12 (8.07)	19.98 (4.47)	5.81 (2.41)	12.60 (3.55)	18.49 (4.30)	26.63 (5.16)	69.39 (8.33)	86.86 (9.32)	155.0 (12.45)	73.96 (8.60)	23.72 (4.87)
Vardan	2.34 (1.53)	3.39 (1.84)	7.24 (2.69)	12.82 (3.58)	22.47 (4.74)	55.80 (7.47)	98.01 (9.90)	48.86 (6.99)	17.22 (4.15)	4.49 (2.12)	10.69 (3.27)	16.73 (4.09)	23.62 (4.86)	51.55 (7.18)	68.06 (8.25)	121.0 (11.0)	58.38 (5.66)	21.81 (4.67)
Varuna	1.80 (1.34)	3.57 (1.89)	7.67 (2.77)	22.66 (4.76)	27.25 (5.22)	44.09 (6.64)	75.5 (8.69)	34.34 (5.86)	11.29 (3.36)	3.65 (1.91)	9.06 (3.01)	13.91 (3.73)	23.33 (4.83)	36.48 (6.04)	58.98 (7.68)	108.16 (7.68)	47.75 (6.19)	13.84 (3.72)
Rohini	1.51 (1.23)	2.96 (1.72)	7.13 (2.67)	22.47 (4.74)	28.20 (5.31)	36.60 (6.05)	55.80 (7.47)	30.69 (5.54)	9.00 (3.00)	2.99 (1.73)	7.40 (2.72)	11.16 (3.34)	17.64 (4.20)	29.05 (5.39)	43.03 (6.56)	86.49 (9.3)	38.19 (6.18)	12.46 (3.53)
SE(d)	0.03	0.97	0.11	0.11	0.12	0.15	0.19	0.17	0.1	0.04	0.08	0.1	0.13	0.18	0.21	0.27	0.14	0.13
CD p=0.05)	0.07	0.2	0.38	0.24	0.27	0.32	0.42	0.37	0.22	0.08	0.16	0.22	0.29	0.39	0.45	0.58	0.31	0.27

Figures in parentheses square root transformed values; SW- standard week

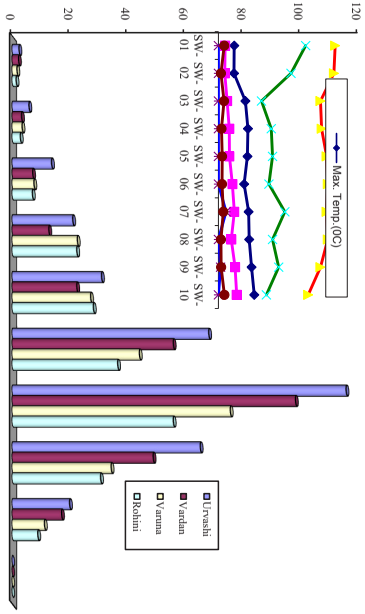
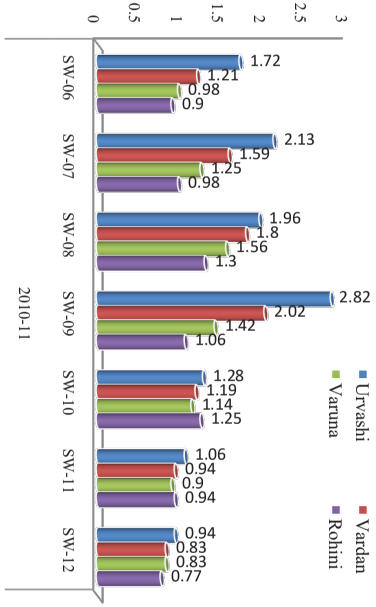


Fig. 1. Population dynamics of *L. erysimi*



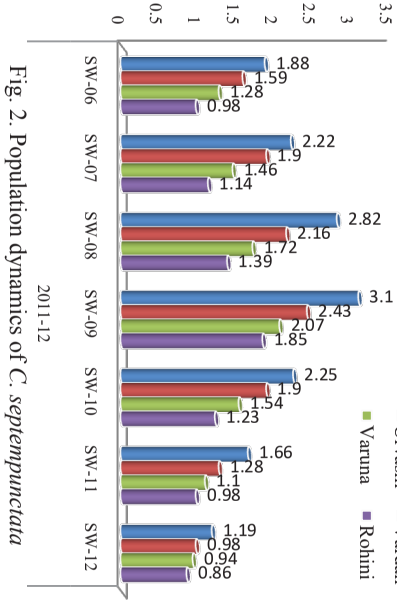


Fig. 2. Population dynamics of *C. septempunctata* in mustard (2010-11 and 2011-12

that *L. erysimi* appeared on *B. napus* in the 1st and 3rd week of January; and reached peak in the 2nd and last week of February. Singh and Malik (1998) reported its population buildup on *B. juncea* cv. Varuna with beginning of January and peaking in middle of February. Biswas and Das (2000) observed the first aphid infestation on mustard in the first/ third week of January with buildup during January-February, reaching the peak on the 8th February. Panda et al. (2000) reported that the aphid infested the crop from the 52nd to the 14th standard week (SW) with its peak during 7th standard week on 70 days old crops. Kumar et al. (2000) reported that the aphid appeared during the second half of January, and rapidly decreased to zero in late February/ early March.

REFERENCES

Bakhetie D R C, Sekhon B S, Brar K S, Ghorband A W. 1989. Determination of economic threshold of *Lipaphis erysimi* Kaltenbach on Indian mustard. Journal of Aphidology 3 (1-2): 125-134.

Biswas G C, Das G P. 2000. Population dynamics of the mustard aphid, *Lipaphis erysimi* (Kalt.) (Homoptera: Aphididae) in relation to weather parameters. Abstracts Bangladesh Journal of Entomology 10(1/ 2): 15-22.

Damodaram T, Hegde D M. 2010. Oilseeds situation: A statistical compendium. Directorate of Oilseeds Research, Hyderabad. 455 pp.

Dhaliwal G S, Arora G. 2006. Integrated pest management. Kalyani publishers, Ludhiana. pp. 61-62.

Kumar J, Singh S V, Malik Y P. 2000. Population dynamics and economic status of *Lipaphis erysimi* on mustard *Brassica juncea.* Indian Journal of Entomology 62(3): 253-259.

Mathur Y K, Singh S V. 1986b. Population dynamics of *Myzus persicae* Sulzer and *Lipaphis erysimi* Kalt. on rapeseed and mustard in Uttar Pradesh. Journal of Oilseeds Research 3(2): 246-250.

Panda D, Thakur B S, Patro B. 2000. Population dynamics of *Lipaphis erysimi* (Kalt.) on *Brassica juncea* L. at Raipur, Madhya Pradesh. Plant Protection Bulletin Faridabad 52(3/4): 28-30.

Rohilla H R, Singh H, Yadava T P. 1996. Seasonal abundance of aphid pests on rapeseed-mustard crops. Annals of Agri Bio Research 1 (1/2): 75-78.

Singh S V, Malik Y P. 1998. Population dynamics and economic threshold of *Lipaphis erysimi* on mustard. Indian Journal of Entomology 60(1)*:* 43-49.

Srivastava A, Singh H, Thakur H L. 1995. Impact of abiotic factors on the population dynamics of mustard aphid, *Lipaphis erysimi* (Kalt.) (Homoptera: Aphididae). Abstracts Journal of Oilseeds Research 12 (2): 197-202.

(Manuscript Received: November, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: April, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20259

Indian Journal of Entomology 84(1): 171-175 (2022) DoI No.: 10.55446/IJE.2021.251

EFFICACY OF PLANT PRODUCTS AGAINST LEAFHOPPER *AMRASCA BIGUTTULA BIGUTTULA* (ISHIDA) IN BT COTTON

Ram Sri Harsha Suryadevara and Vijay Kumar*

Department of Entomology, Punjab Agricultural University, Ludhiana 141001, Punjab, India
*Email: vijay_ento@pau.edu (corresponding author)

ABSTRACT

Field experiments were conducted on Bt cotton at the RRS Abohar and PAU, Ludhiana to evaluate various plant products viz. castor oil, pongamia oil, crude neem oil, sesame oil, linseed oil, garlic extract along with commercial neem-based biopesticides, Nimbecidine (azadirachtin 1500 ppm) and Ecotin (azadirachtin 5000 ppm) against leafhopper, *Amrasca biguttula biguttula* (Ishida) in Bt cotton. Three days after application, maximum mortality was in garlic extract @ 30 ml/ l (54.00 and 52.68%) followed by neem oil @ 10 ml/ l (49.17 and 47.83%), Ecotin (azadirachtin 5000 ppm) @ 1.5 ml/ l (45.39 and 44.17%) at Abohar and Ludhiana, respectively. After five and seven days of second application, it was significantly more with Ecotin @ 1.5 ml/ l (44.56, 44.06 and 28.83, 28.17%) followed by neem oil @ 10 ml/ l (40.34, 39.95 and 28.28 and 27.67%) and Nimbecidine @ 10 ml/ l (37.33, 36.83 and 21.56, 21.17%) at both the locations, respectively. Among various plant products, maximum predator counts were obtained with in garlic extract @ 30 ml/ l. Seed cotton yield was also significantly higher in Ecotin @ 1.5 ml/ l treated plots.

Key words: *Amrasca biguttula biguttula*, Bt cotton, efficacy, azadirachtin, oils, plant products, garlic extract, Ecotin, Nimbecidine, neem oil, seed cotton yield, predators, mortality

Cotton *Gossypium hirsutum* (L.) is the most important commercial crop, and it is attacked by large number of insect pests. Adoption of genetically modified cotton led to reduction in bollworms incidence but sucking pests namely mealybug, whitefly, thrips and leafhopper emerged as serious pests (Vennila, 2008). Among these, leafhopper, *Amrasca biguttula biguttula* (Ishida) (Hemiptera: Cicadellidae) is a serious pest of cotton in North India. Cotton and okra are most preferred hosts of leafhopper (Hussain and Lal, 1940; Afzal and Ghani, 1946). It has become one of the limiting factors in cotton productivity (Balakrishnan et al., 2007). Among the various measures adopted by farmers to manage leafhopper in cotton, insecticides are the major ones. Many insecticides are recommended, even then control failures had been reported. Among the various factors, development of resistance and resurgence are the major ones (Jeya Pradeepa and Regupathy, 2002; Rohini et al., 2012). To manage these problems, utilization of the natural products may prove to be the best. The information related to the management of the leafhopper with such ecofriendly approaches is very scanty. The present study is carried out to test the efficacy of different plant generated oils against leafhopper in Bt cotton.

MATERIALS AND METHODS

The study on the efficacy of various plants products against *A. biguttula biguttula* on *Bt* cotton hybrid, RCH 776 was carried out at two locations namely Abohar and Ludhiana during 2019. The experiment comprised of various treatments namely castor oil @ 20 and 30 ml/l; pongamia oil @ 10 and 20 ml/ l; neem oil @ 5 and 10 ml/ l; sesame oil @ 6 and 12 ml/ l; garlic extract @ 15 and 30 ml/ l; linseed oil @ 20 and 30 ml/ l; Nimbecidine (azadirachtin 1500 ppm) @ 10 ml/ l; Ecotin (azadirachtin 5000 ppm) @ 1.5 ml/ l; surf detergent and untreated control. The crop was sown in randomized block design (RBD) having three replications with a plot size of 50 m^2 each. The crop was raised as per PAU recommended agronomic practices (Anonymous, 2019). The commercially available oils were dissolved in surf detergent powder @ 10g/ l of water before the spray. The mixture was stirred properly so that no lumps of surf were seen and then after obtaining a homogenized solution, it was filtered using a white muslin cloth to avoid clogging of the nozzles. The commercial formulations namely Nimbecidine and Ecotin were mixed directly in water without adding any surfactant. The various plant products were sprayed on clear sunny day with manually operated knap sack sprayer, when the population of leafhopper reached ETL (second injury grade). The nymphal counts/ three leaves were taken a day before spray and one, three, five, seven and ten days after spray. The counts of predators namely spiders, coccinellids and chrysopa were also observed

on per plant basis, and the seed cotton yield (kg/ ha) on whole plot basis. The corrected mortality was worked out by using Henderson and Tilton (1955), and the data subjected to ANOVA after appropriate transformation.

RESULTS AND DISCUSSION

Effect of plant products/ oils on *Amrasca biguttula biguttula* when analysed with data obtained from Abohar revealed that during kharif 2019, the nymphs/ three leaves did not differ significantly among treatments before first application. One days after first application, efficacy was superior in Ecotin (azadirachtin 5000 ppm) @ 1.5 ml/ l (33.89%) followed by garlic extract @ 30 ml/ l (29.95%). After three days after spray, garlic extract @ 30 ml/ l (52.40%) was superior followed by neem oil @ 10 ml/ l (47.50%) and others. After five days, Ecotin @ 1.5 ml/ l (43.89%) was superior followed by neem oil @ 10 ml/ l (39.72%) and others, results were similar after seven days and ten days. With second application, after three days, garlic extract @ 30 ml/ l (54.00%) was the best followed by neem oil @ 10 ml/ l (49.17%). After five days, Ecotin @ 1.5 ml/ l (44.56%) followed by neem oil @ 10 ml/ l (40.43%) were superior; after seven- and ten-days similar trend was observed. The data obtained from Ludhiana again revealed the superiority of garlic extract @ 30 ml/ l (51.51%) followed by neem oil @ 10 ml/ l (46.67%), after three days of first spray. After five days, Ecotin @ 1.5 ml/ l (42.83%) followed by neem oil @ 10 ml/ l (38.67%) were the best, and similar trend was observed after ten days of spray. With second application, after three days garlic extract @ 30 ml/ l (52.68%) proved the best, and after five days, it was Ecotin (44.06%) followed by neem oil @ 10 ml/ l (39.95%). After seven and ten days, almost similar results were obtained. Seed cotton yield was significantly more with Ecotin @ 1.5 ml/ l (24.63 q/ ha), neem oil @ 10 ml/ l (24.47 q/ ha) and garlic extract @ 30 ml/ l (24.43 q/ ha) (Table 1).

From the above results, it can be concluded that Ecotin (azadirachtin 5000 ppm) @ 1.5 ml/ l, neem oil @ 10 ml/ l, nimbecidine @ 10 ml/ l and pongamia oil @ 20 ml/ l were more effective up to seven days of its application. However, garlic extract @ 30 ml/ l proved superior up to five days of spray. These observations corroborates with the earlier ones of Verma et al. (1989), Natarajan and Sundaramurthy (1990), Raju et al. (1992), Uthamasamy and Gajendran (1992) on the effect of neem oil 0.5% containing 0.1% Teepol as surfactant and NSKE (neem seed kernel extract) @ 5%. Natarajan et al. (2000) also revealed that NSKE and garlic extract were effective against leafhopper. Azadirachtin 1500 ppm @ 1000 ml/ ha, neem oil and garlic extract were found effective (Prathibhan and Ananthan, 1998; Iqbal et al., 2015). Rajput et al. (2017) showed that neem oil, linseed oil showed efficacy. Khanzada and Khanzada (2018) and Ullah et al. (2015) revealed that garlic extract was effective.

Pooled data on the effect of plant products on predators (chrysopa, coccinellid beetle and spiders) in Bt cotton at Abohar during kharif 2019 revealed that counts of predators/ plant after three days of spray was significantly higher in garlic extract @ 15 ml/ l (6.11), sesame oil @ 6 ml/ l (6.06), linseed oil @ 20 ml/ l (5.78), garlic extract @ 30 ml/ l (5.55), castor oil @ 20 ml/ l (5.50), pongamia oil @ 10 ml/ l and sesame oil @ 12 ml/ l (5.44) as compared to all other treatments (Table 2); after seven days of spray, significantly higher predator population was recorded in garlic extract @ 30 ml/ l (6.06) and other oils, and similar trend was observed after 10 days of spray. The pooled data obtained from Ludhiana after three days revealed significantly higher counts of predators/ plant again with garlic extract @ 15 ml/ l (6.78), followed by other oils; after seven days and ten days also almost similar results were obtained. Thus, it can be concluded that garlic extract, sesame oil, castor oil and pongamia oil are safe to the predators. Abdullah et al. (2017) reported that neem seed extracts @ 4 and 6% against leafhopper in Bt and non Bt cotton had least effect on natural enemies like Chrysopa, coccinellids and spiders. Among the plant products Ecotin @ 1.5 ml/ l up to seven days and garlic extract @ 30 ml/ l up to five days of sprays are effective against cotton leafhopper. Also, garlic extract, sesame oil, castor oil and pongamia oil are safe to the predators in Bt cotton.

ACKNOWLEDGEMENTS

Authors acknowledge the Department of Science and Technology, New Delhi for support under Department of Science and Technology, PURSE and FIST programme (Project No SR/FST/LSI/636/2015-c).

REFERENCES

Abdullah A, Ullah M I, Hassan M W, Khalid S, Iftikhar Y, Arshad M, Ochoa J M. 2017. Response of *Azadirachta indica* against *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae) and *Amrasca biguttula* Ishida (Homoptera: Cicadellidae) on cotton cultivars. Pakistan Journal of Zoology 49(6): 1983-1987.

Afzal M and Ghani M A. 1946. Cotton jassid in the Punjab. Indian Farming 7: 407-410.

Anonymous. 2019. Package of practices for kharif crops. pp.36-58. Punjab Agricultural University, Ludhiana.

Table 1. Efficacy of plant products and oils against *A. biguttula biguttula* on Bt cotton

Treatment	Dose/ l	No. of nymphs/ 3 leaves	Mortality of nymphs (%) First application					No. of leafhopper/ 3 leaves	Mortality of nymphs (%) Second application					Seed cotton yield (q/ ha)
		Before spray	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	Before spray	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	
Abohar														
Castor oil	20 ml	5.89	15.06 (22.82)	26.72 (31.1)	23.45 (28.95)	14.06 (22.00)	10.83 (19.21)	5.00 (2.45)	15.83 (23.44)	27.67 (31.72)	24.611 (29.73)	14.89 (22.69)	11.83 (20.8)	23.33
Castor oil	30 ml	5.75	17.89 (25.01)	35.72 (36.64)	29.56 (32.91)	17.50 (24.71)	12.06 (20.30)	4.73 (2.39)	18.89 (25.75)	37.00 (37.14)	30.06 (33.22)	18.56 (25.51)	13.11 (21.22)	23.73
Pongamia oil	10 ml	5.95	18.78 (25.67)	32.28 (34.60)	26.00 (30.64)	15.6 (23.26)	11.50 (19.81)	4.89 (2.43)	19.55 (26.23)	33.56 (35.39)	26.61 (31.04)	16.56 (24.00)	12.67 (20.79)	24.27
Pongamia oil	20 ml	6.17	21.83 (27.84)	40.50 (39.51)	34.94 (36.22)	18.83 (25.71)	13.50 (21.54)	4.50 (2.34)	22.78 (28.49)	40.94 (39.77)	35.83 (36.76)	19.61 (26.27)	14.44 (22.33)	24.40
Neem oil	5 ml	5.84	20.44 (26.87)	38.78 (38.50)	32.56 (34.78)	21.17 (27.37)	17.22 (24.50)	4.39 (2.32)	21.11 (27.34)	40.72 (39.64)	32.61 (34.81)	22.06 (28.00)	17.89 (24.99)	24.43
Neem oil	10 ml	6.27	24.22 (29.47)	47.50 (43.55)	39.72 (39.05)	27.34 (31.51)	17.78 (24.92)	4.11 (2.26)	25.06 (30.02)	49.17 (44.50)	40.34 (39.41)	28.28 (32.11)	18.61 (25.55)	24.90
Sesame oil	6 ml	5.89	17.83 (24.07)	28.80 (32.50)	23.22 (28.80)	13.83l (21.82)	10.78 (19.13)	5.11 (2.47)	16.06 (23.61)	30.33 (33.41)	24.22 (29.47)	15.22l (22.94)	11.67 (19.96)	23.60
Sesame oil	12 ml	5.89	19.89 (26.47)	36.89 (37.38)	32.17 (34.54)	17.61 (24.80)	12.39 (20.89)	5.00 (2.45)	17.28 (24.55)	36.22 (36.99)	32.45 (34.71)	17.78 (24.93)	13.39 (21.44)	23.97
Nimbecidine (azadirachtin 1500 ppm)	10 ml	6.56	23.67 (30.00)	44.11 (41.60)	36.55 (37.18)	20.95 (27.22)	14.11 (22.05)	4.60 (2.37)	24.45 (29.62)	45.78 (42.56)	37.33 (34.65)	21.56 (27.65)	13.78 (21.78)	24.63
Linseed oil	20 ml	5.89	16.89 (24.25)	26.22 (30.78)	21.94 (27.92)	13.17 (21.26)	9.94 (18.37)	5.28 (2.50)	17.72 (24.88)	27.67 (31.72)	22.17 (28.06)	14.06 (22.01)	10.50 (18.82)	22.77
Linseed oil	30 ml	5.83	17.83l (24.97)	34.22 (35.79)	30.50 (33.51)	16.17 (23.70)	11.22 (19.55)	5.00 (2.45)	19.05 (25.86)	33.11 (35.12)	27.78 (31.78)	16.17 (23.70)	12.33 (20.55)	23.17
Garlic extract	15 ml	6.28	21.61 (27.69)	41.89 (40.03)	27.55 (31.65)	17.17 (24.46)	8.78 (17.22)	4.61 (2.37)	22.44 (28.27)	42.61 (40.74)	28.17 (32.04)	17.61 (24.80)	7.89 (16.30)	24.17
Garlic extract	30 ml	5.72	29.95 (33.16)	52.40 (46.36)	31.94 (34.40)	21.61 (27.69)	12.67 (20.83)	4.28 (2.30)	29.39 (32.81)	54.00 (47.28)	32.39 (34.67)	22.22 (28.11)	14.28 (22.19)	24.83
Ecotin (azadirachtin 5000 ppm)	1.5 ml	6.50	33.89 (35.59)	45.11 (42.18)	43.89 (41.47)	27.95 (31.90)	19.89 (26.47)	4.22 (2.28)	36.34 (37.06)	45.39 (42.34)	44.56 (41.86)	28.83 (32.43)	21.17 (27.38)	24.97
Surf	10g	6.50	14.28 (22.19)	6.89 (15.20)	3.83 (11.27)	1.78 (7.61)	1.00 (5.74)	7.44 (2.91)	13.39 (21.45)	7.45 (15.83)	4.11 (11.68)	2.56 (9.10)	2.17 (8.45)	20.73
Untreated control	--	5.89	6.17	6.67	6.89	7.28	7.89	7.89	8.17	8.67	9.00	9.33	10.11	20.43
LSD (p=0.05)	--	NS	(0.81)	(0.89)	(0.86)	(1.03)	(1.31)	(0.09)	(0.87)	(0.93)	(1.19)	(1.57)	(1.47)	0.48
Ludhiana														
Castor oil	20 ml	5.22	14.00 (21.96)	25.83 (30.53)	22.50 (28.30)	13.56 (21.59)	10.06 (18.48)	5.11 (2.47)	15.00 (22.77)	26.83 (31.18)	23.84 (29.21)	14.22 (22.13)	11.06 (19.41)	22.90

(Table 1 contd.)

(Table 1 contd.)

Castor oil	30 ml	5.09	16.95 (24.30)	35.00 (36.25)	27.95 (31.89)	16.89 (24.25)	11.28 (19.60)	4.85 (2.42)	17.95 (25.05)	36.17 (36.95)	29.28 (32.74)	17.89 (25.00)	12.28 (20.49)	23.30
Pongamia oil	10 ml	5.33	17.67 (24.84)	31.33 (34.02)	24.50 (29.65)	14.89 (22.69)	10.78 (19.156)	5.00 (2.45)	18.67 (25.59)	32.50 (34.74)	25.83 (30.53)	15.89 (23.48)	11.78 (20.06)	23.83
Pongamia oil	20 ml	5.50	20.83 (27.14)	39.22 (38.76)	33.83 (35.55)	18.17 (25.21)	12.67 (20.84)	4.72 (2.39)	21.78 (27.81)	40.05 (39.25)	35.17 (36.36)	19.11 (25.91)	13.61 (21.63)	23.97
Neem oil	5 ml	5.13	19.33 (26.07)	37.89 (37.98)	31.56 (34.16)	20.44 (26.87)	16.11 (23.65)	4.61 (2.37)	20.33 (26.79)	39.06 (38.66)	31.56 (34.15)	21.39 (27.53)	17.05 (24.37)	24.07
Neem oil	10 ml	5.53	23.17 (28.75)	46.67 (43.07)	38.67 (38.44)	26.67 (31.08)	17.00 (24.34)	4.31 (2.30)	24.22 (29.47)	47.83 (43.74)	39.95 (39.18)	27.67 (31.72)	17.94 (25.05)	24.47
Sesame oil	6 ml	5.18	17.39j (24.63)	27.94 (31.90)	22.17 (28.07)	13.05 (21.17)	9.89 (18.31)	5.33 (2.52)	14.88 (22.67)	28.83 (32.46)	23.17 (28.76)	14.56 (22.41)	10.95 (19.31)	23.17
Sesame oil	12 ml	5.17	18.83 (25.71)	35.94 (36.82)	31.17 (33.92)	16.78 (24.17)	11.61 (19.91)	5.18 (2.49)	16.28 (23.78)	35.06 (36.29)	31.78 (34.30)	17.11 (24.43)	12.61 (20.79)	23.53
Nimbecidine (azadirachtin 1500 ppm)	10 ml	5.82	22.61 (28.38)	43.17 (41.06)	35.56 (36.59)	20.22 (26.71)	13.33 (21.40)	4.77 (2.40)	23.61 (29.06)	44.39 (41.76)	36.83 (37.35)	21.17 (27.38)	13.33 (21.40)	24.20
Linseed oil	20 ml	5.11	15.67 (23.30)	25.28 (30.17)	20.83 (27.14)	12.33 (20.54)	9.17 (17.62)	5.50 (2.55)	16.67 (24.08)	25.89 (30.57)	21.39 (27.53)	13.45 (21.50)	9.67 (18.10)	22.33
Linseed oil	30 ml	5.14	16.78 (24.15)	33.22 (35.18)	29.39 (32.81)	18.50 (23.18)	10.44 (18.84)	5.22 (2.49)	17.94 (25.05)	32.06 (34.47)	30.50 (33.45)	15.56 (23.22)	11.89 (20.16)	22.77
Garlic extract	15 ml	5.55	20.50 (26.91)	40.50 (39.51)	26.83 (31.18)	16.50 (23.95)	7.61 (15.99)	4.83 (2.41)	21.50 (27.61)	41.50 (40.09)	27.50 (31.61)	17.44 (24.68)	8.89 (17.31)	23.70
Garlic extract	30 ml	5.06	28.95 (32.54)	51.51 (45.85)	30.50 (33.50)	20.89 (27.18)	11.56 (19.85)	4.50 (2.35)	28.61 (32.33)	52.68 (46.52)	31.67 (34.23)	21.89 (27.88)	12.72 (20.88)	24.43
Ecotin (azadirachtin 5000 ppm)	1.5 ml	5.83	36.28 (37.02)	43.17 (41.05)	42.83 (40.86)	26.50 (30.97)	19.28 (26.03)	4.33 (2.31)	35.67 (36.66)	44.17 (41.63)	44.06 (41.47)	28.17 (32.03)	20.44 (26.87)	24.63
Surf	10g	5.80	12.95 (21.08)	6.11 (14.29)	3.11 (10.13)	1.44 (6.89)	0.83 (5.18)	7.17 (2.86)	12.72 (20.88)	6.95 (15.27)	3.72 (11.12)	1.89 (7.84)	1.89 (7.89)	19.83
Untreated control	--	5.06	5.17	5.67	6.11	6.83	7.28	7.28 (2.88)	7.44	7.83	8.11	8.39	9.17	19.93
LSD (p=0.05)	--	NS	(1.00)	(1.30)	(1.26)	(0.94)	(1.06)	(0.09)	(1.07)	(0.83)	(1.80)	(1.21)	(1.20)	0.66

Mean of three replications; DAS: Days after spray; Figures in parentheses arc sine transformed values

Table 2. Effect of plant products and oils on predators in Bt cotton

Treatment	Dose/ l	*No. of predators/ plant RRS Abohar						*No. predators/ plant PAU, Ludhiana					
		Before spray	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	Before spray	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS
Castor oil	20 ml	6.94	4.83	5.50	4.61	5.83	6.22	7.78	5.50	6.17	5.28	6.50	6.89
Castor oil	30 ml	6.00	4.50	5.17	4.83	5.28	5.39	6.83	6.17	5.83	5.50	5.94	6.06
Pongamia oil	10 ml	6.72	4.78	5.44	5.55	5.61	5.78	7.56	5.44	6.11	6.22	6.28	6.44
Pongamia oil	20 ml	6.50	4.67	5.33	5.17	5.28	6.17	7.33	5.33	6.00	5.83	5.95	6.83
Neem oil	5 ml	5.94	3.83	4.50	4.50	4.44	5.50	6.78	4.50	5.17	5.17	5.11	6.17
Neem oil	10 ml	6.06	3.83	4.22	4.28	4.17	5.44	6.89	4.50	4.89	4.94	4.83	6.11
Sesame oil	6 ml	7.00	5.39	6.06	5.83	5.11	6.22	7.89	6.05	6.72	6.50	6.11	6.89
Sesame oil	12 ml	6.00	4.78	5.44	5.28	5.33	5.39	6.89	5.44	6.11	6.28	6.00	6.06
Nimbecidine (azadirachtin 1500 ppm)	10 ml	6.83	3.50	4.17	4.11	4.17	5.94	7.67	4.17	4.83	4.78	4.83	6.61
Linseed oil	20 ml	7.11	4.78	5.78	5.50	5.78	5.33	7.94	5.44	6.44	6.17	6.44	6.00
Linseed oil	30 ml	6.83	4.44	5.11	4.94	4.67	6.17	7.67	5.11	5.78	5.61	5.33	6.83
Garlic extract	15 ml	6.05	5.44	6.11	6.05	5.78	6.00	6.89	6.11	6.78	6.72	6.44	6.67
Garlic extract	30 ml	6.89	4.89	5.55	5.44	6.06	6.39	7.78	5.55	6.22	6.10	5.72	7.06
Ecotin (azadirachtin 5000 ppm)	1.5 ml	6.28	4.44	5.11	5.17	5.11	5.44	6.89	5.11	5.78	5.83	5.78	6.11
Surf	10g	7.50	4.00	4.55	4.72	5.22	5.22	8.33	4.67	5.22	5.39	5.89	5.89
Untreated control	--	6.50	6.78	7.11	7.67	8.22	8.44	7.33	7.44	7.78	8.33	8.89	9.11
LSD (p=0.05)	--	NS	0.63	0.68	0.88	0.75	0.72	0.79	0.72	0.58	0.70	0.67	0..64

Mean of three replications; DAS: Days after spray; *Predators include Chrysopa, coccinellids and spiders

Balakrishnan N, Murugesan N, Vanniarajan C, Ramalingam A, Suriachandraselvan M. 2007. Screening of cotton genotypes for resistance to leafhopper, *Amrasca biguttula biguttula* Ishida in Tamil Nadu. Journal of Cotton Research and Development 21: 120-121.

Henderson C F and Tilton E W. 1955. Tests with acaricides against the brown wheat mite. Journal of Economic Entomology 48: 157-161.

Hussian M A, Lal K B. 1940. The binomics of *Empoasca devastans* Distant on some varieties of cotton in the Punjab. Indian Journal of Entomology 2: 123-136.

Iqbal J H, Ali M W, Hassan, Jamil M. 2015. Evaluation of indigenous plant extracts against sucking insect pests of okra crop. Pakistan Entomology 37: 39-44.

Jeya Pradeepa S, Regupathy A. 2002. Generating base line data for insecticide resistance monitoring in cotton leafhopper, *Amrasca devastans* (Distant). Resistant Pest Management Newsletter 11(2): 4-5.

Khanzada K K, Khanzada B. 2018. Using plant extracts to control the sucking insect pests of Brinjal. International Journal of Zolgical Studies 3(4)**:** 58-62.

Natarajan R, Subramanian P, Santaram G. 2000. Efficacy of some botanicals against okra leafhopper, *Amrasca biguttula biguttula* (Ishida). Annals of Plant Protection Science 8: 18-21.

Nataranjan K, Sundaramurthy V T. 1990. Effect of neem oil on cotton whitefly (*Bemisia tabaci*). Indian Journal of Agricultural Science 60: 290-291.

Parthiban M, Ananthan G. 1998. Alternate application of neem and biopesticide in cotton pest management. Insect Environment 3**:** 97-98.

Rajput L B, Gilal A A, Bukero A, Wahocho N A. 2017. Impact of different oils as biopesticide against sucking insect pests in cotton. Journal of Basic Applied Science 13**:** 34-40.

Raju N, Saivaraj K, Kareem A A. 1992. Effect of neem products and insecticides against jassid, *Amrasca biguttula biguttula* (Ishida) on MCU 7 cotton. All India Coordinated Cotton Improvement Project Silver Jubilee Souvenir, September 17-19, 1992, Nagpur. 129 p.

Rohini R T, Prasad N V V S D, Chalam M S V. 2012. Management of major sucking pests in cotton by insecticides. Journal of Cotton Research and Development 20: 102-106.

Ullah A, Javaid M A, Nouroz F. 2015. Bioefficacy evaluation of garlic extract against cotton sucking insects. http://www.thesleuthjournal.com

Uthamasamy S, Gajendran G. 1992. Efficacy of neem products in the management of pests of cotton. Proceedings. National seminar on changing scenario in pests and pest management in India. January 31- February 1, 1992, Hyderabad. 45 p.

Vennila S. 2008. Pest Management for cotton ecosystem or ecosystem management for cotton production. Current Science 94: 1351-1352.

Verma R S, Das S B, Shaw S S, Mandloi K C, Badaya A K. 1989. Chemical control of whitefly (*Bemisia tabaci*) on cotton. Journal of Cotton Research and Development 3: 49-51.

(Manuscript Received: November, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: April, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20262

Indian Journal of Entomology 84(1): 176-177 (2022) DoI No.: 10.55446/IJE.2021.252

EFFECT OF SEED PROTECTANTS AGAINST PULSE BEETLE *CALLOSOBRUCHUS CHINENSIS* INFESTING MUNGBEAN

Sonu Kumari*, S S Yadav, Krishna Rolania and Soniya Dhanda

Department of Entomology, Chaudhary Charan Singh Haryana Agricultural University, Hisar 125004, Haryana, India
*Email: ysonu9951@gmail.com (corresponding author)

ABSTRACT

Efficacy of some seed protectants against pulse beetle *Callosobruchus chinensis* (L.) in stored mungbean variety MH 421 was evaluated under laboratory conditions in the Department of Entomology, CCSHAU, Hisar during October- December 2018. The result revealed that the neem leaf powder (30g/ kg) and neem oil (10 ml/ kg) were found most effective with maximum adult mortality (100 and 98.33%, respectively), lowest grain damage and weight loss (1.06 and 1.20%) and (0.75 and 0.81%, respectively), followed by mentha oil (2.5 ml/ kg) and lemongrass oil (2.5 ml/ kg). Turmeric powder resulted in only less adult mortality (48.33%) with maximum infestation and weight loss (14.66 and 4.13%, respectively).

Key words: *Callosobruchus chinensis*, mungbean, plant oil, neem leaf powder, turmeric powder, adult mortality, infestation, grain damage, weight loss

Pulses are main source of protein and minerals contribute in sustainable agriculture (Kumbhare et al., 2014). India, though being the world's largest producers of pulses, productivity is low because of biotic and abiotic stresses. Mungbean is a major kharif pulse crop which is grown in arid and semi arid regions of the country. In India, it is cultivated in 43.26 million ha with total productivity of 500 kg/ ha (Anonymous, 2016-2017). Stored mungbean suffers enormous losses due to *Callosobruchus chinensis* (L.) infestation in field as well as storage (Fletcher and Ghosh, 2002). Control measures in stored grains rely on the use of insecticides/ fumigants (Shaheen and Khaliq, 2005). Use of botanicals such as neem seed powder, custard apple seed powder, edible and some non-edible oils, turmeric, bel, lantana etc for mixing in grain legume has increasingly become an ecofriendly option. These botanicals are environmentally safe, less hazardous, readily available and less expensive (Das, 1986). This study evaluates the effect of seed protectants against pulse beetle *C. chinensis* infesting mungbean in storage conditions.

MATERIALS AND METHODS

Studies were carried out using various seed protectants viz., neem oil (10 ml), neem leaf powder (30 g), mustard oil (7.5 ml), groundnut oil (7.5 ml), turmeric powder (3.5 mg), custard apple seed powder (5 g), mentha oil (2.5 ml), lemongrass oil (2.5 ml) and control (untreated) under laboratory conditions (30-35^{0}C, 75-80% R.H.). Required dose of various seed protectants were mixed with 50 g mungbean grains (variety MH 421) by shaking it manually. The treated grains were dried under shade for 24 hr. Newly emerged ten pairs of *C. chinensis* adults were released in plastic containers having treated seeds. Adult mortality was observed after 7 days of treatment. For estimation of grain and weight loss, observations were taken after 60 days of treatment and calculated (Adams and Schulten, 1978). The data were subjected to statistical analysis using OPSTAT software.

RESULTS AND DISCUSSION

The data on adult mortality revealed that neem leaf powder and neem oil were most effective protectants, whereas turmeric powder was the least effective against *C. chinensis* (Table 1). After 7 days of treatment, maximum mortality was in neem leaf powder (100%) and neem oil (98.33%) statistically at par with each other followed by mentha oil (91.66%) and lemongrass oil (88.33%) which were also, being statistically at par. The least mortality was found to be in the treatment of turmeric powder (48.33%) after control (8.33%). Maximum grain infestation by number and weight loss was also with turmeric powder (14.66 and 4.13%, respectively) after control (34.00 and 21.08%, respectively). The least infestation/ weight loss was observed with neem leaf powder (1.06 and 0.75%, respectively) and neem oil (1.20 and 0.81%, respectively) which was statistically at par

Table 1. Efficacy of seed protectants against *C. chinensis* infesting mungbean

Treatment	Adult mortality (%) 7 DAT*	Grain damage (%) 60 DAT	Weight loss (%) 60 DAT
Neem oil (10 ml/ kg)	98.33 (85.68)**	1.20 (6.27)	0.81 (5.17)
Neem leaf powder (30 g/ kg)	100.00 (90.00)	1.06 (5.92)	0.75 (4.97)
Mustard oil (7.5 ml/ kg)	81.66 (64.66)	2.26 (8.65)	1.82 (7.74)
Groundnut oil (7.5 ml/ kg)	68.33 (55.74)	2.86 (9.74)	2.10 (8.32)
Turmeric powder (3.5 mg/ kg)	48.33 (44.02)	14.66 (22.49)	4.13 (11.72)
Custard apple seed powder (5 g/ kg)	80.00 (63.52)	2.33 (8.78)	2.02 (8.18)
Mentha oil (2.5 ml/ kg)	91.66 (73.37)	1.66 (7.41)	1.11 (6.06)
Lemongrass oil (2.5 ml/ kg)	88.33 (70.08)	1.73 (7.55)	1.18 (6.23)
Control	8.33 (16.59)	34.00 (35.64)	21.08 (27.31)
CD (p=0.05)	5.93	0.99	0.71

*DAT- Days After Treatment; ** Figure in parentheses angular transformed values

with each other, followed by mentha (1.66 and 1.11%, respectively) and lemon grass oil (1.73 and 1.18%, respectively). Thus, it was concluded that neem leaf powder (30 g) and neem oil (10 ml) were the most effective against *C. chinensis* on stored mungbean. These findings derive support from Tabu et al. (2012) with neem leaf powder (20 g/ kg seed). Reddy et al. (1999) reported that neem oil at 1.0% was an effective protectant. The present findings agree with those of Khan et al. (2015) on neem leaf powder @ 2.5 g/ kg mungbean as regards damage and weight loss. Kumar et al. (2017) reported that treatment of grains with neem oil, mentha oil and lemongrass oil @ 2.5 ml/ kg seed were very effective.

REFERENCES

Adams J M, Schulten G G M. 1978. Loss caused by insects, mites and micro-organisms in post-harvest grain loss assessment methods. American Associate Cereal Chemist St. Paut Minnesota, U.S.A., 193.

Anonymous 2016-2017. Agricultural Statistics at a Glance. Ministry of Agriculture and Farmers Welfare, Government of India.

Das G P. 1986. Pesticidal efficacy of some indigenous plant oils against the pulse beetle, *Callosobruchus chinensis* Linn. (Coleoptera: Bruchidae). Bangladesh Journal Zoology 14(1): 15-18.

Fletcher T B, Ghosh C C. 2002. Stored grain pests. Rep. Proc. 3rd Ent. Meeting, Pusa, New Delhi. 712-716 pp.

Khan Z M, Ali R M, Bhuiyan S I, Hossain M A. 2015. Eco-friendly management of pulse beetle, *Callosobruchus chinensis* Linn. using botanicals on stored mungbean. International Journal of Scientific and Research Publications 5(5): 2250-3153.

Kumar L, Chakravarty S, Agnihotri M, Karnatak A K. 2017. Efficacy of some plant oils against pulse beetle, *Callosobruchus chinensis* (L.) infesting greengram under storage conditions. Research on Crops 18 (1): 157-163.

Kumbhare N, Dubey S K, Nain M S, Bahal R. 2014. Micro analysis of yield gap and profitability in pulses and cereals. Legume Research 37: 532-536.

Reddy M U, Bharati S R, Reddy D D R. 1999. Efficacy of some vegetable oils as protectants against the pulse beetle (*Callosobruchus chinensis*) in green gram (*Phaseolus aureus*) during storage. Indian Journal of Nutrition and Dietetics 36 (10): 436-442.

Shaheen F A, Khaliq A. 2005. Management of pulse beetle, *Callosobruchus chinensis* L. (Coleoptera : Bruchidae) in stored chickpea using ashes, red soil powder and turpentine e oil. Pakistan Journal of Entomology 27: 19-24.

Tabu D, Selvaraj T, Singh S K, Mulugeta N. 2012. Management of azuki bean beetle (*Callosobruchus chinensis* L.) using some botanicals, inert materials and edible oils in stored chickpea. Journal of Agricultural Technology 8 (3): 881-902.

(Manuscript Received: November, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: April, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20264

Indian Journal of Entomology 84(1): 178-180 (2022) DoI No.: 10.55446/IJE.2021.253

EVALUATION OF *EUCALYPTUS* CLONES FOR SUSCEPTIBILITY TO THE GALL WASP *LETOCYBE INVASA* FISHER AND LA SALLE

Akashdeep Singh, G P S Dhillon*, Nirmaljit Kaur[1] and K S Sangha

Department of Forestry and Natural Resources;
[1]Department of Botany, Punjab Agricultural University, Ludhiana 141004, India
*Email: dhillongps1@pau.edu (corresponding author)

ABSTRACT

This study investigates the variation among *Eucalyptus* clones for incidence of gall wasp (*Letocybe invasa*) and relative changes in biochemical parameters. The three years, and replicated clonal trial involved 14 clones with monthly observations made on the gall wasp incidence. Significant variation was found among the clones, with maximum incidence being in F-316 and relatively the least incidence in C-413, PE-11, PE-14 and C-72. Gall wasp incidence gradually increased from January to April and declined thereafter. The total soluble sugars and phenol content in the infested leaves were found to increase by 49.2 and 22.8% respectively, whereas the protein content decreases (8.8% decrease).

Key words: Punjab, *Eucalyptus*, *Letocybe invasa*, incidence, soluble sugar, total phenol, protein, seasonal incidence, clone, F-316, C-413, PE-11, PE-14 and C-72

Eucalyptus is most widely planted exotic tree due to its wider adaptability, short rotation, straight stem, fast growth and variety of uses. Since the introduction of clonal technology from 1992, about 2,50,000 ha land had come under clonal plantations (Kulkarni, 2004). The plantations established from genetically uniform materials are highly vulnerable to climatic factors particularly for insects and diseases due to the narrow genetic base (Aradhya and Phillips, 1993). Since 2000, a new invasive pest (*Leptocybe invasa*) is wreaking havoc on *Eucalyptus* plantations throughout the world (Aytar 2003; Mendel et al., 2004; Fatih, 2006). This pest is reported in almost all of the tropical regions including India. In India, *L. invasa* was first reported from the Mandya district of Karnataka and later at Tamil Nadu (Kumar et al., 2007). In Punjab, it was first noticed in 2009 (Sangha et al., 2011). The spread of the gall wasp is causing huge economic losses to the clonal plantations of the country. More than 20,000 ha of young trees have already been affected in southern states of India (Jacob and Kumar, 2009). Severe attack leads to deformation of leaves, bump-shaped galls on leaves, midribs, petioles, reduction of growth. With the increasing pest threats, the future thrust of genetic improvement should be for productivity and tolerance against this severe pest. Another area for improvement is better management practices for insect-pests. Keeping in view the threat of large scale spread of the gall wasp, the present study evaluates the variation for tolerance to gall wasp and the biochemical changes as a consequence of the gall wasp infestation.

MATERIALS AND METHODS

The study was carried out at experimental area, Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana (30°90'N, 75°81'E, 247 masl). Fourteen clones were planted at the spacing of 4x 3 m following randomized block design with three replications and plot size of five trees in each block. Five commercial clones (C-2135, F-316, C-413, C-72 and C-407) and nine PAU clones (PE-6, PE-14, PE-7, PE-5, PE-11, PE-13, PE-8, PE-12, PE-9) were used. The incidence of gall wasp was recorded at monthly intervals from March 2018 to February 2019. For this, three trees of each clone were selected in all three replications and further three branches were selected. The total number of galls induced on both leaf and petiole were counted and converted to % damage. Three sets of fresh leaves and infested leaves of all clones were taken to the laboratory of Department of Botany. Various biochemical parameters such as total soluble sugars (Dubois et al., 1956), total soluble proteins (Lowry et al., 1951) and total phenols (Swain and Hillis, 1959) were estimated following standard procedures. The data were subjected to ANOVA and means were compared using LSD (p=0.05) under completely randomized block design (CRBD) following the CPCS statistical software developed by Punjab Agricultural University, Ludhiana.

RESULTS AND DISCUSSION

The incidence of gall wasp given in Fig. 1 reveals significant differences among the months, with maximum infestation being in April (36.0%), which decreased thereafter, with moderate infestation in September (15.4 %) and February (12.7 %), and the least infestation being in November and December (7.5 %). The temporal variation reported by Rameshbhai (2010) in Gujarat revealed that the incidence increased from April, and peak was in June. Singh (2012) reported that the incidence starts increasing from February to May. Rajpoot (2012) found maximum leaf damage in *Eucalyptus* clones during May to June in *E. camaldulensis* and *E. citrodora.* The results from present study are in conformity with those of Kulkarni (2010) who found maximum gall intensity in April. Pooled data obtained from the clones revealed significant ($p<0.05$) differences among the clones in incidence (Fig. 2); three clones (F-316, PE-12 and C-2135 were found to be relatively more susceptible, while F-316 registered the maximum incidence (40.0%); no clone escaped from the attack. The minimum gall infestation was in C-413 which was statistically on par with PE-14, PE-11 and C-72. These results are in accordance with the findings of Rameshbhai (2010). Kumar et al. (2015) also found significant differences among the 19 clones.

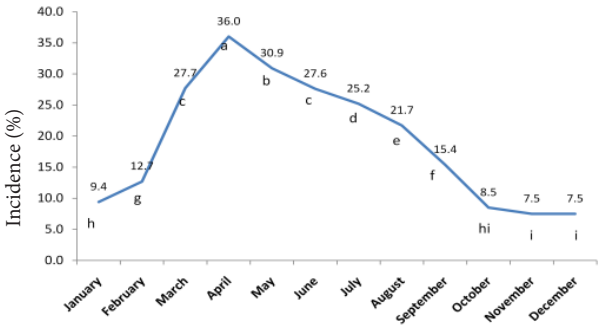


Fig.1. Seasonal incidence (%) of *L. invasa* (pooled mean of months)

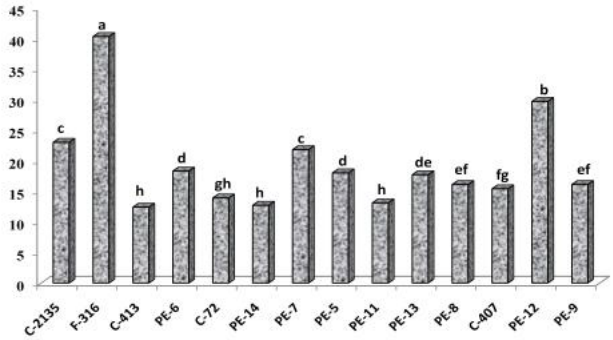


Fig. 2. Incidence of *L. invasa* on *Eucalyptus* (pooled mean of all clones)

Javaregowda and Prabhu (2010) and Kulkarni (2010) also reported significant variation among the *Eucalyptus* clones in susceptibility.

These differences may be due to host physical and nutritional characteristics, and host biochemical defences (Bentur and Kaslode, 1996; Singh, 2012). The content of total soluble sugars was significantly higher in the infested leaves with mean increase being 49.2%, and this increase may act as growth stimulant for *L. invasa.* The higher sugar content in leaves was reported to be beneficial for the insect feeding (Hartleg, 1998; Yang et al., 2003). Similarly, Singh (2012) reported the increase of sugar content in gall infested leaves of highly susceptible entries of *Eucalyptus*. Similarly, total phenol content also increased after infestation (Fig. 3); mean increase was 22.8%. Mukherjee et al. (2016) also observed increased level of total phenol which increases with gall severity on leaves of *Terminalia tomentosa and T. arjuna.* The results are in conformity with findings Singh (2012), who reported the increase of total phenol content in gall infested leaves. The total protein content in the infested leaves was significantly lower and the relative decrease in infested leaves was of 8.8%. Similar findings were obtained by Khattab and Khattab (2005).

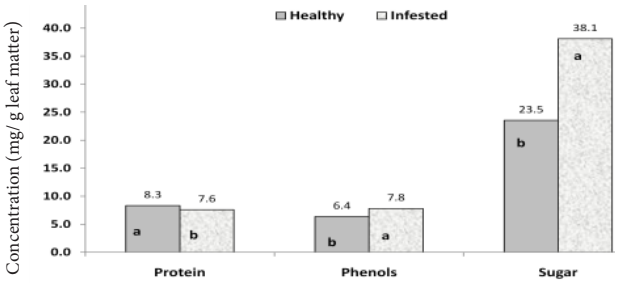


Fig. 3. Biochemical parameters of *Eucalyptus* leaf (after infestation by *L. invasa*)

REFERENCES

Aytar F. 2003. Natural biology, distribution and control method of *Leptocybe invasa* Fisher & La Salle (Hymnoptera: Eulophidae) Eucalyptus gall wasp in Turkey. DOA Dergisi Journal 9: 47-66.

Bentur J S, Kaslode M B. 1996. Hypersensitive reaction and induced resistance in rice against the Asian rice gall midge *Orseolia oryzae*. Entomologia Experimentalis et Applicata 78: 77-81.

Dubois Michel, K A, Gilles E, Hamilton J K, Rebers P A J, Smith F. 1956. Calorimetric dubois method for determination of sugar and releated substances. Analytical Chemistry 28: 350-356.

Fatih A. 2006. Natural history, distribution and hosts of *Eucalyptus* gall wasp in Turkey. In: Poster Presentation, VIIIth European Congress of Entomology, Izmir. 17-22 pp.

Hartleg S E. 1998. The chemical composition of plant galls: are levels of nutrients and secondary compounds controlled by the gall former. Oecologia 113: 492-501.

Jacob J P, Kumar R A. 2009. Incidence of galls induced by *Leptocybe invasa* on seedlings of *Eucalyptus camaldulensis* and *E. tereticornis*

from different seed sources in Southern India. International Journal of Ecology and Environment Science 35: 187-198.

Khattab H, Khattab I. 2005. Responses of eucalypt trees to the insect feeding (gall- forming psyllid). International Journal Agricultural Biology 7 (6): 979-984.

Kulkarni H D. 2004. Clonal forestry for industrial wood production. An ITC experience. Parthiban K T (ed.). Compendium on clonal forestry. Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalyam, India. 92-113 pp.

Kulkarni H D. 2010. Screening *Eucalyptus* clones against Leptocybe. *invasa* Fisher and-.La Salle (Hymenoptera: Eulophidae). Karnataka Journal of Agricultural Sciences 23: 87-90.

Kumar A, Sangha K S, Dhillon G P S. 2015. Screening of 19 genotypes of *Eucalyptus* spp. against gall wasp (*Leptocybe invasa*) in North-western India. Journal of Forestry Research 26: 355-359.

Kumar S S, Kant S K, Emmanuel T. 2007. Emergence of gall including insect *Leptocybe invasa* (Hymenoptera: Eulophidae) in *Eucalyptus* plantations in Gujarat, India. The Indian Forester 133: 1566-1568.

Lowry O H, Rosebrough N, Farr L A, Randall R J. 1951. Protein measurement with the folin phenol reagent. Journal of Biological Chemistry 193: 265-275.

Mendel Z, Protasov A, Fisher N, La Salle J. 2004. Taxonomy and biology of *Leptocybe invasa* (Hymenoptera: Eulophidae) and invasive gall inducer on *Eucalyptus*. Australian Journal of Entomology 43: 101-113.

Mukherjee S, Lokesh G, Aruna A S, Sharma S P, Sahay A. 2016. Studies on the foliar biochemical changes in the gall (*Trioza fletcheri minor*) infested tasar food plants *Terminalia arjuna* and *Terminalia tomentosa*. Journal of Entomology and Zoology Studies 4: 154-158.

Rajpoot R S. 2012. Evaluation of *Eucalyptus* clones and species against gall insect *Leptocybe invasa* Fisher and La salle (hymnoptera: eulophidae) on morphological basis. M Sc Thesis Navsari Agricultural University, Navsari, India.

Rameshbhai P T. 2010. Surveillance of gall insect (*Leptocybe invasa* Fisher & La Salle) in *Eucalyptus* in different agro-climatic regions of South Gujarat and Vadodara. M Sc Thesis, Navsari Agricultural University, Navsari, India.

Singh S K. 2012. Biochemical investigation of Eucalyptus for gall tolerance. M Sc Thesis, Navsari Agricultural University, Navsari, India.

Swain T, Hillis W E. 1959. The phenolic constituents of *Prunus domestica*. Journal of the Science of Food and Agriculture 10: 135-144.

(Manuscript Received: November, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: April, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20265

Indian Journal of Entomology 84(1): 181-183 (2022) DoI.: 10.55446/IJE.2021.256

MANAGEMENT OF LEAF MINERS INFESTING TOMATO UNDER PROTECTED CULTIVATION

Monica Jat*, Narayan Lal Dangi[1] and K V Nagarjuna Reddy[2]

Division of Entomology, ICAR- Indian Agricultural Research Institute, New Delhi 110012
[1]Department of Entomology, Maharana Pratap University of
Agriculture and Technology, Udaipur 313004, Rajasthan, India
[2]Department of Entomology, Indira Gandhi Krishi Vishwavidyalaya, Raipur 492006, Chhattisgarh, India
*Email: jmonicaiari@yahoo.com (corresponding author)

ABSTRACT

This study evaluates the effectiveness of YST (yellow sticky trap) and BST (blue sticky trap) in monitoring the leaf miners *Liriomyza trifolii* and *Tuta absoluta* on tomato under protected cultivation. The efficacy of insecticides viz., acephate 75SP, acetamiprid 20SP, diafenthiuron 50WP, spiromesifen 22.9SC, *Beauveria bassiana* @ 4g/ l and neem oil @ 10ml/ l including untreated control were also evaluated along with. The maximum trap catches (11.25/ trap) of *T. absoluta* was observed during 39th standard meteorological week (SMW), and with *L. trifolii*, it was (8.25/ trap) during 37th SMW in YST. Among the insecticides, acephate 75SP was highly effective with 59.50% reduction in incidence.

Key words: *Liriomyza trifolii*, *Tuta absoluta*, acephate, acetamiprid, diafenthiuron, spiromesifen, *Beauveria bassiana*, neem oil, yellow and blue sticky trap, yellow par trap, blue par trap, trap catches, standard meteorological week

Tomato is one of the most popular vegetables, and in India, its production is 18.7 mt area of 0.9 million ha (Saxena and Gandhi, 2015). It is grown in both open field and protected condition. During export and import, the movement of materials is responsible for accidental introduction or invasion of pests. American serpentine leaf miner *Liriomyza trifolii* (Burgess) and South American tomato moth or tomato leaf miner or tomato pin worm *Tuta absoluta* (Meyrick) have invaded India in 1990 and 2014, respectively. In India, *T. absoluta* M. was first reported from the Indian Institute of Horticultural Research (IIHR), Hessaraghatta, Bengaluru, Karnataka (Sridhar et al., 2014); then from Pune (Shashank et al*.,* 2015); and Malnad and in Hyderabad- Karnataka region (Kalleshwaraswamy et al., 2015**)**. *Tuta absoluta* is a neotropical oligophagous pest and solanaceous crops are its major hosts. These pests devastate tomato both in protected and open fields (Desneux et al*.,* 2010). The leaf miner causes losses up to 100% and it is a key pest of greenhouse and open field tomato (Arturo et al*.,* 2012*). Tuta absoluta* deposits eggs on the underside of leaves, stems and also on fruits, while the neonate larvae penetrate fruits, leaves and create mines and galleries. The use of insecticides is the most effective method to reduce *T. absoluta*, but chlorantraniliprole, the most effective insecticide had also been observed to suffer due to resistance. There is a need to devise more control measures and it is essential to find the efficacy of insecticides (Bawin et al*.,* 2014). Keeping these in view, this study evaluates the blue and yellow sticky traps along with certain insecticides under protected conditions.

MATERIALS AND METHODS

The study was done under protected cultivation at the High-tech Unit of Department of Horticulture, Rajasthan College of Agriculture, MPUAT, Udaipur. The seedlings of tomato variety "Dev" were transplanted during first week of July, 2018. The observations on pests were made during morning hours between 7 and 9 am. Completely randomized design (CRD) was followed with four replications in plots of size 7.0x 1.0 m with row to row and plant to plant spacing of 50x 45 cm. Four traps viz. YST (yellow sticky trap), BST (blue sticky trap), YPT (yellow pan trap), BPT (blue pan trap) were installed at the height of 130 cm above ground level in these 16 plots to record the pest complex. These traps were observed regularly and the insects caught, were segregated and counted separately under 10x hand magnifying lens. The number of leaf miners caught on traps were approximated at an interval of 7 days. Traps were also replaced to avoid the glue material getting dried up. For comparison between traps (YST and BST), the catches/ trap was subjected to the

test of significance using two sample t test. Efficacy of insecticides was followed with seven treatments inclusive of control, with each treatment applied twice; the first when sufficient pest buildup was observed and second 30 days after first spray. Leaf miner incidence was estimated by visual count, during the early morning hours from five randomly tagged plants/ plot, before spray as pretreatment counts and at 1, 3, 5 and 7 days after spray (DAS). These data were converted to % reduction in incidence (Henderson and Tilton, 1955), transformed into arc sine values and then subjected to ANOVA to find out the significance of the efficacy of treatments.

RESULTS AND DISCUSSION

The results obtained on the comparison of sticky traps reveal that the maximum incidence of *T. absoluta* was observed in 39th SMW on YST with 11.25/ trap, while that of *L. trifolii* was during 37th SMW (8.25/ trap). Thus, YST was more effective than BST (Table 1). Previously, Nayana et al. (2017) observed that the *T. absoluta* caused devastation in both open field and in polyhouse, and its density increased with the growth of crop under both field and polyhouse. Bayisa et al. (2017) observed that YST impregnated with castor, lavender and lemon oils attracted more catches. Kaur et al. (2010) with *L. trifolii* observed that its incidence was less during the early season; and Martin et al. (2005) with red, blue, violet-, green-, white-, and yellow-coloured traps in celery observed that yellow opaque or translucent sticky cards attracted more insects.

The insecticides when evaluated revealed that there are significant reductions in leaf miner incidence at 1, 3, 5 and 7 days after first as well as second spray;

Table 1. Efficacy of traps against leaf miners under protected cultivation (2018)

SMW	Mean No./ trap			
	T. absoluta		*L. trifoli*	
	YST	BST	YST	BST
06-Aug (32)	3.50	1.25	3.00	0.75
13-Aug (33)	4.50	1.75	3.75	1.25
20-Aug (34)	5.50	1.75	3.50	1.25
27-Aug (35)	6.75	2.25	5.50	2.00
03-Sep (36)	7.00	2.50	6.00	2.25
10-Sep (37)	8.75	2.75	8.25	3.00
17-Sep (38)	9.50	2.75	7.75	2.00
24-Sep (39)	11.25	3.00	7.00	2.50
Mean	7.09	2.25	5.59	1.81
t-cal	2.21*		2.17*	
t-tab (5%)	2.14		2.14	

*significant at p=0.05

Table 2. Efficacy of insecticides on leaf miners in tomato under protected cultivation (2018)

S.No.	Treatments	Reduction (%) in incidence									
		1st Spray				2nd Spray					
		PTP/ 5 plants	1 DAS	3 DAS	5 DAS	7 DAS	PTP/ 5 plants	1 DAS	3 DAS	5 DAS	7 DAS
1.	Spiromesifen (22.9SC) @ 0.10%	19.00	47.08^{b}	51.47^{b}	52.65^{b}	53.27^{b}	38.33	45.55^{c}	46.40^{c}	47.50^{c}	48.14^{c}
		(4.41)	(57.10)	(61.36)	(63.03)	(64.24)	(6.22)	(50.95)	(52.44)	(54.36)	(55.47)
2.	Acetamiprid (20SP) @ 0.02%	18.33	51.10^{a}	53.90^{ab}	58.76^{a}	57.14^{a}	39.67	49.95^{ab}	51.56^{ab}	52.87^{ab}	54.34^{ab}
		(4.33)	(66.56)	(65.28)	(69.95)	(70.39)	(6.33)	(58.59)	(61.34)	(63.57)	(66.01)
3.	Neem oil @ 10ml/ l	21.00	45.69^{bc}	46.70^{c}	46.76^{c}	48.42^{c}	46.00	36.61^{d}	37.37^{d}	38.56^{d}	41.69^{d}
		(4.63)	(51.20)	(54.70)	(56.38)	(57.68)	(6.79)	(35.56)	(36.84)	(38.85)	(44.23)
4.	*Beauveria bassiana* @ 4g/ l	24.00	43.78^{c}	45.97^{c}	46.24^{c}	47.03^{c}	44.00	35.47^{d}	35.95^{d}	37.11^{d}	40.57^{d}
		(4.94)	(47.87)	(51.70)	(53.90)	(53.54)	(6.64)	(33.68)	(34.46)	(36.41)	(42.29)
5.	Diafenthiuron (50WP) @ 0.04%	19.67	46.15^{b}	50.45^{b}	52.36^{b}	52.89^{b}	50.02	47.06^{bc}	48.35^{bc}	49.91^{bc}	50.49^{bc}
		(4.49)	(55.48)	(60.14)	(62.20)	(63.59)	(7.10)	(53.94)	(55.83)	(58.57)	(59.52)
6.	Acephate (75SP) @ 0.20%	21.33	51.77^{a}	55.21^{a}	59.50^{a}	58.96^{a}	45.33	51.06^{a}	52.99^{a}	55.25^{a}	56.87^{a}
		(4.67)	(61.70)	(67.28)	(71.13)	(73.42)	(6.77)	(60.49)	(63.77)	(67.51)	(70.13)
7.	Control	22.34	-	-	-	-	43.33	-	-	-	-
		(4.77)					(6.61)				
	SEm	0.16	1.09	1.24	1.85	1.28	0.31	1.30	1.61	1.58	1.34
	C.D. at 5%	0.50	3.23	3.70	5.53	3.84	0.93	3.95	4.89	4.80	4.06

Figures in parentheses of PTP $\sqrt{x+0.5}$ transformed values; Figures in parentheses (after spray) arc sine transformed values; PTP: Pretreatment, 1day before treatment; Numbers followed by same alphabets in each column not significantly different at p=0.05; DAS: Days after spray

pretreatment counts were uniform and varied from 18.33 to 24.00/ 5 plants; after first spray, acephate 75SP was significantly superior with 51.77 to 59.50% reduction, followed by acetamiprid 20SP being at par; spiromesifen 22.9SC and diafenthiuron 50WP were moderately effective, while the least effective one was *Beauveria bassiana* @4g/ l at par with neem oil @10ml/ l. Similarly, after the second spray acephate led to 51.06- 56.87% reduction followed by acetamiprid being at par; also, spiromesifin and diafenthiuron were moderately effective; the least effective was again *B.a bassiana* being at par with neem oil (Table 2).

Wankhede et al. (2007) against *L. trifolii* in tomato, observed that neem oil @ 10ml/ l was the least effective, followed by 0.01% spinosad and 5% NSKE. Moussa et al. (2013) observed that indoxcarb 15EC, chlorantraniliprole 20SC, chlorfenapyr 36SC, spinosad 24SC, chlofenapyr 36SC mixed with indoxacarb 15EC, spinosad 24SC mixed with abamectin 1.8%, emamectin benzoate 5SG and imidacloprid 20SC provided excellent control of *T. absoluta*. Derbalah et al. (2012) suggested that the mixing of imidacloprid with *Artemesia cina* extract improved the efficiency against *T. absoluta* on tomato crop under greenhouse conditions. Mondal (2016) against *Liriomyza sp.* found that imidacloprid (0.01%) followed by acephate (0.15%) were effective.

ACKNOWLEDGEMENTS

Authors thank the Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan for facilitating the work.

REFERENCES

Arturo C, Salvatore D, Gavino D. 2012. Integrated control in protected crops. Mediterranean Climate IOBC-WPRS Bulletin 80: 319-324.

Bawin T, De Backer L, Dujeu D. 2014. Infestation level influences oviposition site selection in the tomato leaf miner *Tuta absoluta* (Lepidoptera: Gelechiidae). Insects 5(4): 877-884.

Bayisa N G, Hundesa N, Tefera B N. 2017. Essential oils applied on sticky traps increase trapping of sucking pests under greenhouse condition. International Journal of Research Studies in Agricultural Sciences 25: 36-45.

Derbalah A S, Morsey S Z, Samahy M. 2012. Some recent approaches to control *Tuta absoluta* in tomato under greenhouse conditions. African Entomology 20(1): 27-34.

Desneux N, Wajnberg E, Kag W, Burgio G, Arpaia S, Narvaezvasquez CA et al. 2010. Biological invasion of European tomato crops by *Tuta absoluta*: Ecology, history of invasion and prospects for biological control. Journal of Pesticide Science 83: 197-215.

Kalleshwaraswamy C M, Murthy M S, Viraktamath C A, Kumar N K K. 2015. Occurrence of *Tuta absoluta* (Lepidoptera: Gelechiidae) in the Malnad and Hyderabad-Karnataka Regions of Karnataka, India. Florida Entomologist 98(3): 970-971.

Kaur S, Srinivasan R, Cheema D S, Lal T, Ghai T R, Chadha M L. 2010. Monitoring of major pests on cucumber, sweet pepper and tomato under net-house conditions in Punjab, India. Pest Management in Horticultural Ecosystems 16: 148-155.

Hinderson C F, Tilton E W. 1955. Tests with acaricides against the brown wheat mite. Journal of Economic Entomology 48: 157-161.

Martin A D, Vernon R S, Hallett R H. 2005. Influence of colour and trap height on captures of adult pea leaf miner, *Liriomyza huidobrensis* (Blanchard) (Diptera: Agromyzidae) in celery. Journal of Entomological Society 136: 25-35.

Moussa S, Baiomy F, Sharma A, Adl F E. 2013. The status of tomato leaf miner in Egypt and potential effective pesticides. Academic Journal of Entomology 6(3): 110-115.

Mondol D. 2016. Efficacy of some insecticides in the management of *Liriomyza brassicae* on *Pisum sativum*. International Journal of Engineering Science and Computing 6: 1640-1642.

Nayana B P, Shashank P R, Kalleshwaraswamy C M. 2017. Seasonal incidence of invasive tomato leaf miner, *Tuta absoluta* (Lepidoptera: Gelechiidae) on tomato in Karnataka, India. Journal of Entomology and Zoological Studies 6(1): 400-405.

Saxena M, Gandhi C P. 2015. Indian Horticulture Database-2014. National Horticulture Board, Ministry of Agriculture, Government of India P. 286.

Shashank P R, Chandrashekar K, Naresh M, Sreedevi K. 2015. Occurrence of *Tuta absoluta* (Lepidoptera: Gelechiidae): An invasive pest from India. Indian Journal of Entomology 77(4): 323-329.

Sridhar V, Chakravarthy A K, Asokan R, Vinesh L S, Rebijith K B, Vennila S. 2014. New record of the invasive South American tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in India. Pest Management in Horticultural Ecosystems 20(2): 148-154.

Wankhede S M, Deotale V Y, Undirwade D B, Mane P N, Deotale R O, Kahare R N. 2007. Performance of some insecticides and biopesticides against tomato leaf miner *Liriomyza trifolii* Burgess. Journal of Soils Crops 17: 136-138.

(Manuscript Received: October, 2020; Revised: January, 2021;
Accepted: January, 2021; Online Published: March, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20278

Indian Journal of Entomology 84(1): 184-212 (2022) DoI.: 10.55446/IJE.2021.116

THE INDIAN PLATYNINAE - A CHECKLIST (COLEOPTERA: CARABIDAE)#

Ashly Kurian* and Sabu K Thomas

Post-Graduate & Research Department of Zoology,
St. Joseph's College (Autonomous) Devagiri, Kozhikode 673008, Kerala, India
*Email: ashlykurian29@gmail.com (corresponding author)

ABSTRACT

An updated checklist of 188 species of the Platyninae (with 139 species under Platynini and 49 species under Sphodrini) known in the Indian subcontinent, along with details of the revisions, literature, and distribution patterns is provided. One hundred twenty-five species of these occur only in the Indian landmass, with 89 in the Platynini and 36 in the Sphodrini. Of the 125 Indian species, 94 occur within the Palaearctic region in India, 22 in the Oriental, and five in both Oriental and Palaearctic regions. Among the 125 Indian species, 111 are endemic to three global hotspots of biodiversity in the Indian subcontinent: (i) 96 endemic to the Himalaya, (ii) eight to the Western Ghats and Sri Lanka, and (iii) seven to the Indo-Burma hotspot of biodiversity. Five genera are endemic to the Indian mainland, and 10 genera to the Himalaya hotspot of biodiversity.

Key words: Carabidae, Platynini, Sphodrini, India, checklist, Atranopsina, Calathina, Dolichina, Pristosiina, Synuchina, distribution endemism, Himalaya, Western Ghats, Indo-Burma hotspot, Oriental, Palaearctic

The Carabidae (ground beetles) is one of the most speciose of beetle families that includes 39,358 extant taxa. The Platyninae is speciose that includes more than 3,900 species under the Omphreini, Platynini, and Sphodrini (Lorenz 2005, 2021). The Platyninae in India and Sri Lanka are represented by 188 species belonging to Platynini and Sphodrini. The Platynini is more diverse in tropical than in temperate regions (Bousquet 2012, Fedorenko 2011, 2015) and less understood due to limited revisionary works (Fedorenko 2015). The Sphodrini is principally distributed in temperate regions (Casale 1988, Ruiz et al., 2009). Of the 188 Platyninae species known from India, 68 were reported by Andrewes (1930-1937) with 49 from the Palaearctic Himalaya, 14 from the non-Himalayan Oriental, and five from both Himalayan and non-Himalayan regions. The present checklist updates the Indian taxa of the Platyninae with all the nomenclatural changes and revisions after 1929, supplemented with details of distribution patterns and pertienent references.

Distribution data for each species were collected by verifying records and descriptions of the Indian taxa determined between 1758 and 1929 from the *Catalogue of Indian Carabidae* (Andrewes 1930). Subsequent species additions and revisions were collected by tracing the references of species in Lorenz (2005), Löbl & Löbl (2017), Lorenz (2021) and from the *Carabidae of the World* website (Anichtchenko et al., 2021). In this article, we treat *Colpodes* following Liebherr (1998) as a taxon that includes three Javanese species and the non-Javanese species as species of *Platynus* and not as two genera, *sensu* Lorenz (2005, 2021). Data for the four Platynini taxa were collected by examining insect collections available at St. Joseph's College, Kozhikode (11°25'N, 75°77'E) and at various museums of the Zoological Survey of India. Specimens collected and verified by the authors (marked *) are deposited in the national insect collections of Zoological Survey of India Western Ghats Regional Centre, Kozhikode (ZSIK). Locality details of 184 species of Indian landmass from the descriptions and records are supplied. Species from the upper Himalaya (500 amsl and above) are recognized as the Palaearctic species of the Indian subcontinent (PAR - India), and the others as the Oriental species of the Indian subcontinent (ORR - India). Species from ORR and PAR in the upper ranges of the Himalaya of the Indian subcontinent have been categorized as ORR - India/PAR - India. Four species with no locality details in the descriptions are indicated 'India'.

The following are the symbols and abbreviations used: = Synonym; † Untraceable references and full paper not in hand; # Reference which led to the synonymy; AUR Australian Region; NAR Nearctic Region; ORR Oriental Region; PAR Palaearctic Region; ssp. Subspecies

#Invited Review: Courtesy Review Editor– Dr. A. Anantanaryanan Raman, CSIRO, Australia.

Checklist of species

A. Platynini Bonelli 1810

Platynina (*sensu stricto*)

1. *Agonidium* Jeannel 1948

Type species. *Megalonychus madagascariensis* Chaudoir 1843.

Agonidium Jeannel 1948: 523, Liebherr & Schmidt 2004: 151, 153.

***Agonidium birmanicum* (Bates 1892)**

Megalonychus birmanicus Bates 1892: 369, Andrewes, 1930a: 211.

Agonidium birmanicum (Bates 1892), Liebherr & Schmidt 2004: 151, Lorenz 2005: 407.

ORR - India. Assam (26°20'N, 92°937'E): Noa Dehing, Naga Hills; Meghalaya (25°57'N, 91°36'E): Khasi Hills; New Delhi (28°36'N, 77°12'E): Pusa; Uttar Pradesh (26°84'N, 80°94'E): Saharanpur; West Bengal (22°98'N, 87°85'E): Gopaldhara; PAR - India. Uttarakhand (30°06'N, 79°01'E): Dehra Dun. Also known in the Lao People's Democratic Republic, Myanmar and North Korea.

***Agonidium cyanipenne* (Bates 1892)**

Megalonychus cyanipennis Bates 1892: 370, Andrewes 1930a: 211.

Agonidium cyanipenne (Bates 1892): Liebherr & Schmidt 2004: 151, Lorenz 2005: 407.

ORR - India. Assam: Noa Dehing; Meghalaya: Khasi Hills: PAR - India. Sikkim (27°53'N, 88°51'E): Tista Bridge.

2. *Agonum* Bonelli 1810

Type species. *Carabus marginatus* Linnaeus 1758.

Agonum Bonelli 1810: Tabula synoptica, Casey 1920: 98, Liebherr 1994: 2, Liebherr & Schmidt 2004: 151, Lorenz 2005: 407, Löbl & Löbl 2017: 642.

=*Agonops* Bousquet 2002: 5, #Liebherr & Schmidt 2004: 151, =*Amolyntus* Gistel 1848: viii [Homonym], =*Megalonychus* Chaudoir 1843: 418, Liebherr & Schmidt 2004: 151#.

***Agonum (incertae) abnormale* Jedlička 1960**

Agonum abnormale Jedlička 1960: 593, Lorenz 2005: 412, Löbl & Löbl 2017: 649.

PAR - India. Jammu & Kashmir (33°27'N, 75°34'E): Pahalgam.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Agonum (Agonum) chinense* (Boheman 1858)**

Anchomenus chinensis Boheman 1858: 15, Bates 1891b: 335, Andrewes 1924a: 49, Andrewes 1930a: 24.

Agonum chinense (Boheman 1858): Liebherr & Schmidt 2004: 202, Lorenz 2005: 409, Schmidt 2008: 200, Löbl & Löbl 2017: 643.

=*Agonocyrtes orbicollis* Motschulsky 1865: 323 [Homonym], =*Agonum javanense* Louwerens 1955: 54, =*Agonum sinensis* Csiki 1931: 868 [Replaced Name], =*Anchomenus indicus* Andrewes 1922a: 165, =*Anchomenus irideus* Bates 1873b: 329, Bates 1891b: 335, =*Platynus hasegawai* Habu 1975: 65.

ORR - India. Karnataka (15°31'N, 75°71'E): Belgaum; Madhya Pradesh (22°97'N, 78°65'E): South Mandla, Motinala, Khawasa, Mhow, Seoni; Chota Nagpur (Tetara); Maharashtra (19°75'N, 75°71'E): Bhiwapur; Sri Lanka. Also known in Indonesia, Singapore, Vietnam; PAR - China, Japan and Taiwan.

Remarks: Only species of *Agonum* reported in south India.

***Agonum (incertae) comatum* (Andrewes 1923)**

Anchomenus comatus Andrewes 1923b: 219, Andrewes 1930a: 24.

Agonum comatum (Andrewes 1923): Löbl & Smetana 2003: 454, Lorenz 2005: 412, Löbl & Löbl 2017: 649.

ORR - India. Assam: Kobo; Bank of Dihong below Pasighat; Eastern Duars. Also known in Vietnam; PAR - India. Uttarakhand: Kumaon, Almora, Tanakpur, Ranikhet, Dehra Dun.

***Agonum euroum* (Andrewes 1924)**

Anchomenus eurous Andrewes 1924a: 105, Andrewes 1926a: 69, Andrewes 1930a: 24.

Agonum euroum (Andrewes 1924): Lorenz 2005: 412.

=*Colpodes eurous* Löbl & Löbl 2017: 654.

PAR - India. Himachal Pradesh (31°10'N, 77°17'E): Spiti, Kulu; Uttarakhand: Kumaon, West Almora, Dehra Dun, Mundali, Gori Valley and Gorge, Girgaon path to Munsyari, Sunderdhunga Valley, Kali Valley.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Agonum (Agonum) illocatum* (Walker 1858)**

Argutor degener Walker 1858: 204, Bates 1886: 146, Andrewes 1919b: 189 (*Anchomenus*), Andrewes 1930a: 24.

Agonum illocatum (Walker 1858): Andrewes 1930a: 24.

=*Anchomenus illocatus* Bates 1886: 146, Andrewes 1930a: 24.

ORR - Sri Lanka.

***Agonum (Celaenagonum) kucerai* (Morvan 2002)**

Celaenagonum kucerai Morvan 2002: 6, Löbl & Löbl 2017: 653.

Agonum kucerai (Morvan 2002): Lorenz 2005: 412.

PAR - India. Sikkim.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Agonum (Agonum) ladakense* (Bates 1878)**

Anchomenus ladakensis Bates 1878: 718†, Bates 1891a: 11, Andrewes 1924a: 48, Andrewes 1930a: 25.

Agonum ladakense (Bates 1878): Lorenz 2005: 412, Löbl & Löbl 2017: 649.

PAR - India. Jammu & Kashmir: Leh, Kargil, Pangong Valley (between Tangtze and Chagra). Also known in China and Tajikistan.

***Agonum (Agonum) mesostictum* (Bates 1889)**

Anchomenus mesostictus Bates 1889b: 215, Andrewes 1930a: 25.

Agonum mesostictum (Bates 1889): Liebherr & Schmidt 2004: 202, Lorenz 2005: 409, Löbl & Löbl 2017: 644.

=*Agonum chotjaii* Morvan 1973: 184, = *Agonum corvinum* Reitter 1907: 69.

PAR - India. Jammu & Kashmir: Goorais Valley. Also known in Afghanistan, Georgia, Iran, Kazakhstan, Kyrgyzstan, Pakistan, Syria, Turkmenistan and Uzbekistan.

***Agonum (incertae) praetor* (Andrewes 1930)**

Anchomenus praetor Andrewes 1930b: 35.

Agonum praetor (Andrewes 1930): Lorenz 2005: 412, Löbl & Löbl 2017: 649.

PAR - India. West Bengal (22°98'N, 87°85'E): Darjeeling.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Agonum (Agonum) scintillans* (Boheman 1858)**

Anchomenus scintillans Boheman 1858: 16, Andrewes 1921: 180, Andrewes 1930a: 26.

Agonum scintillans (Boheman 1858): Liebherr & Schmidt 2004: 202, Lorenz 2005: 408, Schmidt 2008: 200, Löbl & Löbl 2017: 645.

=*Anchomenus aeneotinctus* Bates 1873a: 330, Bates 1892: 371, =*Agonum kumataianum* Habu 1973b: 105, Löbl & Löbl 2017: 645.

PAR - India. Sikkim; Uttarakhand. Also known in Bhutan, China, Pakistan, Nepal; ORR - The Lao People's Democratic Republic, Myanmar and Vietnam.

3. *Andrewesius* Jedlička 1932

Type species. *Andrewesius vimmeri* Jedlička 1932.

Andrewesius Jedlička 1932: 74, Jedlička 1934: 178, Andrewes 1939: 131, Kryzhanovskij 1993: 297, Lorenz 2005: 413, Löbl & Löbl 2017: 651.

***Andrewesius vikara* (Andrewes 1923)**

Colpodes vikara Andrewes 1923e: 684, Andrewes 1930a: 126, Louwerens 1953: 84, Löbl & Smetana 2003: 456, Löbl & Löbl 2017: 655.

Andrewesius vikara (Andrewes 1923): Lorenz 2005: 413.

PAR - India. Sikkim; Uttarakhand: Almora, Kumaon, Pindar Valley; West Bengal: Tonglu.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Andrewesius vulpinus* (Andrewes 1923)**

Colpodes vulpinus Andrewes 1923e: 685, Andrewes 1930a: 126, Louwerens 1953: 86, Löbl & Smetana 2003: 456, Löbl & Löbl 2017: 655.

Andrewesius vulpinus (Andrewes 1923): Lorenz 2005: 413.

PAR - India. West Bengal: Kurseong, Darjeeling.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

4. *Aparupa* Andrewes 1930

Type species. *Aparupa exophthalmica* Andrewes 1930

Aparupa Andrewes 1930b: 39, Lorenz 2005: 413, Löbl & Löbl 2017: 651.

Remarks: Wingless species, with restricted distribution in the Himalaya. Belongs to the 'tertiary Tibetan faunal components of Himalaya' (Schmidt 2003, Schmidt & Hartmann 2009).

***Aparupa andrewesi* Casale 1980**

Aparupa andrewesi Casale 1980: 401, Lorenz 2005: 413, Löbl & Löbl 2017: 651.

PAR - India. West Bengal: Darjeeling (Ghoom).

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Aparupa exophthalmica* Andrewes 1930**

Aparupa exophthalmica Andrewes 1930b: 40, Lorenz 2005: 413, Löbl & Löbl 2017: 651.

PAR - India. Sikkim: Karponang.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Aparupa villosa* Andrewes 1930**

Aparupa villosa Andrewes 1930b: 41, Lorenz 2005: 413, Löbl & Löbl 2017: 652.

PAR - India. Sikkim: Karponang.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

5. *Arhytinus* Bates 1889

Type species. *Arhytinus bembidioides* Bates 1889.

Arhytinus Bates 1889c: 278, Bates 1892: 378, Andrewes 1930a: 34, Andrewes 1931a: 473, Csiki 1931: 821, Darlington 1952: 116, Stork 1986: 12†, Lorenz 1998: 391, Lorenz 2005: 413, Baehr 2010: 7, Baehr 2012: 42, Baehr 2014: 219, Baehr & Reid 2017: 430, Löbl & Löbl 2017: 652.

***Arhytinus bembidioides* Bates 1889**

Arhytinus bembidioides Bates 1889c: 279, Bates 1892: 378, Darlington 1952: 118, Stork 1986: 12†, Andrewes 1930a: 34, Andrewes 1931a: 474, Csiki 1931: 821, Lorenz 1998: 391, Lorenz 2005: 413, Baehr 2010: 7, Baehr 2012: 59, Löbl & Löbl 2017: 652.

PAR - India. Sikkim. Also known in; ORR - Indonesia, Myanmar, Malaysia, Thailand and Vietnam.

****Arhytinus indicus* Baehr 2010**

Arhytinus indicus Baehr 2010: 9, Baehr 2012: 59.

ORR - India. Karnataka: Puttur, Mudigere.

Remarks: Endemic to the Western Ghats and Sri Lanka hotspot of biodiversity.

***Arhytinus lorenzi* Baehr 2010**

Arhytinus lorenzi Baehr 2010: 10, Baehr 2012: 59.

ORR - India. Karnataka: Kushalnagar.

Remarks: Endemic to the Western Ghats and Sri Lanka hotspot of biodiversity.

6. *Callidagonum* Lorenz 1998

Type species. *Callidula pallida* Jedlička 1955.

Callidagonum Lorenz 1998: 12, Lorenz 2005: 415, Löbl & Löbl 2017: 653.

=*Callidula* Jedlička 1955: 120 [Homonym].

Remarks: Endemic to Indian mainland.

***Callidagonum pallidum* Jedlička 1955**

Callidula pallida Jedlička 1955: 120.

Callidagonum pallidum (Jedlička 1955): Lorenz 2005: 415, Löbl & Löbl 2017: 653.

PAR - India. West Bengal: Kurseong.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

7. *Deliaesianum* Morvan 1999

Type species. *Deliaesianum deliae* Morvan 1999.

Deliaesianum Morvan 1999b: 14, Lorenz 2005: 418, Löbl & Löbl 2017: 656.

Remarks: Wingless species, with restricted distribution in the mountains of Himalaya. Belongs to the 'tertiary Tibetan faunal components of Himalaya' (Schmidt 2003, Schmidt & Hartmann 2009).

***Deliaesianum bengalense* (Chaudoir 1878)**

Colpodes bengalensis Chaudoir 1878: 312, Andrewes 1930a: 121, Andrewes 1946: 82, Louwerens 1953: 101.

Deliaesianum bengalense (Chaudoir 1878): Lorenz 2005: 418, Löbl & Löbl 2017: 656 (*bengalensis)*.

PAR - India. Sikkim; West Bengal: Kurseong, Simana Basti; Nepal-Sikkim Frontier.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Deliaesianum kucerai* Morvan 2007**

Deliaesianum kucerai Morvan 2007: 34, Löbl & Löbl 2017: 656.

PAR - India. Sikkim; Darjeeling.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

8. *Deltocolpodes* Morvan 1992

Type species. *Deltocolpodes rolex* Morvan 1992

Deltocolpodes Morvan 1992: 331, Lorenz 2005: 418, Löbl & Löbl 2017: 656.

***Deltocolpodes championi* Morvan 1992**

Deltocolpodes championi Morvan 1992: 335, Lorenz 2005: 418, Löbl & Löbl 2017: 656.

PAR - India. Sikkim: Ratong Chu.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Deltocolpodes pierremorvani* Deuve 2006**

Deltocolpodes pierremorvani Deuve 2006: 123, Löbl & Löbl 2017: 656.

ORR - India. Arunachal Pradesh (28°21'N, 94°72'E).

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Deltocolpodes jalepensis* Morvan 1992**

Deltocolpodes jalepensis Morvan 1992: 343, Lorenz 2005: 418, Löbl & Löbl 2017: 656.

PAR - India. Sikkim: Jalep.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Deltocolpodes sikkimensis* Morvan 1992**

Deltocolpodes sikkimensis Morvan 1992: 343, Lorenz 2005: 418, Löbl & Löbl 2017: 656.

PAR - India. Sikkim: between Padamchen and Lington.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

9. *Dicranoncus* Chaudoir 1850

Type species. *Dicranoncus femoralis* Chaudoir 1850

Dicranoncus Chaudoir 1850: 392, Chaudoir 1878: 277, Lacordaire 1854: 358, Sloane 1910: 456, Andrewes 1930a: 144, Darlington 1952: 125, Darlington 1971: 274, Lorenz 2005: 419, Löbl & Löbl 2017: 657.

=*Menera* Motschulsky 1859: 32, Andrewes 1928: 17, =*Monacanthonyx* Bates 1892: 367.

***Dicranoncus cinctipennis* Chaudoir 1878**

Dicranoncus cinctipennis Chaudoir 1878: 278.

ORR - Sri Lanka. Also known in PAR - China.

***Dicranoncus femoralis* Chaudoir 1850**

Dicranoncus femoralis Chaudoir 1850: 392, Chaudoir 1878: 277, Bates 1873a: 278, Bates 1891b: 335, Bates 1892: 378, Andrewes 1930a: 144, Lorenz 2005: 419, Löbl & Löbl 2017: 657.

=*Loxocrepis coelestinus* Motschulsky 1865: 310, Andrewes 1928: 23, =*Agonum eberti* Jedlička 1965: 102, =*Dicranoncus pallidicornis* Fairmaire 1891: clxxxviii, =*Anchomenus relucens* Andrewes 1923e: 681, =*Colpodes rufotibis* Jedlička 1934: 187.

ORR - India. Jharkhand (23°61'N, 85°27'E): Chota Nagpur (Tetara). Also known in Indo-China, Indonesia, The Lao People's Democratic Republic, Myanmar, Malaysia, and Vietnam; PAR - India. Sikkim: Lachung; Uttarakhand; West Bengal: Gopaldhara, Darjeeling (Tonglu); Himalayan tract from Shimla to Manipur. Also known in China, Japan, Nepal, North Korea, Russia and Taiwan.

****Dicranoncus quadridens* (Motschulsky 1859)**

Menera quadridens Motschulsky 1859: 32, Andrewes 1928: 17.

Dicranoncus quadridens (Motschulsky 1859): #Andrewes 1928: 17, Andrewes 1930a: 145, Lorenz 2005: 419, Löbl & Löbl 2017: 657.

=*Loxocrepis ruficeps* Brullé (not MacLeay) 1834: 325, =*Colpodes ruficeps* Bates 1883: 263, Bates 1886: 147, Bates 1892: 376, =*Loxocrepis amabilis* Chaudoir 1859: 350, 359, =*Dicranoncus amabilis* Chaudoir 1878: 277, Andrewes 1923a: 57.

ORR - India. Anamalai Hills (10°30'N, 77°00'E); Assam: Rotung; Karnataka: Mudigere, Coorg; Kerala (10°85'N, 76°27'E): Thiruvananthapuram; Meghalaya: Shillong; Nilgiri Hills (11°37'N, 76°76'E); Andaman Island. Also known in Indo-China, Indonesia, Myanmar, Malay Peninsula and Archipelago, Malaysia and Philippines; PAR - India. West Bengal: Mungpoo, Gopaldhara; Uttarakhand: Almora, Bhimtal, Mussoorie. Also known in Nepal.

****Dicranoncus queenslandicus* (Sloane 1903)**

Platynus queenslandicus Sloane 1903: 633.

Dicranoncus queenslandicus (Sloane 1903): #Sloane 1910: 456, Sloane 1920: 322, Darlington 1952: 125, Darlington 1971: 274, Lorenz 2005: 419, Baehr & Reid 2017: 432.

ORR - India. Kerala: Ambalavayal, Tholpetty; Southern India; Sri Lanka. Also known in Indonesia, Philippines; AUR - Papua New Guinea and Solomon Islands.

***Dicranoncus ravus* Andrewes 1936**

Dicranoncus ravus Andrewes 1936: 205, Lorenz 2005: 419.

=*Colpodes madrasensis* Jedlička 1969: 3.

ORR - India. Madras: Anamalai Hills; Nilgiri Hills; Sri Lanka.

10. *Dirotus* MacLeay 1825

Type species. *Rembus subiridescens* MacLeay 1825.

Dirotus MacLeay 1825: 16, Lacordaire 1854: 312, Andrewes 1930a: 152, Lorenz 2005: 419, Löbl & Löbl 2017: 657.

=*Pirantillus* Bates 1889a: 108, Andrewes 1930a: 152.

***Dirotus feae* (Bates 1889)**

Pirantillus feae Bates 1889a: 109, Bates 1892: 370, Andrewes 1930a: 152.

Dirotus feae (Bates 1889): Lorenz 2005: 419.

ORR - India. West Bengal: Tarkhola-Teesta valley. Also known in Myanmar and The Lao People's Democratic Republic.

***Dirotus sikkimensis* Jedlička 1955**

Dirotus sikkimensis Jedlička 1955: 119, Lorenz 2005: 419, Löbl & Löbl 2017: 657.

PAR - India. West Bengal: Kurseong.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

11. *Euleptus* Klug 1833

Type species. *Euleptus geniculatus* Klug 1833.

Euleptus Klug 1833: 43 [= Klug 1834: 131], Lacordaire 1854: 353, Alluaud 1916: 77, Andrewes 1930a: 164, Liebherr et al., 2003: 457, Lorenz 2005: 419, Löbl & Löbl 2017: 657.

=*Atamuka* Habu 1978b: 17 [Replaced Name], =*Dolichodes* Motschulsky 1865: 317, =*Kumataia* Habu 1973b: 103 [Homonym].

***Euleptus ooderus* Chaudoir 1850**

Euleptus ooderus Chaudoir 1850: 364, Andrewes 1926a: 69, Andrewes 1930a: 164, Lorenz 2005: 419, Löbl & Löbl 2017: 657.

=*Kumataia coriacea* Habu 1973b: 103, =*Euleptus geniculatus* Motschulsky 1865: 321, Liebherr et al., 2003: 457, =*Dolichodes geniculatus* Motschulsky 1865: 317, =*Colpodes himalaycus* Jedlička 1970: 439.

ORR - India. Mountains of North West India; PAR - India. Himachal Pradesh: Simla Hills, Theog, Matiana, Fagu, Kangra Valley; Uttarakhand: Kumaon, Upper Gumti Valley, Gori Valley, East Ramganga Valley, Mussoorie, Dehra Dun, Lansdowne; West Bengal: Darjeeling. Also known in Nepal and Pakistan.

Remarks: *Euleptus ooderus* is the only species of the genus *Euleptus* with 12 species recorded outside Africa from Oriental and Palaearctic regions (India, Pakistan & Nepal). How *E. ooderus* closely related to *E. caffer* with distribution confined to South Africa & Zimbabwe (Chaudoir 1850) reached Indian PAR in Himalayan belts and Indian ORR regions close to Indian PAR remains to be explored.

12. *Euplynes* Schmidt-Göbel 1846

Type species. *Euplynes cyanipennis* Schmidt-Göbel 1846.

Euplynes Schmidt-Göbel 1846: 52, Lacordaire 1854: 131, Chaudoir 1859: 350, Bates 1883: 264, Bates 1886: 147, Andrewes 1923a: 28, Andrewes 1930a: 164, Lorenz 2005: 419, Makarov & Sundukov 2011: 34, Löbl & Löbl 2017: 658.

=*Anarmosta* Péringuey 1896: 221, =*Xatis* Fairmaire 1901: 125, =*Pseudocalleida* Kirschenhofer 2010, #Casale & Shi 2018: 7.

***Euplynes cyanipennis* Schmidt-Göbel 1846**

Euplynes cyanipennis Schmidt-Göbel 1846: 52, Bates 1886: 147, Andrewes 1923a: 28, Andrewes 1930a: 164, Louwerens 1956: 221, Lorenz 2005: 419, Löbl & Löbl 2017: 658, Baehr & Reid 2017: 432.

=*Colpodes schmidtii* Chaudoir 1859: 360 [Replaced Name].

ORR - India. Andaman Island. Also known in Indonesia, Philippine Island, Myanmar; PAR - Taiwan; AUR - Papua New Guinea.

Remarks: Genus *Euplynes* is represented by 28 species globally with only *E. cyanipennis* (exact Indian locality unknown) reported from India.

***Euplynes marginatus* Andrewes 1923**

Euplynes marginatus Andrewes 1923c: 241, Andrewes 1930a: 164.

ORR - Sri Lanka.

13. *Henvelik* Morvan 1999

Type species. *Henvelik kalchhigenn* Morvan 1999.

Henvelik Morvan 1999a: 6, Lorenz 2005: 421, Löbl & Löbl 2017: 658.

Remarks: Wingless species, with restricted distribution in the mountains of Himalaya. Belongs to the 'tertiary Tibetan faunal components of Himalaya' (Schmidt 2003, Schmidt & Hartmann 2009).

***Henvelik kucerai* Morvan 2004**

Henvelik kucerai Morvan 2004: 28, Lorenz 2005: 421, Löbl & Löbl 2017: 658.

PAR - India. West Bengal: Tonglu.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

14. *Kuceraianum* Morvan 2002

Type species. *Kuceraianum kucerai* Morvan 2002.

Kuceraianum Morvan 2002: 2†, Löbl & Löbl 2017: 660.

Remarks: Endemic to Indian mainland.

***Kuceraianum azureum* Morvan 2002**

Kuceraianum azureum Morvan 2002: 4†, Löbl & Löbl 2017: 660.

PAR - India. Sikkim.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Kuceraianum kucerai* Morvan 2002**

Kuceraianum kucerai Morvan 2002: 2†, Löbl & Löbl 2017: 660.

PAR - India. Sikkim.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

15. *Lepcha* Andrewes 1930

Type species. *Lepcha jelepa* Andrewes 1930.

Lepcha Andrewes 1930b: 31, Morvan 1997: 1, Lorenz 2005: 422, Löbl & Löbl 2017: 660.

=*Nepalagonum* Habu 1973b: 124, #Morvan 1997: 1.

Remarks: Wingless species, with restricted distribution in the mountains of Himalaya. Belongs to the 'tertiary Tibetan faunal components of Himalaya' (Schmidt 2003, Schmidt & Hartmann 2009).

***Lepcha bengalensis* Morvan 1997**

Lepcha bengalensis Morvan 1997: 17, Lorenz 2005: 422.

PAR - India. West Bengal: Darjeeling Hills, Sandakphu.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Lepcha cameroni* Morvan 1997**

Lepcha cameroni Morvan 1997: 18, Lorenz 2005: 422, Löbl & Löbl 2017: 660.

PAR - India. West Bengal: Darjeeling, Ghoom.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Lepcha holzschuhi* Morvan 1997**

Lepcha holzschuhi Morvan 1997: 12, Lorenz 2005: 422, Löbl & Löbl 2017: 660.

PAR - India. Sikkim: Dzongri.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Lepcha jelepa* Andrewes 1930**

Lepcha jelepa Andrewes 1930b: 32, Lorenz 2005: 422, Löbl & Löbl 2017: 660.

PAR - India. Sikkim: Jelep La; West Bengal: Tonglu. Also known in China and Nepal.

***Lepcha lampra* Andrewes 1930**

Lepcha lampra Andrewes 1930b: 32, Lorenz 2005: 422, Löbl & Löbl 2017: 660.

PAR - India. Sikkim: Karponang.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Lepcha ovoideus* Morvan 1997**

Lepcha ovoideus Morvan 1997: 18, Lorenz 2005: 422, Löbl & Löbl 2017: 660 (*ovoidea)*.

PAR - India. Sikkim: Naza Ora.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Lepcha similis* Morvan 1997**

Lepcha similis Morvan 1997: 19, Lorenz 2005: 422, Löbl & Löbl 2017: 660.

PAR - India. West Bengal: Tonglu.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Lepcha subdiscolus* Morvan 1997**

Lepcha subdiscolus Morvan 1997: 11, Lorenz 2005: 422, Löbl & Löbl 2017: 661 (*subdiscola)*.

PAR - India. West Bengal: Gopaldhara, Tonglu.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

16. *Lorostema* Motschulsky 1865

Type species. *Lorostema alutacea* Motschulsky 1865.

Lorostema Motschulsky, 1865: 329, Andrewes 1928: 11, Andrewes 1930a: 203, Lorenz 2005: 423, Liebherr 2005: 267.

=*Feanus* Bates 1889a: 107, Andrewes 1924a: 48, =*Lorostemmoides* Habu 1978a: 98, #Liebherr 2005: 267.

***Lorostema alutacea* Motschulsky 1865**

Lorostema alutacea Motschulsky 1865: 330, Bates 1889: 108, Andrewes 1928: 11, Andrewes 1930a: 203, Lorenz 2005: 423.

= *Feanus nigripes* Andrewes 1926b: 257.

ssp. *Lorostema alutacea alutacea* Motschulsky 1865: 330

ssp. *Lorostema alutacea spinipennis* (Bates 1889): 108.

ORR - India. Assam: Sadiya, Karimganj; Bihar (25°09'N, 85°31'E): Pusa, Chapra, Purnea; Haryana (29°05'N, 76°08'E): Kalka; Meghalaya: Garo Hills; Odisha (20°95'N, 85°09'E): Barkuda I. (Lake Chilka); Tamil Nadu (11°12'N, 78°65'E): Tranquebar; West Bengal: Sunderbans, Kolkata; Sri Lanka. Also known in Bangladesh and Indonesia; PAR - India. Himachal Pradesh: Simla Hills.

17. *Loxocrepis* Eschscholtz 1829

Type species. *Lamprias ruficeps* MacLeay 1825.

Loxocrepis Eschscholtz 1829: 6, Lacordaire 1854: 362, Lorenz 2005: 423, Löbl & Löbl 2017: 661.

***Loxocrepis cruralis* (Chaudoir 1879)**

Colpodes cruralis Chaudoir 1879: 376, Andrewes 1930a: 122, Jedlička 1934: 180, Louwerens 1953: 92.

Loxocrepis cruralis (Chaudoir 1879): Lorenz 2005: 423, Löbl & Löbl 2017: 661.

=*Colpodes ischioxanthus* Bates 1892: 376, #Andrewes 1921: 148 (*Colpodes cruralis*).

ORR - India. Assam: Silonibari; Kerala: Malappuram (Edakkara), Palakkad (Paranabikulam); Maharashtra: Satara; Manipur (24°66'N, 93°90'E); Meghalaya: Garo Hills; Nilgiri Hills. Also known in Myanmar and Vietnam; PAR - India. West Bengal: Gopaldhara. Also known in Taiwan.

***Loxocrepis ruficeps* (MacLeay 1825)**

Lamprias ruficeps MacLeay 1825: 25.

Loxocrepis ruficeps (MacLeay 1825): #Eschscholtz 1829: 6, Chaudoir 1859: 348, Lorenz 2005: 423, Löbl & Löbl 2017: 662.

=*Colpodes ruficeps* Chaudoir 1878: 376, Andrewes 1919b: 164, Andrewes 1930a: 125, Louwerens 1953: 92, =*Euplynes dorhni* Nietner 1858: 429, Chaudoir 1878: 375, Bates 1886: 147, Andrewes 1924b: 137, Andrewes 1927b: 105, =*Euplynes cyanipennis* Chaudoir 1859: 350, 360, =*Euplynes schmidti* Chaudoir 1859: 350, 360.

ORR - India. Anamalai Hills; Bihar: Pusa, Chapra; Coromandel; Jharkhand: Ranchi; Karnataka: Belgaum, North Kanara; Maharashtra: Nagpur; West Bengal: Kolkata; Sri Lanka. Also known in Indonesia, Myanmar and Philippine Island; PAR - India. Uttarakhand: Haldwani.

18. *Lucicolpodes* Schmidt 2000

Type species. *Colpodes lucens* Andrewes 1947.

Lucicolpodes Schmidt 2000b: 30, Löbl & Löbl 2017: 662.

***Lucicolpodes (Lucicolpodes) eberti* Schmidt 2009**

Lucicolpodes eberti mahakaliensis Schmidt 2009a: 145, Löbl & Löbl 2017: 662.

ssp. *Lucicolpodes eberti eberti* (Jedlicka 1965)

ssp. *Lucicolpodes eberti laliguras* (Schmidt 2000): 30

ssp. *Lucicolpodes eberti mahakaliensis* Schmidt 2009a: 145 (India)

ssp. *Lucicolpodes eberti ocularis* Schmidt 2009: 145

PAR - India. Himachal Pradesh. Also known in Nepal.

***Lucicolpodes (Lucicolpodes) obsoletus* (Louwerens 1953)**

Colpodes obsoletus Louwerens 1953: 117, Lorenz 2005: 416, Löbl & Löbl 2017: 662.

Lucicolpodes obsoletus (Louwerens 1953): #Schmidt 2000b: 42, Schmidt 2009a: 144.

PAR - India. West Bengal: Darjeeling, Ghoom.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

19. *Meleagros* Kirschenhofer 1999

Type species. *Meleagros coeruleus* Kirschenhofer 1999.

Meleagros Kirschenhofer 1999: 68, Lorenz 2005: 423, Löbl & Löbl 2017: 662, Fedorenko 2020: 140.

***Meleagros sikkimensis* (Andrewes 1923)**

Colpodes sikkimensis Andrewes 1923e: 683, Andrewes 1930a: 126.

Meleagros sikkimensis (Andrewes 1923): #Morvan 2004: 4, Lorenz 2005: 423, Löbl & Löbl 2017: 662, Fedorenko 2020: 141.

PAR - India. Sikkim; West Bengal: Gopaldhara, Maria Basti and Pedong. Also known in Bhutan, China, Nepal; ORR - Myanmar and Malaysia.

20. *Metacolpodes* Jeannel 1948

Type species. *Colpodes buchanani* Hope 1831.

Metacolpodes Jeannel 1948: 516; Habu 1978a: 123, Kirschenhofer 1992: 13, Lorenz 2005: 423, Löbl & Löbl 2017: 662.

****Metacolpodes buchanani* (Hope 1831)**

Colpodes buchannani Hope 1831: 21, Chaudoir 1859: 359, Chaudoir 1878: 369, Andrewes 1930a: 122, Jedlička 1934: 191, Louwerens 1953: 90, Malkin & Hatch 1953: 133.

Metacolpodes buchannani (Hope 1831): Lacordaire 1854: 361, #Jeannel 1948: 516, Lorenz 2005: 423, Liebherr 2005: 264, Habu 1978a: 124, Bousquet 2012: 1256, Löbl & Löbl 2017: 662.

=*Colpodes amoenus* Chaudoir 1859: 326, Chaudoir 1879: 367, Bates 1886: 147, Bates 1890: 213, Heller 1916: 276, =*Colpodes pryeri* Bates 1883: 289, =*Dyscolus splendens* Morawitz 1862a: 324 [=Morawitz 1862b: 241], Bates 1873a: 275 (*Colpodes*), Putzeys 1875: 50, Harold 1878a: 67, Harold 1878b: 213 (*Colpodes*), =*Agonum sargentorum* Malkin & Hatch 1952: 107, Malkin & Hatch 1953: 134, Bousquet 2012: 1256.

ORR - India. North-West India; Sri Lanka. Also known in Throughout South-East Asia, Indonesia, Myanmar, Malaysia, Philippines, Vietnam; PAR - China, Japan, Nepal, North Korea, Pakistan, Russia, South Korea, Taiwan, Vanuatu; NAR - Canada, Washington, Oregon; AUR - French Polynesia.

Remarks: Native to Asia and adventive species in North America and Hawaii (Habu 1978a, Bousquet 2012).

***Metacolpodes hardwickii* (Hope 1831)**

Colpodes hardwickii Hope 1831: 21; Andrewes 1930a: 123, Louwerens 1953: 90.

Metacolpodes hardwickii (Hope 1831): Lorenz 2005: 423, Löbl & Smetna 2003: 460, Löbl & Löbl 2017: 662.

PAR - India. Sikkim; West Bengal: Kurseong, Gopaldhara, Darjeeling. Also known in Nepal.

***Metacolpodes incertus* (Chaudoir 1879)**

Colpodes incertus Chaudoir 1879: 369, Andrewes 1930a: 123, Louwerens 1953: 93.

Metacolpodes incertus (Chaudoir 1879): Lorenz 2005: 423.

ORR - India East India.

***Metacolpodes janelloides* (Louwerens 1953)**

Colpodes janelloides Louwerens 1953: 125.

Metacolpodes janelloides (Louwerens 1953): Lorenz 2005: 423.

ORR - India. Manipur.

Remarks: Endemic to the Indo Burma hotspot of biodiversity.

***Metacolpodes nilgherriensis* (Chaudoir 1878)**

Colpodes nilgherriensis Chaudoir 1878: 301, Andrewes 1930a: 124, Louwerens 1953: 102.

Metacolpodes nilgherriensis (Chaudoir 1878): #Jeannel 1948: 516, Lorenz 2005: 423.

ORR - India. Malabar Coast; Nilgiri Hills; Tamil Nadu: Ooty, Naduvattam.

Remarks: Endemic to the Western Ghats and Sri Lanka hotspot of biodiversity.

***Metacolpodes olivius* (Bates 1873)**

Colpodes olivius Bates 1873a: 330; Bates 1892: 373, Andrewes 1924c: 591, Andrewes 1930a: 124, Jedlička 1934: 193, Louwerens 1953: 88.

Metacolpodes olivius (Bates 1873): Lorenz 2005: 423, Löbl & Löbl 2017: 663.

=*Colpodes coelopterus* Chaudoir 1879: 368, Andrewes 1924c: 591.

ORR - India. Meghalaya: Shillong. Also known in Cambodia, Myanmar, and Vietnam; PAR - India. West Bengal: Gopaldhara, Tonglu, Kurseong. Also known in China and Taiwan.

***Metacolpodes planithorax* (Louwerens 1953)**

Colpodes planithorax Louwerens 1953: 122.

Metacolpodes planithorax (Louwerens 1953): Lorenz 2005: 423.

India.

***Metacolpodes rotundatus* (Chaudoir 1878)**

Colpodes rotundatus Chaudoir 1878: 302, Andrewes 1930a: 125, Louwerens 1953: 102.

Metacolpodes rotundatus (Chaudoir 1878): Lorenz 2005: 423.

ORR - India. Malabar; Nilgiri Hills. Also known in Myanmar.

21. *Onycholabis* Bates 1873

Type species. *Onycholabis sinensis* Bates 1873.

Onycholabis Bates 1873a: 329, Andrewes 1930a: 237, Liang & Kavanaugh 2005: 508, Löbl & Löbl 2017: 665.

***Onycholabis acutangulus* Andrewes 1923**

Onycholabis acutangulus Andrewes 1923e: 682, Andrewes 1930a: 237, Liang & Kavanaugh 2005: 510, Löbl & Löbl 2017: 665.

ORR - India. Assam: Yambung; PAR - India. Uttarakhand: Dehra Dun, Kumaon (West Almora, Haldwani). Also known in China and Nepal.

***Onycholabis melitopus* Bates 1892**

Onycholabis melitopus Bates 1892: 371, Andrewes 1930a: 238, Liang & Kavanaugh 2005: 510, Löbl & Löbl 2017: 665.

=*Cardiomera oberthuri* Maindron 1899: 155, Maindron 1905: 94, Bedel 1902: 215†.

ORR - India. Assam. Also known in The Lao People's Democratic Republic and Myanmar; PAR - India. Sikkim; Himalayan tract from Shimla Hills to Bhutan. Also known in Bhutan and China.

22. *Orthotrichus* Peyron 1856

Type species. *Anchomenus cymindoides* Dejean 1831.

Orthotrichus Peyron 1856: 717, Andrewes 1924a: 47, Andrewes 1930a: 250, Schmidt 2008: 195, Serrano et al., 2017: 257, Löbl & Löbl 2017: 665.

=*Trichotarus* Motschulsky 1865: 327, =*Metagonum* Jeannel 1948: 518 & 521, #Schmidt 2008: 195, =*Kalchtacha* Morvan 2002: 19†, #Schmidt 2008: 195.

***Orthotrichus alternatus* Bates 1892**

Orthotrichus alternatus Bates 1892: 368, Andrewes 1930a: 250.

ORR - India. Nagaland (26°15'N, 94°56'E): Naga Hills. Also known in Myanmar.

***Orthotrichus baehri* (Morvan 2002)**

Kalchtacha baehri Morvan 2002: 19–21, 30, 32†.

Orthotrichus baehri (Morvan 2002): #Schmidt 2008:197.

ORR - India. Karnataka: Talakaveri; Maharashtra: Mahabaleshwar; Throughout the Western Ghats of southwestern India.

Remarks: Endemic to the Western Ghats and Sri Lanka hotspot of biodiversity. Closely related to the East African species *O. patroboides* (Murray 1859†) and is endemic to the Western Ghats (Schmidt 2008) indicating that it might be the derivative of the East African species group arrived from East Africa to India and the Western Ghats during the separation of India from Gondwana land.

***Orthotrichus indicus* Bates 1891**

Orthotrichus indicus Bates 1891b: 334, Bates 1892: 368, Andrewes 1924a: 47, Andrewes 1930a: 250, Löbl & Löbl 2017: 665.

ORR - India. Jharkhand: Chota Nagpur, Konbir; Manipur; Nilgiri Hills; Rajasthan (27°02'N, 74°21'E): Tetara; Throughout North India to the Central Provinces. Also known in The Lao People's Democratic Republic, Myanmar and Vietnam; PAR-India. Himachal Pradesh: Bajaura. Also known in Afghanistan and China.

23. *Platynus* Bonelli 1810

Type species. *Platynus complanatus* Dejean 1831.

Platynus Bonelli 1810: Tabula synoptica, Bousquet & Larochelle 1993: 261, Schmidt 2000a: 9, Bousquet 2012: 1242, Liebherr & Will 1996: 301, Larochelle & Larivière 2001: 138, Larochelle & Larivière 2007: 79, 82, Löbl & Löbl 2017: 666.

=*Batenus* Motschulsky 1865: 317, =*Dyscolus* Dejean 1831: 437, Lacordaire 1854: 356, =*Paranchomenus* Casey 1920: 30, =*Platynidius* Casey 1920: 4, 6, =*Platynomenus* Ádám 1996: 12, =*Pseudoplatynus* Habu 1973a: 11, =*Vulcanophilus* Heller 1896: 2†, Andrewes 1927c: 271.

***Platynus acroglyptus* (Bates 1892)**

Colpodes acroglyptus Bates 1892: 374, Andrewes 1930a: 121, Jedlička 1934: 189, Louwerens 1953: 98, Terada et al., 2016: 1, Lorenz 2005: 416, Löbl & Löbl 2017: 653.

Platynus acroglyptus (Bates 1892): Liebherr 1998: 987, Bousquet 2003: 464.

ORR - India. Assam: Naga Hills; Manipur. Also known in The Lao People's Democratic Republic, Myanmar, Vietnam; PAR - Taiwan.

***Platynus aenescens* (Chaudoir 1879)**

Colpodes aenescens Chaudoir 1879: 368, Louwerens 1953: 142, Andrewes 1930a: 121, Lorenz 2005: 416.

Platynus aenescens (Chaudoir 1879): Liebherr 1998: 987. ORR - India.

***Platynus andrewesi* (Morvan 1996)**

Batenus andrewesi Morvan 1996: 44.

Platynus andrewesi (Morvan 1996): Lorenz 2005: 434.

ORR - India (Punjab, 31°14'N, 75°34'E); PAR - India. Himachal Pradesh: Seraj, Jalori Pass.

***Platynus (Batenus) azbleotroades* (Morvan 1996)**

Batenus azbleotroades Morvan 1996: 38.

Platynus azbleotroades (Morvan 1996): Lorenz 2005: 429, Löbl & Löbl 2017: 667.

PAR - India. Jammu & Kashmir: Yusmarg, Gulmarg.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus baconi* (Chaudoir 1878)**

Colpodes baconi Chaudoir 1878: 311, Andrewes 1930a: 121, Andrewes 1946: 82, Louwerens 1953: 81, Lorenz 2005: 416, Löbl & Löbl 2017: 654.

Platynus baconi (Chaudoir 1878): Liebherr 1998: 987.

PAR - India. Sikkim: Karponang; West Bengal.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus (Batenus) batesi* (Morvan 2004)**

Batenus batesi Morvan 2004: 13.

Platynus batesi (Morvan 2004): Lorenz 2005: 429, Löbl & Löbl 2017: 667.

PAR - India. Jammu & Kashmir: Goorais Valley.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus (Batenus) benardi* (Andrewes 1924)**

Anchomenus benardi Andrewes 1924a: 102, Andrewes 1930a: 23.

Platynus benardi (Andrewes 1924): Lorenz 2005: 429, Löbl & Löbl 2017: 667.

PAR - India. Himachal Pradesh: Lahaul (Gandla, Keiling, Sisu), Spiti (Pulga, Tchary-Djoni, Manikaran), Kulu (Koty, Parbatti Valley), Seraj (Jalori Pass).

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus bipars* (Walker 1858)**

Lebia bipars Walker 1858: 203, Bates 1886: 148.

Platynus bipars (Walker 1858): Liebherr 1998: 987.

=*Colpodes bipars* (Walker 1858): Andrewes 1919b: 185, Andrewes 1930a: 121, Louwerens 1953: 144, =*Colpodes lampriodes* Bates 1886: 147, Louwerens 1953: 144, =*Colpodes dohrni,* Chaudoir 1878: 375, Andrewes 1924b: 137.

ORR - Sri Lanka.

***Platynus (Batenus) bruskelchus* (Morvan 1996)**

Batenus bruskelchus Morvan 1996: 45.

Platynus bruskelchus (Morvan 1996): Lorenz 2005: 430, Löbl & Löbl 2017: 667.

PAR - India. Uttarakhand: Kumaon: Pindar Valley.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus corpulentus* (Louwerens 1953)**

Colpodes corpulentus Louwerens 1953: 87, 119, Lorenz 2005: 416.

Platynus corpulentus (Louwerens 1953): Liebherr 1998: 987.

ORR - India. Manipur.

Remarks: Endemic to the Indo Burma hotspot of biodiversity.

***Platynus (Batenus) deuvei* (Morvan 1996)**

Batenus deuvei Morvan 1996: 38.

Platynus deuvei (Morvan 1996): Lorenz 2005: 434, Löbl & Löbl 2017: 667.

PAR - India. Jammu & Kashmir: Bhadarwah, Yusmarg.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus dohertyi* (Louwerens 1953)**

Colpodes dohertyi Louwerens 1953: 79, 105, Lorenz 2005: 416.

Platynus dohertyi (Louwerens 1953): Liebherr 1998: 987.

India.

***Platynus elegantellus* (Lorenz 1998)**

Colpodes elegantellus Lorenz 1998: 12, Löbl & Löbl, 2017: 654.

Platynus elegantellus (Lorenz 1998): Liebherr 1998: 987.

=*Colpodes elegantulus* Louwerens 1953: 112 [Homonym], [not Chaudoir 1878: 309], Lorenz 2005: 416, Löbl & Löbl 2017: 654.

PAR - India. Sikkim.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus eulabes* (Bates 1889)**

Colpodes eulabes Bates 1889a: 215, Andrewes 1930a: 122, Louwerens 1953: 146.

Platynus eulabes (Bates 1889): #Schmidt 2009b: 207, Löbl & Löbl 2017: 667.

=*Xestagonum eulabes* Lorenz 2005: 437.

PAR - India. Jammu & Kashmir: Goorais Valley.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus euparyphus* (Andrewes 1923)**

Colpodes euparyphus Andrewes 1923d: 448, Louwerens 1953: 92, Andrewes 1930a: 122, Lorenz 2005: 416.

Platynus euparyphus (Andrewes 1923): Liebherr 1998: 987.

ORR - India. Tamil Nadu: Madras (Palani Hills, Kodaikanal); Karnataka: Mysore, Chikkaballapura.

***Platynus fletcheri* Andrewes 1923**

Colpodes fletcheri Andrewes 1923c: 240, Andrewes 1930a: 123, Louwerens 1953: 88.

Platynus fletcheri (Andrewes 1923): Liebherr 1998: 987.

ORR - Sri Lanka.

***Platynus (Batenus) fur* (Andrewes 1930)**

Anchomenus fur Andrewes 1930b: 39.

Platynus fur (Andrewes 1930): Lorenz 2005: 429.

=*Agonum fur* Löbl & Löbl 2017: 649.

PAR - India. West Bengal: Darjeeling.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus (Batenus) grassator* (Andrewes 1932)**

Anchomenus grassator Andrewes 1932: 139.

Platynus grassator (Andrewes 1932): Lorenz 2005: 429, Löbl & Löbl 2017: 667.

PAR - India. Uttarakhand: Kumaon Ranikhet, Bhatkot, West Almora Division, Sunderdhunga Valley, Dudhatoli, Sukhatal, Bagarkote, Garhwal (Painsur, Above Lohba).

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus (Batenus) henvelus* (Morvan 1996)**

Batenus henvelus Morvan 1996: 42.

Platynus henvelus (Morvan 1996): Löbl & Löbl 2017: 667.

PAR - India. Himachal Pradesh: Kulu.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus hirmocoelus* (Chaudoir 1879)**

Colpodes hirmocoelus Chaudoir 1879: 365, Louwerens 1953: 85, Andrewes 1930a: 123, Lorenz 2005: 417, Löbl & Löbl 2017: 654.

Platynus hirmocoelus (Chaudoir 1879): Liebherr 1998: 987.

PAR - India. Uttarakhand: Kumaon-Nainital, Sunderdhunga Valley, West Almora, Swal River basin, Mussoorie; West Bengal: Darjeeling, Lebong. Also known in Nepal.

***Platynus impressiceps* (Louwerens 1953)**

Colpodes impressiceps Louwerens 1953: 135, Lorenz 2005: 417, Löbl & Löbl 2017: 654.

Platynus impressiceps (Louwerens 1953): Liebherr 1998: 987.

ORR - India. Arunachal Pradesh: Mishmi Hills; PAR - India. Sikkim: Teesta River; West Bengal: Tonglu.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus impunctatus* (Andrewes 1923)**

Colpodes impunctatus Andrewes 1923e: 685, Andrewes 1930a: 123, Louwerens 1953: 86, Lorenz 2005: 417, Löbl & Löbl 2017: 654.

Platynus impunctatus (Andrewes 1923): Liebherr 1998: 987.

PAR - India. Sikkim; West Bengal: Darjeeling, Tonglu.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus (Batenus) incisus* (Andrewes 1927)**

Anchomenus incisus Andrewes 1927a: 77, Andrewes 1930a: 25.

Platynus incisus (Andrewes 1927): Lorenz 2005: 429, Löbl & Löbl 2017: 667.

PAR - India. Jammu & Kashmir: Sintan.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus indiae* Louwerens 1953**

Colpodes indiae Louwerens 1953: 137, Lorenz 2005: 417, Löbl & Löbl 2017: 654.

Platynus indiae (Louwerens 1953): Liebherr 1998: 987.

ORR - India. Uttar Pradesh: Allahabad; PAR - India. Sikkim.

***Platynus isomorphus* (Louwerens 1953)**

Colpodes isomorphus Louwerens 1953: 105, Lorenz 2005: 417.

Platynus isomorphus (Louwerens 1953): Liebherr 1998: 987.

ORR - India. Manipur.

Remarks: Endemic to the Indo Burma hotspot of biodiversity.

***Platynus iteratus* Bates 1886**

Colpodes iteratus Bates 1886: 149, Andrewes 1930a: 123, Louwerens 1953: 97.

Platynus iteratus (Bates 1886): Liebherr 1998: 987.

ORR - Sri Lanka.

***Platynus komala* (Andrewes 1932)**

Colpodes komala Andrewes 1932: 140, Louwerens 1953: 99, Lorenz 2005: 417, Löbl & Löbl 2017: 654.

Platynus komala (Andrewes 1932): Liebherr 1998: 987.

PAR - India. Uttarakhand: Dehra Dun, Haldwani District, Banks of Nandhaur River, Nainital, Mussoorie, Arni Gad, Kempty Falls.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus (Batenus) kucerai* (Morvan 2004)**

Batenus kucerai Morvan 2004: 11.

Platynus kucerai (Morvan, 2004): Lorenz 2005: 429, Löbl & Löbl 2017: 667.

ORR - India. Uttar Pradesh.

***Platynus lautulus* (Andrewes 1931)**

Colpodes lautulus Andrewes 1931a: 457, Louwerens 1953: 92, Lorenz 2005: 417.

Platynus lautulus (Andrewes 1931): Liebherr 1998: 987.

ORR - India; Indonesia and Malaysia.

***Platynus (Batenus) meurguesae* (Morvan 1996)**

Batenus meurguesae Morvan 1996: 39.

Platynus meurguesae (Morvan 1996): Löbl & Löbl 2017: 668.

ssp. *Platynus meurguesae hiemeieri* (Morvan 1996): 40.

ssp. *Platynus meurguesae meurguesae* (Morvan 1996): 39.

PAR - India. Uttarakhand: Hemkunt.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus nathani* (Jedlička 1969)**

Colpodes nathani Jedlička 1969: 2, Lorenz 2005: 417.

Platynus nathani (Jedlička 1969): Liebherr 1998: 987.

ORR - India. Tamil Nadu: Madras: Anamalai Hills.

Remarks: Endemic to the Western Ghats and Sri Lanka hotspot of biodiversity.

***Platynus nigriceps* (Motschulsky 1865)**

Loxocrepis nigriceps Motschulsky 1865: 310, Lorenz 2005: 417.

Platynus nigriceps (Motschulsky 1865): Liebherr 1998: 987.

=*Colpodes nigriceps* Louwerens 1953: 143, Andrewes 1928: 10, Andrewes 1930a: 124,

ORR - India. East India.

***Platynus plagioderus* (Chaudoir 1879)**

Colpodes plagioderus Chaudoir 1879: 374, Andrewes 1930a: 124, Louwerens 1953: 123, Lorenz 2005: 417, Löbl & Löbl 2017: 655.

Platynus plagioderus (Chaudoir 1879): Liebherr 1998: 987.

ORR - India. East India; PAR -India. Sikkim.

***Platynus (Batenus) praedator* (Andrewes 1930)**

Anchomenus praedator Andrewes 1930b: 38.

Platynus praedator (Andrewes 1930): Lorenz 2005: 430, Löbl & Löbl 2017: 668.

=*Colpodes bigutticeps* Louwerens 1953: 138.

ORR - India. Assam; West Bengal: Kolkata; PAR - India. Sikkim: Karponang; West Bengal: Kurseong, Darjeeling, Gopaldhara, Kalimpong, Ghoom, Sitong. Also known in Bhutan, China and Nepal.

***Platynus (Batenus) rarus* Schmidt 2009**

Platynus rarus Schmidt 2009b: 209, Löbl & Löbl 2017: 668.

PAR - India. Jammu & Kashmir: Gulmarg/Pir Panjal Mountains.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus repletus* Bates 1886**

Colpodes repletus Bates 1886: 148, Andrewes 1930a: 125, Louwerens 1953: 85.

Platynus repletus (Bates 1886): Liebherr 1998: 987.

ORR - Sri Lanka.

***Platynus retusus* Bates 1886**

Colpodes retusus Bates 1886: 148, Andrewes 1930a: 125, Louwerens 1953: 145.

Platynus retusus (Bates 1886): Liebherr 1998: 987.

ORR - Sri Lanka.

***Platynus (Batenus) rougemonti* (Morvan 1996)**

Batenus rougemonti Morvan 1996: 36.

Platynus rougemonti (Morvan 1996): Bousquet 2003: 463†, Lorenz 2005: 434, Schmidt 2009b: 217, Löbl & Löbl 2017: 668.

ORR - India. Assam: Tinsukia; PAR - Nepal.

***Platynus rufitarsis* (Chaudoir 1850)**

Dyscolus rufitarsis Chaudoir 1850: 121.

Platynus rufitarsis (Chaudoir 1850): Liebherr 1998: 987.

=*Colpodes rufitarsis* Chaudoir 1859: 351, Chaudoir 1879: 375, Bates 1892: 377, Bouchard 1903: 172, Andrewes 1930a: 125, Louwerens 1953: 91, Lorenz, 2005: 417.

ORR - India. Also known in Indonesia, Myanmar, Malay Peninsula and Archipelago and Malaysia.

***Platynus saphyripennis* (Chaudoir 1878)**

Colpodes saphyripennis Chaudoir 1878: 334, Andrewes 1930a: 125, Louwerens 1953: 83, Lorenz 2005: 417, Löbl & Löbl 2017: 655.

Platynus saphyripennis (Chaudoir, 1878): Liebherr 1998: 987.

ORR - East India. Also known in Indonesia; PAR - China.

***Platynus sebosus* Andrewes 1926**

Colpodes sebosus Andrewes 1926b: 257, Andrewes 1930a: 125, Louwerens 1953: 98.

Platynus sebosus (Andrewes 1926): Liebherr 1998: 987.

ORR - Sri Lanka.

***Platynus semistriatus* (Chaudoir 1879)**

Colpodes semistriatus Chaudoir 1879: 365, Andrewes 1926a: 69, Andrewes 1930a: 126, Lorenz 2005: 418, Löbl & Löbl 2017: 655.

Platynus semistriatus (Chaudoir 1879): Liebherr 1998: 987.

PAR - India. Sikkim; Uttarakhand: Almora, Chakrata, Mundali, Dudhatoli, Gori Valley, Pindar Vallley, Sunderdhunga Valley.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus semiviridis* (Louwerens 1953)**

Colpodes semiviridis Louwerens 1953: 107, Lorenz 2005: 418, Löbl & Löbl 2017: 655.

Platynus semiviridis (Louwerens 1953): Liebherr 1998: 987.

PAR - India. West Bengal: Darjeeling, Ghoom.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus shebbearei* (Andrewes 1930)**

Colpodes shebbearei Andrewes 1930b: 34, Lorenz 2005: 418, Löbl & Löbl 2017: 655.

Platynus shebbearei (Andrewes 1930): Liebherr 1998: 987.

PAR - India. Sikkim: Phadamchen.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus spinulifer* (Bates 1892)**

Colpodes spinulifer Bates 1892: 377, Andrewes 1930a: 126, Lorenz 2005: 418.

Platynus spinulifer (Bates 1892): Liebherr 1998: 987.

PAR - India. West Bengal: Gopaldhara; ORR - Myanmar.

***Platynus straneoi* Jedlička 1963**

Colpodes straneoi Jedlička 1963: 306, Lorenz 2005: 418.

Platynus straneoi (Jedlička 1963): Liebherr 1998: 987.

ORR - India. Anamalai Hills, Cinchona.

Remarks: Endemic to the Western Ghats and Sri Lanka hotspot of biodiversity.

***Platynus (Batenus) ustus* (Andrewes 1927)**

Anchomenus ustus Andrewes 1927a: 75, Andrewes 1930a: 26.

Platynus ustus (Andrewes 1927): Lorenz 2005: 430, Löbl & Löbl 2017: 668.

ssp. *Platynus ustus belli* (Andrewes 1927a): 77.

ssp. *Platynus ustus ustus* (Andrewes 1927a): 75.

PAR - India. Jammu & Kashmir: Kishtawar, Panjal, Lidar Valley.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus (Batenus) viator* (Andrewes 1931)**

Anchomenus viator Andrewes 1931b: 517.

Platynus viator (Andrewes 1931): Lorenz 2005: 430, Löbl & Löbl 2017: 668.

PAR - India. Himachal Pradesh: Tharoch, Simla, Talratach, Jubbul; Uttarakhand: Mussoorie, Dehra Dun, Deoban.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Platynus xenos* Bates 1886**

Colpodes xenos Bates 1886: 146, Andrewes 1930a: 127, Louwerens 1953: 146.

Platynus xenos (Bates 1886): Liebherr 1998: 987.

ORR - Sri Lanka.

24. *Promecoptera* Dejean 1831

Type species. *Promecoptera marginalis* (Wiedemann 1823).

Promecoptera Dejean 1831: 443, Andrewes 1919b: 165.

***Promecoptera marginalis* (Wiedemann 1823)**

Lebia marginalis Wiedemann 1823: 60.

Promecoptera marginalis (Wiedemann 1823): #Dejean 1831: 444, Brullé 1834: 227, Andrewes 1921: 172 , Andrewes 1930a: 25 (*Anchomenus*).

PAR - India. West Bengal.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

25. *Rupa* Jedlička 1935

Type species. *Rupa japonica* Jedlička 1935.

Rupa Jedlička 1935a: 32†, Habu 1978a: 5, 283, Guéorguiev & Morita 2009: 93.

***Rupa (Rupa) lama* Schmidt 1998**

Rupa lama Schmidt 1998: 205, Löbl & Löbl 2017: 669.

PAR - India. Sikkim.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

26. *Sericoda* Kirby 1837

Type species. *Sericoda bembidioides* Kirby 1837.

Sericoda Kirby 1837: 14, Casey 1920: 5, 92, Bousquet & Larochelle 1993: 248, Bousquet 2012: 1177, Hatch 1953: 139, Tanaka 1960: 90, Lindroth 1966: 565, Darlington 1971: 274, Reichardt 1977: 412, Habu 1978a: 36, 87, Liebherr 1991: 60, Schmidt & Kabak 2016: 32, Löbl & Löbl 2017: 669.

=*Rhytiderus* Chaudoir 1844: 470, Bousquet & Larochelle 1993: 248, Liebherr 1991: 60, =*Rhytidoderus* Agassiz 1846: 327, =*Tanystoma* Reitter 1907 [non Motschulsky 1845], Liebherr 1991: 60, =*Agonodromius* Reitter 1908: 139, Gray & Hatch 1941: 19, Csiki 1931: 822, Jeannel 1942: 872, Liebherr 1991: 60, Bousquet & Larochelle 1993: 248, Bousquet 2012: 1178.

***Sericoda ceylonica* (Motschulsky 1859)**

Agonothorax ceylonicus Motschulsky 1859: 36.

Sericoda ceylonica (Motschulsky 1859): Liebherr 1991: 80.

=*Anchomenus ceylonicus* Bates 1886: 146, Andrewes 1928: 18, Andrewes 1930a: 24, =*Sericoda karasawai* Tanaka 1960: 91, 93, 94, #Darlington 1971: 274, =*Agonum (Agonodromius) philippinense* Jedlička 1935b: 79, #Darlington 1971: 274.

ORR - Sri Lanka. Also known in Indonesia, Myanmar, Philippines,

PAR - Japan; AUR - Papua New Guinea.

***Sericoda lissoptera* (Chaudoir 1854)**

Anchomenus lissoptera Chaudoir 1854: 136, Andrewes 1926a: 69.

Sericoda lissoptera (Chaudoir 1854): Liebherr 1991: 68, Löbl & Löbl 2017: 669.

=*Anchomenus politissima* Bates 1878: 719, #Andrewes 1919c: 475.

PAR - India. Himachal Pradesh: Chamba, Phagu, Simla Hills; Jammu & Kashmir; Sikkim: Khamba Jong, Lachen, Phadamchen; Uttarakhand: Gori Valley, Chakrata, Kumaon, Burphu; West Bengal: Darjeeling, Tonglu; Common throughout the Himalayan tract. China, Nepal; ORR - Myanmar.

***Sericoda quadripunctata* (De Geer 1774)**

Carabus quadripunctata De Geer 1774: 102, Dejean 1828: 170, Schaum 1858: 411†, Bates 1873a: 281, Reitter 1907: 63, Andrewes 1926a: 69.

Sericoda quadripunctata (De Geer 1774), Liebherr 1991: 62, Bousquet 2012: 1180, Schmidt & Kabak 2016: 32, Löbl & Löbl 2017: 669.

=*Anchomenus quadripunctatus* Bach 1849: 76†, Andrewes 1930a: 25, #Csiki 1931: 824, Liebherr 1991: 63, =*Carabus foveolatus* Illiger 1801: 61, #Gyllenhal 1810: 160, =*Agonum cupratus* Sturm 1824: 218, #Gemminger & de Harold 1868: 376, Liebherr 1991: 64, =*Anchomenus octocolus* Mannerheim 1853: 144, #Ganglbauer 1892: 255†, LeConte 1879: 57, =*Platynus stigmosus* LeConte 1854: 58, #Ganglbauer 1892: 255†, Lindroth 1966: 568, =*Anchomenus nigrosericans* Heller 1923: 298, #Csiki 1931: 824, Andrewes 1926b: 258, =*Anchomenus ambiguus* Mäklin 1857: 339, #Csiki 1931: 824, =*Metabletus eberti* Jedlička 1965: 106, #Schmidt & Kabak 2016: 32.

PAR - India. Himachal Pradesh: Simla, Narkanda; Jammu & Kashmir: Daksum; Sikkim; Uttarakhand: Milam, Burphu (Gori Valley), Girthi Valley; West Bengal: Darijeeling. Also known in Austria, Belgium, Bosnia Herzegovina, Bhutan, China, Czech Republic, Denmark, England, Estonia, Finland, France, Germany, Great Britain, Hungary, Iran, Italy, Japan, Kyrgyzstan, Latvia, Lithuania, Nepal, North Korea, Norway, Poland, Russia, Slovakia, Sweden, Sweden, Taiwan, Ukraine.

ORR - Philippine Island, Vietnam; NAR - North America (Washington).

Remarks: Widely distributed Holarctic species (Bousquet 2012, Liebherr 1991) reported from North America to several European countries, Asian countries, Himalayan Mountains and Philippines Islands which is an adventive species in the Indian mainland.

27. *Skorlagad* Morvan 1999

Type species. *Skorlagad nepalensis* Morvan 1999.

Skorlagad Morvan 1999a: 2, Löbl & Löbl 2017: 670.

Remarks: Wingless species, with restricted distribution in the mountains of Himalaya. Belongs to the 'tertiary Tibetan faunal components of Himalaya' (Schmidt 2003, Schmidt & Hartmann 2009).

***Skorlagad cameroni* (Louwerens 1953)**

Colpodes cameroni Louwerens 1953: 102.

Skorlagad cameroni (Louwerens 1953): Löbl & Löbl 2017: 670.

PAR - India. West Bengal: Darjeeling, Ghoom.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Skorlagad kornbihanik* Morvan 2007**

Skorlagad kornbihanik Morvan 2007: 37†, Löbl & Löbl 2017: 670.

PAR - India. West Bengal: Darjeeling, Gairibans; Sikkim.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Skorlagad kucerai* Morvan 2007**

Skorlagad kucerai Morvan 2007: 38†, Löbl & Löbl 2017: 670.

PAR - India. West Bengal: Tonglu.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

28. *Skouedhirraad* Morvan 1999

Type species. *Skouedhirraad sikkimensis* Morvan 1999.

Skouedhirraad Morvan 1999b: 5.

Remarks: Wingless species, with restricted distribution in the mountains of Himalaya. Belongs to the 'tertiary Tibetan faunal components of Himalaya' (Schmidt 2003, Schmidt & Hartmann 2009).

***Skouedhirraad kucerai* Morvan 2004**

Skouedhirraad kucerai Morvan 2004: 29, Löbl & Löbl 2017: 670.

PAR - India. West Bengal: Rimbick-Sirikhola.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Skouedhirraad sikkimensis* Morvan 1999**

Skouedhirraad sikkimensis Morvan 1999b: 6, Löbl & Löbl 2017: 670.

PAR - India. Sikkim.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

29. *Tarsagonum* Darlington 1952

Type species. *Tarsagonum latipes* Darlington 1952.

Tarsagonum Darlington 1952: 114, 120, Louwerens 1966: 36, Fedorenko 2020: 144.

***Tarsagonum (Louwerensium) indicum* Fedorenko 2020**

Tarsagonum indicum Fedorenko 2020: 146.

ORR - India. Karnataka: Western Ghats (Shimoga: Jog Falls).

Remarks: Endemic to the Western Ghats and Sri Lanka hotspot of biodiversity.

30. *Xestagonum* Habu 1978

Type species. *Anchomenus xestus* Bates 1883.

Xestagonum Habu 1978a: 100, Löbl & Löbl 2017: 671.

=*Andobour sanum* Morvan 2010: 12, =*Deuveius* Morvan 1998: 16, #Schmidt 2001: 13†, =*Polychaetagonum* Kryzhanovskij 1993: 299, #Schmidt 2001: 13, =*Batenoplatynus* Morvan 1998: 18, #Schmidt 2001: 13.

***Xestagonum ambulator* (Andrewes 1930)**

Anchomenus ambulator Andrewes 1930b: 36.

Xestagonum ambulator (Andrewes 1930): Löbl & Löbl 2017: 671.

PAR - India. Sikkim: Natang, Karponang.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Xestagonum assamensis* (Morvan 1999)**

Batenoplatynus assamensis Morvan 1999: 18, Löbl & Löbl 2017: 652.

Xestagonum assamensis (Morvan 1999): #Schmidt 2001: 13.

PAR - India. Sikkim.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Xestagonum bisetosum* Morvan 2007**

Xestagonum bisetosum Morvan 2007: 11†, Löbl & Löbl 2017: 671.

PAR - India. Jammu & Kashmir: Gulmarg.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Xestagonum brancuccianum* Morvan 2007**

Xestagonum brancuccianum Morvan 2007: 25†, Löbl & Löbl 2017: 671.

ORR - India. Arunachal Pradesh: Sela Pass.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Xestagonum caesitius* (Andrewes 1924)**

Anchomenus caesitius Andrewes 1924a: 104, Andrewes 1926a: 69, Andrewes 1930a: 24.

Xestagonum caesitius (Andrewes 1924): Löbl & Löbl 2017: 672.

PAR - India. Himachal Pradesh: Lahaul (Sisu, Sumdeo), Kulu (Kandi, Koty); Uttarakhand: Sunderdhunga Valley, West Almora, Kumaon, Gori Valley and Gorge, Burphu.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Xestagonum cursor* (Andrewes 1930)**

Anchomenus cursor Andrewes 1930b: 37.

Xestagonum cursor (Andrewes 1930): Löbl & Löbl 2017: 672.

PAR - India. Sikkim: Karponang.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Xestagonum dentatum* Morvan 2002**

Xestagonum dentatum Morvan 2002: 6, Löbl & Löbl 2017: 672.

PAR - India. Sikkim: Singalila Range.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Xestagonum melittus* (Bates 1889)**

Colpodes melittus Bates 1889b: 215, Andrewes 1930a: 124, Louwerens 1953: 81.

Xestagonum melittus (Bates 1889): Löbl & Löbl 2017: 674.

PAR - India. Jammu & Kashmir: Goorais valley.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Xestagonum ovaliceps* (Bates 1878)**

Colpodes ovaliceps Bates 1878: 719, Bates 1891a: 12, Andrewes 1930a: 124, Louwerens 1953: 101.

Xestagonum ovaliceps (Bates 1878): Löbl & Löbl 2017: 674.

PAR - India. Jammu & Kashmir: Pir Panjal. Also known in Pakistan.

***Xestagonum robustum* Morvan 2007**

Xestagonum robustum Morvan 2007: 2, Löbl & Löbl 2017: 674.

PAR - India. Jammu & Kashmir: Bhadarwah.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Xestagonum sikkimensis* Morvan 1998**

Xestagonum sikkimensis Morvan 1998: 38, Löbl & Löbl 2017: 674.

PAR - India. Sikkim.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Xestagonum viridicans* (Andrewes 1926)**

Anchomenus viridicans Andrewes 1926a: 69, 78, Andrewes 1930a: 26.

Xestagonum viridicans (Andrewes 1926): Schmidt 2003:140, Löbl & Löbl 2017: 675

=*Agonum viridicans* Lorenz 2005: 412.

PAR - India. Uttarakhand: Kumaon, Gori valley.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

B. Sphodrini Laporte 1834

Atranopsina Baehr 1982

31. *Broter* Andrewes 1923

Type species. *Broter ovicollis* Andrewes 1923.

Broter Andrewes 1923d: 449.

Remarks: Represented by a single species *Broter ovicollis* Andrewes 1923 confined to the Indian mainland and is endemic to the south Western Ghats.

***Broter ovicollis* Andrewes 1923**

Broter ovicollis Andrewes 1923d: 449, Andrewes 1930a: 55, Lorenz 2005: 395.

ORR - India. Tamil Nadu: Kodaikanal, Shembaganur.

Remarks: Endemic to the Western Ghats and Sri Lanka hotspot of biodiversity.

Calathina Laporte 1834

32. *Calathus* Bonelli 1810

Type species. *Carabus cisteloides* Panzer 1793 (= *Carabus fuscipes* Goeze 1777).

Calathus Bonelli 1810: Tabula synoptica, Dejean 1828: 62, Lacordaire1854: 342, Gautier 1867: 235- 286, Putzeys 1873: 26, Jeannel 1914: 236, Jeannel 1942: 838, Andrewes 1919a: 91, Andrewes 1924a: 46, Andrewes 1930a: 57, Muller 1926: 230, Löbl & Löbl 2017: 760.

***Calathus (incertae) algens* Andrewes 1934**

Calathus algens Andrewes 1934: 210, Lindroth 1956: 489, 561, Lorenz 2005: 398, Löbl & Löbl 2017: 767.

PAR - India. Jammu & Kashmir: Khelanmarg, Lolab Valley.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Calathus (incertae) gelascens* Andrewes 1934**

Calathus gelascens Andrewes 1934: 211, Lindroth 1956: 489, 561, Lorenz 2005: 399, Löbl & Löbl 2017: 767.

PAR - India. Jammu & Kashmir: Lidar Valley, Lidarwat, Shisram Nagar, Tanin.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Calathus (incertae) himalayae* Bates 1891**

Calathus himalayae Bates 1891a: 9, Andrewes 1924a: 47, Andrewes 1926a: 69, Andrewes 1930a: 58, Lindroth 1956: 489, Lorenz 2005: 397, Löbl & Löbl 2017: 767.

PAR - India. Himachal Pradesh: Kulu, Koty, Rotang Valley; Uttarakhand: Gori River Gorge, Kali Valley, Dhauli Ganga (Almora), Kumaon.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Calathus (Indocalathus) kirschenhoferi* F. Battoni 1982**

Calathus kirschenhoferi F. Battoni 1982: 21, Löbl & Löbl 2017: 767.

PAR - India. Jammu & Kashmir: Lahinvan.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Calathus (Neocalathus) kollari* Putzeys 1873**

Calathus kollari Putzeys 1873: 72, Bates 1891b: 334, Andrewes 1924a: 46, Andrewes 1926a: 69, Andrewes 1930a: 58, Andrewes 1934: 212, Lindroth 1956: 489, Lorenz 2005: 397, Löbl & Löbl 2017: 765.

=*Calathus angustatus* Kollar & Redtenbacher 1844: 500 [Homonym] [not Rambur 1838], Bates 1891a: 11, Bates 1891b: 334.

ORR - India. Jharkhand: Chota Nagpur (Tetara); PAR - India. Jammu & Kashmir; Sikkim; West Bengal: Darjeeling; Uttarakhand; The whole Himalayan tract: North Western India. Also known in Afghanistan, China, Nepal, Pakistan and Tajikistan.

Remarks: Wider presence of *C. kollari*, across the Western to Eastern Himalayan tract of the Indian PAR region and in Afghanistan, Pakistan, Tajikistan, Nepal and China indicate the possibility that the five Indian endemic species (*C. algens, C. gelascens, C. himalayae, C. kirschenhoferi* & *C. suffuscus*) are derivatives of *C. Kollari* intermediate between *C. mollis* and *C. micropterus* (Putzeys 1873).

***Calathus (incertae) suffuscus* Andrewes 1934**

Calathus suffuscus Andrewes 1934: 217, Lindroth 1956: 489, Lorenz 2005: 399, Löbl & Löbl 2017: 767.

PAR - India. Jammu & Kashmir: Pahalgam.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

Dolichina Brulle 1834

33. *Xestopus* Andrewes 1937

Type species. *Pristonychus alticola* Fairmaire 1889.

Xestopus Andrewes 1937a: 59, 60, Lorenz 2005: 399, Löbl & Löbl 2017: 769.

=*Nepalocalathus* Habu 1973b: 100, #Casale 1981: 389, Zhu et al., 2021: 141, =*Wittmerosphodrus* Morvan 1978: 100, #Casale 1981: 389, Zhu et al., 2021: 141.

***Xestopus alticola* (Fairmaire 1889)**

Pristonychus alticola Fairmaire 1889: 16, Andrewes 1930a: 286.

Xestopus alticola (Fairmaire 1889): Andrewes 1937a: 60, Lorenz 2005: 399.

PAR - India. Sikkim; China; ORR - Myanmar

Pristosiina Lindroth 1956

34. *Pristosia* Motschulsky 1865

Type species. *Pristosia picea* Motschulsky 1865.

Pristosia Motschulsky 1865: 311, Lindroth 1956: 537, Löbl & Löbl 2017: 770, Schmidt & Hartmann 2009: 1–26, Sasakawa et al., 2006: 1006.

***Pristosia acraea* (Andrewes 1934)**

Calathus acraeus Andrewes 1934: 220.

Pristosia acraea (Andrewes 1934): Lindroth 1956: 548, Lorenz 2005: 400.

ORR - India. Assam: Naga Hills; Manipur.

Remarks: Endemic to the Indo Burma hotspot of biodiversity.

***Pristosia aereipennis* (Andrewes 1934)**

Calathus aereipennis Andrewes 1934: 222.

Pristosia aereipennis (Andrewes 1934): Lindroth 1956: 549, Lorenz 2005: 400.

ORR - India. Assam.

Remarks: Endemic to the Indo Burma hotspot of biodiversity.

***Pristosia amaroides* (Putzeys 1877)**

Calathus amaroides Putzeys 1877: 103, Andrewes 1922b: 250, Andrewes 1930a: 58, Andrewes 1934: 218.

Pristosia amaroides (Putzeys 1877): Lindroth 1956: 552, Hovorka & Sciaky 2003: 530, Lorenz 2005: 400, Schmidt & Hartmann 2009: 1, 3, 6, 7, 20, Löbl & Löbl 2017: 771.

PAR - India. Sikkim: Maria Basti; West Bengal: Gopaldhara, Pedong, Darjeeling. Also known in Bhutan and Nepal.

***Pristosia aquilo* (Andrewes 1934)**

Calathus aquilo Andrewes 1934: 212.

Pristosia aquilo (Andrewes 1934): Lindroth 1956: 549, Lorenz 2005: 400, Löbl & Löbl 2017: 771.

PAR - India. Sikkim.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia atrema* (Andrewes 1926)**

Calathus atrema Andrewes 1926a: 69, 77.

Pristosia atrema (Andrewes 1926): Lindroth 1956: 551, Hovorka & Sciaky 2003: 530, Lorenz 2005: 400, Schmidt & Hartmann 2009: 1, 4, 7, 10, Löbl & Löbl 2017: 771.

PAR - India. Uttarakhand: Kumaon: Burphu (Gori Valley) and Gori River Gorge, Pindar Valley.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia braccata* (Andrewes 1934)**

Calathus braccatus Andrewes 1934: 211.

Pristosia braccata (Andrewes 1934): Lindroth 1956: 549, Lorenz 2005: 400, Löbl & Löbl 2017: 771.

PAR - India. Jammu & Kashmir: Pahalgam.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia brancuccii* Deuve, Lassalle & Queinnec 1985**

Pristosia brancuccii Deuve, Lassalle & Queinnec 1985: 79, Lorenz 2005: 400, Schmidt & Hartmann 2009: 12, Löbl & Löbl 2017: 771.

PAR - India. Uttarakhand: Kumaon Himalaya.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia chambae* (Andrewes 1934)**

Calathus chambae Andrewes 1934: 215.

Pristosia chambae (Andrewes 1934): Lindroth 1956: 549, Lorenz 2005: 400, Löbl & Löbl 2017: 772.

PAR - India. Himachal Pradesh: Chamba, Dalhousie.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia championi* (Andrewes 1934)**

Calathus championi Andrewes 1934: 214.

Pristosia championi (Andrewes 1934): Lindroth 1956: 549, Hovorka & Sciaky 2003: 530, Lorenz 2005: 400, Schmidt & Hartmann 2009: 4, 5, Löbl & Löbl 2017: 772.

PAR - India. Uttarakhand: Gori River Gorge, Kumaon.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia chlorodes* (Andrewes 1934)**

Calathus chlorodes Andrewes 1934: 217, Lorenz 2005: 400.

Pristosia chlorodes (Andrewes 1934): Lindroth 1956: 548.

ORR - India. Assam; Manipur. Also known in Myanmar.

***Pristosia clara* (Andrewes 1924)**

Calathus clarus Andrewes 1924a: 101.

Pristosia clara (Andrewes 1924): Lindroth 1956: 550, Lorenz 2005: 400, Löbl & Löbl 2017: 772.

=*Calathus edax* Andrewes 1934: 216.

PAR - India. Jammu & Kashmir; Himachal Pradesh: Spiti (Pulga), Kulu, Jalori, Lahaul; Sikkim.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia crenata* (Putzeys 1873)**

Calathus crenatus Putzeys 1873: 82, Andrewes 1934: 215.

Pristosia crenata (Putzeys 1873): Lindroth 1956: 547, Hovorka & Sciaky 2003: 531, Lorenz 2005: 400, Schmidt & Hartmann 2009: 1, 3, 6, 22, Löbl & Löbl 2017: 770.

=*Calathus yunnanensis* Jedlička 1937: 78, Lindroth 1956: 547.

ORR - India. Uttar Pradesh. Also known in Myanmar.

PAR - India. The southern slope of the North–Western Himalaya of Indian provinces; Himachal Pradesh: Kulu; Jammu & Kashmir; Uttarakhand: Mussoorie, Mossy Falls, Nainital, Ranikhet, West Almora. Also known in China and Nepal.

***Pristosia dodensis* Deuve, Lasalle & Queinnec 1985**

Pristosia dodensis Deuve, Lasalle & Queinnec 1985: 76, Lorenz 2005: 400, Löbl & Löbl 2017: 772.

PAR - India. Jammu & Kashmir.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia flava* (Andrewes 1934)**

Calathus flavus Andrewes 1934: 220.

Pristosia flava (Andrewes 1934): Lindroth 1956: 552, Lorenz 2005: 400.

ORR - India. Assam: Cachar.

Remarks: Endemic to the Indo Burma hotspot of biodiversity.

***Pristosia glacialis* (Andrewes 1934)**

Calathus glacialis Andrewes 1934: 219.

Pristosia glacialis (Andrewes 1934): Lindroth 1956: 551, Lorenz 2005: 400, Löbl & Löbl 2017: 772.

=*Calathus raptor* Andrewes 1934: 219, =*Laemostenopsis wittmeri* Morvan 1978: 96.

PAR - India. Jammu & Kashmir: Khelanmarg.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia lacerans* (Bates 1889)**

Pristodactyla lacerans Bates 1889b: 214.

Pristosia lacerans (Bates 1889): Lindroth 1956: 551, Lorenz 2005: 400, Löbl & Löbl 2017: 772.

=*Calathus rubricrus* Andrewes 1934: 220.

ssp. *Pristosia lacerans holzschuhi* Battoni 1982: 19†.

ssp. *Pristosia lacerans lacerans* Bates 1889b: 214.

PAR - India. Jammu & Kashmir: Goorais Valley, Pahalgam, Lidar Valley, Shishram Nag, Lidarwat, Tanin, Lolab Valley, Nagmarg, Nagaberan.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia ledouxi* Deuve, Lassalle & Queinnec 1985**

Pristosia ledouxi Deuve, Lassalle & Quéinnec 1985: 77, Lorenz 2005: 400, Löbl & Löbl, 2017: 772.

PAR - India. Jammu & Kashmir.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia leptodes* (Andrewes 1934)**

Calathus leptodes Andrewes 1934: 216.

Pristosia leptodes (Andrewes 1934): Lindroth 1956: 551, Lorenz 2005: 400, Löbl & Löbl 2017: 772.

PAR - India. Uttarakhand: Chakrata.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia leurops* (Andrewes 1934)**

Calathus leurops Andrewes 1934: 211.

Pristosia leurops (Andrewes 1934): Lindroth 1956: 549, Lorenz 2005: 400, Löbl & Löbl 2017: 772.

PAR - India. Jammu & Kashmir: Uri, Pahalgam.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia macra* (Andrewes 1934)**

Calathus macer Andrewes 1934: 212.

Pristosia macra (Andrewes 1934): Lindroth 1956: 549, Lorenz 2005: 400, Löbl & Löbl 2017: 772.

PAR - India. Jammu & Kashmir: Khelanmarg.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Pristosia minutalis* (Andrewes 1934)**

Calathus minutalis Andrewes 1934: 216.

Pristosia minutalis (Andrewes 1934): Lindroth 1956: 551, Lorenz 2005: 400.

ORR - India.

***Pristosia picea* Motschulsky 1865**

Pristosia picea Motschulsky 1865: 312, Lindroth 1956: 551, Lorenz 2005: 400.

=*Calathus pectiniger* Putzeys 1873: 86, Andrewes 1928: 11, Andrewes 1930a: 59, Andrewes 1934: 218, =*Calathus piceus* Andrewes 1928: 11, Andrewes 1934: 218.

ORR - India. East India, North India.

***Pristosia quadricolor* (Andrewes 1934)**

Calathus quadricolor Andrewes 1934: 222.

Pristosia quadricolor (Andrewes 1934): Lindroth 1956: 549, Lorenz 2005: 400.

ORR - India. Assam; Meghalaya: Shillong.

Remarks: Endemic to the Indo Burma hotspot of biodiversity.

Sphodrina Laporte 1834

35. *Himalosphodrus* Casale 1988

Type species. *Sphodropsis cnesipus* Andrewes 1937.

Himalosphodrus Casale 1988: 377†, Lorenz 2005: 403, Löbl & Löbl 2017: 773.

Remarks: Wingless species, with restricted distribution in the mountains of Himalaya. Belongs to the 'tertiary Tibetan faunal components of Himalaya' (Schmidt 2003, Schmidt & Hartmann 2009).

***Himalosphodrus cnesipus* (Andrewes 1937)**

Sphodropsis cnesipus Andrewes 1937a: 63.

Himalosphodrus cnesipus (Andrewes 1937): Casale 1988: 377†, Lorenz 2005: 403, Löbl & Löbl 2017: 773.

PAR - India. Himachal Pradesh: Simla, Tharoch, Tabratach; Uttarakhand: Dehra Dun, Chakrata district, Kanasar, Jaunsar, Deoban.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

36. *Laemostenus* Bonelli 1810

Type species. *Carabus janthinus* Duftschmid 1812.

Laemostenus Bonelli 1810: Tabula synoptica, Jeannel 1914: 236, Jeannel 1942: 854, Muller 1926: 232, Hatch 1953: 132, Casale & Wrase 2012: 1111, Lorenz 2005: 403, Löbl & Löbl 2017: 773.

***Laemostenus (Pristonychus) brancuccii* (Casale 1982)**

Pristonychus brancuccii Casale 1982: 148.

Laemostenus brancuccii (Casale 1982): Lorenz 2005: 403, Löbl & Löbl 2017: 781.

ORR - India. Uttar Pradesh; PAR - Nepal.

***Laemostenus (Pristonychus) colossus* Casale 1988**

Laemostenus colossus Casale 1988: 848†, Lorenz 2005: 406, Löbl & Löbl 2017: 781.

PAR - India. Jammu & Kashmir.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Laemostenus (Pristonychus) kashmirensis* (Bates 1889)**

Pristonychus kashmirensis Bates 1889b: 214.

Laemostenus kashmirensis (Bates 1889): Lorenz 2005: 406, Löbl & Löbl 2017: 781.

ssp. *Laemostenus kashmirensis kashmirensis* Bates 1889b: 214.

ssp. *Laemostenus kashmirensis swaticus* Casale 1982: 147.

PAR - India. Himachal Pradesh; Jammu & Kashmir: Goorais Valley; Pakistan.

***Laemostenus (Pristonychus) lestes* (Andrewes 1937)**

Pristonychus lestes Andrewes 1937b: 564.

Laemostenus lestes (Andrewes 1937): Lorenz 2005: 406, Löbl & Löbl 2017: 782.

PAR - India. Himachal Pradesh: Simla; Jammu & Kashmir; Pakistan.

***Laemostenus (Pristonychus) spinifer* (Schaufuss 1862)**

Pristonychus spinifer Schaufuss 1862: 66, Schaufuss 1865: 174†.

Laemostenus spinifer (Schaufuss 1862): Lorenz 2005: 406, Löbl & Löbl 2017: 783.

PAR - India. Jammu & Kashmir; Uttarakhand; Montes Himalaya; Pakistan.

***Laemostenus (Pristonychus) tentiobtusus* (Morvan 1979)**

Pristonychus tentiobtusus Morvan 1979: 31, Casale 1982: 149.

Laemostenus tentiobtusus (Morvan 1979): Lorenz 2005: 406, Löbl & Löbl 2017: 783.

PAR - India. Sikkim; Kalimpong.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Laemostenus (Pristonychus) tenuis* (Andrewes 1937)**

Pristonychus tenuis Andrewes 1937a: 61.

Laemostenus tenuis (Andrewes 1937): Lorenz 2005: 406, Löbl & Löbl 2017: 783.

ORR - India. Punjab; PAR - Pakistan.

***Laemostenus (Pristonychus) terricola* (Herbst 1784)**

Carabus terricola Herbst 1784: 140.

Laemostenus terricola (Herbst 1784): Bousquet 2012: 69, Löbl & Löbl 2017: 783.

=*Pristonychus castillanus* Coiffait 1956: 26†, =*Pristonychus cyanescens* Fairmaire 1862: 577, =*Carabus episcopus* Drapiez 1819: 130†, =*Carabus inaequalis* Panzer 1796: 18, =*Pristonychus lithuanicus* Motschulsky 1850: 43, =*Carabus marginatus* Descourtilz 1827: 159† [Homonym], =*Pristonychus reichenbachii* Schaufuss 1861: 243, =*Pristonychus sardeus* Dejean 1828: 46, =*Pristonychus silvaticus* Coiffait 1956: 26, =*Pristonychus subaequalis* Schaufuss 1865: 149, =*Carabus subcyaneus* Illiger 1801: 57, =*Pristonychus subterraneus* Dejean 1831: 707, =*Pristonychus torressalai* Coiffait 1956: 27.

ssp. *Laemostenus terricola punctatus* (Herbst 1784)

ssp. *Laemostenus terricola terricola* Dejean 1828: 47.

PAR - India. Himalchal Pradesh. Also known in Austria, Austria, Croatia, Czech Republic, Denmark, Finland, France, Great Britain, Germany, Hungary, Ireland, Norway, Pakistan, Poland, Portugal, Romania, Slovenia, Spain, Sweden, Switzerland and

NAR - North America. Cosmopolitan.

Remarks: Native to Europe and adventive in India and North America and has probably been introduced with stored products and household goods (Bousquet 2012).

***Laemostenus (Pristonychus) wittmeri* (Morvan 1978)**

Pristonychus wittmeri Morvan 1978: 100.

Laemostenus wittmeri (Morvan 1978): Lorenz 2005: 406, Löbl & Löbl 2017: 783.

PAR - India. Sikkim; Darjeeling: Tiger Hill.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

37. *Sphodropsis* Seidlitz 1887

Type species. *Sphodrus ghilianii* Schaum 1858†.

Sphodropsis Seidlitz 1887: 33, Jeannel 1914: 236, 237, Jeannel 1942: 838, 853, Andrewes 1937a: 59, Lorenz 2005: 402, Löbl & Löbl 2017: 789.

***Sphodropsis heinzi* Casale 1982**

Sphodropsis heinzi Casale 1982: 144, Casale & Heinz 2000: 167, Lorenz 2005: 403, Löbl & Löbl 2017: 789.

PAR - India. Himachal Pradesh: Rohtang Pass; Jammu & Kashmir: Pir Panjal.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Sphodropsis physignatha* Andrewes 1937**

Sphodropsis physignatha Andrewes 1937a: 62, Lorenz 2005: 403, Löbl & Löbl 2017: 789.

PAR - India. Himachal Pradesh: Simla.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

38. *Sphodrus* Clairville 1806

Type species. *Carabus planus* Fabricius 1792 (= *Carabus leucophthalmus* Linnaeus 1758)

Sphodrus Clairville 1806: 68, Dejean 1828: 87, Lacordaire 1854: 340, Motschulsky 1865: 314, Schaufuss 1865: 116, Jeannel 1914: 236, 237, Jeannel 1942: 838, 852, Andrewes 1924a: 45, Andrewes 1930a: 316, Andrewes 1937a: 59, Muller 1926: 232, Lorenz 2005: 403, Löbl & Löbl 2017: 789.

***Sphodrus leucophthalmus* (Linnaeus 1758)**

Carabus leucophthalmus Linnaeus 1758: 413, Fabricius 1792: 132†.

Sphodrus leucophthalmus (Linnaeus 1758): Motschulsky 1865: 314, Schaufuss 1865: 116, Jeannel 1914: 236, 237, Jeannel 1942: 852, Muller 1926: 232, Lorenz 2005: 403, Löbl & Löbl 2017: 789.

=*Sphodrus armeniacus* Osculati 1844: 72, =*Sphodrus indus* Chaudoir 1852: 67, Bates 1891a: 10, Andrewes 1930a: 316, =*Carabus obsoletus* Rossi 1790: 209, =*Carabus planus* Fabricius 1792: 133†, =*Sphodrus siculus* Motschulsky 1865: 315, =*Carabus spiniger* Paykull 1790: 43.

PAR - India. Himachal Pradesh: Kasauli, Chamba; Jammu & Kashmir; Punjab: Badia; Uttarakhand: Dehra Dun. Also known in Afghanistan, Algeria, Armenia, Austria, Belgium, Bulgaria, Canary Islands, Croatia, Cyprus, Czech Republic, Denmark, Egypt, Finland, France, Great Britain, Germany, Georgia, Greece, Hungary, Iran, Iraq, Israel, Italy, Jordan, Libya, Macedonia, Moldova, Morocco, The Netherlands, Pakistan, Poland, Portugal, Romania, Russia, Saudi Arabia, Slovakia, Slovenia, Spain, Sweden, Syria, Switzerland, Turkey, Tunisia, Ukraine, Serbia, Montenegro and Yemen.

Remarks: Genus *Sphodrus* is represented by two species globally, *S. Trochanteribus* Mateu, 1990 endemic to Yemen and *S. leucophthalmus* (Linnaeus 1758) distributed in Europe, North Africa & Asia. The only species *S. Leucophthalmus* recorded in India (Himachal Pradesh, Jammu & Kashmir, Punjab, Uttarakhand) and widely distributed in Europe, North Africa & Asia is considered to have resulted from accidental introduction (Gillet 2009).

Synuchina Lindroth 1956

39. *Synuchus* Gyllenhal 1810

Type species. *Carabus vivalis* Illiger 1798.

Synuchus Gyllenhal 1810: 77, Jeannel 1942: 838, 840, Lindroth 1956: 492, Lorenz 2005: 400, Löbl & Löbl 2017: 791.

=*Crepidactyla* Motschulsky 1862: 4, Lindroth 1956: 492, =*Fuerthius* Jedlička 1953: 106, Lindroth 1956: 492, =*Parcalathus* Jedlička 1953: 105, Lindroth 1956: 492, =*Pristodactyla* Dejean 1828: 82, Andrewes 1930a: 285, Lindroth 1956: 492, =*Semenovia* Jedlička 1953: 107, Lindroth 1956: 492, =*Taphria* Dejean 1821: 10, Lindroth 1956: 492, =*Calathosynuchus* Habu 1978c: 318, =*Diplosaccus* Habu 1978c: 318, =*Parasynuchus* Habu 1955: 139.

***Synuchus adelosia* (Andrewes 1934)**

Calathus adelosia Andrewes 1934: 213.

Synuchus adelosia (Andrewes 1934): Lindroth 1956: 489, 495, Lorenz 2005: 400, Löbl & Löbl 2017: 791.

PAR - India. Uttarakhand: West Almora.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Synuchus andrewesi* Habu 1955**

Synuchus andrewesi Habu 1955: 139, Lorenz 2005: 400, Löbl & Löbl 2017: 791.

PAR - India. North West India.

***Synuchus himalayicus* (Jedlička 1935)**

Pristodactyla himalayicus Jedlička 1935c: 278.

Synuchus himalayicus (Jedlička 1935): Lindroth 1956: 486, Lorenz 2005: 400, Löbl & Löbl 2017: 792.

PAR - India. Jammu & Kashmir). Also known in Pakistan.

***Synuchus pallipes* (Andrewes 1934)**

Calathus pallipes Andrewes 1934. 213.

Synuchus pallipes (Andrewes 1934): Lindroth 1956: 489, 496, Lorenz 2005: 400, Löbl & Löbl 2017: 793.

PAR - India. Uttarakhand: West Almora, Ranikhet, Chakrata (Sainj Khud), Manjgaon.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

***Synuchus sikkimensis* (Andrewes 1934)**

Calathus sikkimensis Andrewes 1934. 213.

Synuchus sikkimensis (Andrewes 1934): Lindroth 1956: 498, 519, Lorenz 2005: 400, Löbl & Löbl 2017: 793.

PAR - India. Sikkim; West Bengal: Gopaldhara.

Remarks: Endemic to the Himalaya hotspot of biodiversity.

The Indian Platyninae are represented by 188 species belonging to the Platynini (30 genera, 139 species) and Sphodrini (9 genera, 49 species). Among the represented 188, 115 are known from the Indian PAR, whereas 38 are known from the Indian ORR, and 20 from both the Indian PAR and Indian ORR regions. Of the 188, 133 are known from higher elevations of the Indian Himalaya (>500 masl) and the remaining are known from both lower elevations of the Himalaya and the non-Himalayan regions of the Indian subcontinent. Just 17 species are known from the peninsular India. Of the 188, 125 are exclusive Indian species with reports only from the Indian Mainland, and the remaining 63 occur widely Among the 125 exclusive Indian species, 94 (65 of the Platynini and 29 species of the Sphodrini) are known from the PAR region in the Indian mainland, 22 (16 of

the Platynini and six of the Sphodrini) from the ORR region in the Indian mainland, five (all Platynini) with records from both PAR and ORR regions of mainland India. Precise localities in India for the remaining four species are not known.

Among the 125 exclusively Indian Platyninae, 111 are endemic to the three global hotspots of biodiversity in the Indian subcontinent. Five genera of Platyninae, *viz*., *Callidagonum* Lorenz 1998, *Kuceraianum* Morvan 2002, *Skouedhirraad* Morvan 1999 of the Platynini and *Broter* Andrewes 1923 and *Himalosphodrus* Casale 1988 of the Sphodrini are endemic to the Indian mainland. Ten genera of Indian Platyninae, *viz*., *Aparupa* Andrewes 1930, *Callidagonum* Lorenz 1998, *Deliaesianum* Morvan 1999, *Deltocolpodes* Morvan 1992, *Henvelik* Morvan 1999, *Kuceraianum* Morvan 2002, *Skorlagad* Morvan 1999, *Skouedhirraad* Morvan 1999 and *Lepcha* Andrewes 1930 of the Platynini and *Himalosphodrus* Casale 1988 of the Sphodrini are endemic to the Himalaya hotspot of biodiversity (Global Biodiversity Hotspots with Special Emphasis on Indian Hotspots, 2020). Seven Himalayan hotspot endemic genera *Aparupa, Himalosphodrus, Lepcha, Henvelik*, *Skouedhirraad, Skorlagad* and *Deliaesianum* are wingless and support the 'tertiary Tibetan faunal components of Himalaya' hypothesis suggested for several groups of nonflying ground beetles (Schmidt 2003, Schmidt & Hartmann 2009).

ACKNOWLEDGEMENTS

Financial assistance provided by the University Grants Commission (UGC) and infrastructure provided by DST FIST are gratefully acknowledged. Director, Zoological Survey of India and Regional Agricultural Research Station (RARS), Kerala Agricultural University, Ambalavayal, Wayanad are acknowledged for access to insect collections; Dr Seiji Morita, Japan for providing some literature; and Dr Raman A, Australia for the crtical review of the manuscript. Akhil S V, Jithmon V A and Divya M (St. Joseph's College, Devagiri, Kozhikode) acknowledged for logistical support.

REFERENCES

Ádám L. 1996. A checklist of the Hungarian caraboid beetles (Coleoptera). Folia Entomologica Hungarica (S.N.) 57: 5-64.

Agassi J L R. 1846. Nomenclatoris zoologici. Index universalis, continens nomina systematica classium, ordinum, familiarum et generum animalium omnium, tam viventium quam fossilium, secundum ordinem alphabeticum unicum disposita, adjectis homonymiis plantarum, nec non variis adnotationibus et emendationibus. Jent and Gassmann, Switzerland. 393 pp.

Alluaud C. 1916. Coleoptera of the Mascareignes and Séchelles. Scientific missions of MM. C. Alluaud (1892, 1893 and 1897) and P.Carié (1910-1913). Cicindelidae and Carabidae. Annales de la Société entomologique de France 85: 37-90.

Andrewes H E. 1919a. Note on Bonelli's "Tableau Synoptique." The Transactions of the Entomological Society of London 89-92.

Andrewes H E. 1919b. On the types of Oriental Carabidae in the British Museum, and in the Hope Department of the Oxford University Museum. The Transactions of the Entomological Society of London 119-217.

Andrewes H E. 1919c. Papers on Oriental Carabidae - I. The Annals and Magazine of Natural History 3: 469-483.

Andrewes H E. 1921. Notes on synonymy and on some types of Oriental Carabidae in various foreign collections. The Transactions of the Entomological Society of London 69: 145-190.

Andrewes H E. 1922a. Papers on Oriental Carabidae - VIII. The Annals and Magazine of Natural History 10: 161-169.

Andrewes H E. 1922b. Notes on the types of Oriental Carabidae in Stettin Museum. Transactions of Entomological Society of London 9: 245-250.

Andrewes H E. 1923a. On the types of Carabidae described by Schmidt-Göbel in his Faunula coleopterorum Birmaniae. The Transactions of the Entomological Society of London 71: 1-63.

Andrewes H E. 1923b. Papers on Oriental Carabidae - X. The Annals and Magazine of Natural History 12: 212-223.

Andrewes H E. 1923c. Descriptions of some new Carabidae from Ceylon (Part I.). Spolia Zeylanica 12: 223-251.

Andrewes H E. 1923d. Papers on Oriental Carabidae - XI. The Annals and Magazine of Natural History 12: 442-455.

Andrewes H E. 1923e. Papers on Oriental Carabidae - XII. The Annals and Magazine of Natural History 12: 679-690.

Andrewes H E. 1924a. Mission Guy Babault dans les Provinces Centrales de l'Inde et dans la région occidentale de l'Himalaya 1914. Resultes scientifiques, Insectes coléoptères Carabidae. Generale Lahure, Paris. 125 pp.

Andrewes H E. 1924b. Description on some new Carabidae from Ceylon. Spolia Zeylanica 13: 129-141.

Andrewes H E. 1924c. Papers on Oriental Carabidae-XIV. The Annals and Magazine of Natural History 14: 585-593.

Andrewes H E. 1926a. On a collection of Carabidae from the Kumaon-Tibetan frontier. The Entomologist's Monthly Magazine 62: 65-80.

Andrewes H E. 1926b. Papers on Oriental Carabidae - XVI. The Annals and Magazine of Natural History 17: 252-259.

Andrewes H E. 1927a. Descriptions of some new species of Carabidae from North India. Eos (Revista Española de Entomologia) 3: 65-77.

Andrewes H E. 1927b. Papers on Oriental Carabidae - XIX. The Annals and Magazine of Natural History 19: 97-111.

Andrewes H E. 1927c. Papers on Oriental Carabidae - XX. The Annals and Magazine of Natural History 20: 263-272.

Andrewes H E. 1928. On the types of Oriental Carabidae described by V. de Motchulsky. The Transactions of the Entomological Society of London 76: 1-24.

Andrewes H E. 1930a. Catalogue of Indian Insects (Part 18-Carabidae). Government of India Central Publication, Calcutta. 389 pp.

Andrewes H E. 1930b. The Carabidae of the third Mount Everest Expedition, 1924. Transactions of the Entomological Society of London 78: 1-44.

Andrewes, H E. 1931a. On the Carabidae of Mt. Kinabalu. Journal of the Federated Malay Museums 16: 431-485.

Andrewes H E. 1931b. Papers on Oriental Carabidae - XXV. The Annals and Magazine of Natural History 7: 513-528.

Andrewes H E. 1932. Papers on Oriental Carabidae - XXVI. The Annals and Magazine of Natural History 9: 133-146.

Andrewes H E. 1934. Keys to some Indian genera of Carabidae (Col.). IV. The genus *Calathus*. Stylops 3: 209-222.

Andrewes H E. 1936. Descriptions of some new Carabidae from Ceylon (Part III). Spolia Zeylanica 19: 201-209.

Andrewes H E. 1937a. Keys to some Indian genera of Carabidae (Col.). VIII. The genera of the Sphodrini group. The Proceedings of the Royal Entomological Society of London 6: 59-63.

Andrewes H E. 1937b. Papers on Oriental Carabidae - XXXII. The Annals and Magazine of Natural History 20: 561-576.

Andrewes H E. 1939. Papers on Oriental Carabidae - XXXV. On the types of some Indian genera. The Annals and Magazine of Natural History 3: 128-139.

Andrewes H E. 1946. Stray notes on Eastern Coleoptera - I. The Proceedings of the Royal Entomological Society of London B 15: 81-83.

Andrewes H E. 1947. Entomological results from the Swedish expedition 1934 to Burma and British India. Coleoptera: Carabidae. Collected by René Malaise. Arkiv för Zoologi 38A: 1-49.

Anichtchenko A et al. (editors): Carabidae of the world. http://www.carabidae.org Available from: http://carabidae.org/taxa/foveodromica-cassola-2002 (last edit 6 June 2014, accessed 8 November 2017)

Bach M. 1849. Beetle fauna for northern and central Germany. Holscher, Coblenz. 414 pp.

Baehr M. 1982. *Atranopsis* n. gen., eine neue Laufkäfer-Gattung der Agonini aus Syrien (Insecta: Coleoptera: Carabidae). Senckenbergiana Biologica 62: 261-266.

Baehr M. 2010. A revision of the genus *Arhytinus* Bates (Coleoptera: Carabidae: Platynini). Entomologie 80: 5-50.

Baehr M. 2012. New species and new records of the genus *Arhytinus* Bates. 2nd supplement to the "Revision of the genus *Arhytinus* Bates". (Coleoptera; Carabidae; Platynini). Koleopterologische Rundschau 82: 41-64.

Baehr M. 2014. New species of the genus *Arhytinus* Bates. 3rd supplement to the "Revision of the genus *Arhytinus* Bates" (Coleoptera, Carabidae, Platynini). Spixiana 37: 219-230.

Baehr M, Reid C. 2017. On a collection of Carabidae from Timor Leste, with descriptions of nine new species (Insecta: Coleoptera, Carabidae). Records of the Australian Museum 69: 421-450.

Bates H W. 1873a. On the geodephagous Coleoptera of Japan. The Transactions of the Entomological Society of London 1873: 219-322.

Bates H W. 1873b. Descriptions of new genera and species of geodephagous Coleoptera, from China. The Transactions of the Entomological Society of London 1873: 323-334.

Bates H W. 1878. On new species of coleopterous insects (Geodephaga and Longicornia) taken by Dr Stoliczka during the Forsyth Expedition to Kashgar in 1873-74. Proceedings of the Scientific Meetings of the Zoological Society of London 1878: 713-721.

Bates H W. 1883. Supplement to the geodephagous Coleoptera of Japan, chiefly from the collection of Mr. George Lewis, made during his second visit, from February, 1880, to September, 1881. The Transactions of the Entomological Society of London 1883: 205-290, pl. xiii.

Bates H W. 1886. On the geodephagous Coleoptera collected by Mr. George Lewis in Ceylon- XIV. The Annals and Magazine of Natural History 17: 143-156.

Bates H W. 1889a. Journey of Leonardo Fea in Burma and neighboring regions, XVI. On some Carabidae from Burma collected by Mr. L. Fea. Annali del Museo Civico di Storia Naturale di Genova 2: 100-111.

Bates H W. 1889b. On new species of the coleopterous family Carabidae, collected by Mr. J.H. Leech in Kashmir and Baltistan. Proceedings of the Zoological Society of London 57: 210-215.

Bates H W. 1889c. Contributions to Indo-Chinese fauna, 3rd volume (1). Annales de la Société entomologique de France 6: 262-286.

Bates H W. 1890. Coleoptera collected by Mr. Pratt on the Upper Yang-Tsze, and on the borders of Tibet. The Entomologist (Supplement) 23: 209-213.

Bates H W. 1891a. Coleoptera from Kulu in N.W. India. The Entomologist (Supplement) 24: 7-23.

Bates H W. 1891b. List of the Carabidae (ord. Coleoptera) obtained by Père Cardon in Chota-Nagpore. Bulletin de la Société entomologique de Belgique 1891: cccxxiv-cccxxxix.

Bates H W. 1892. Viaggio di Leonardo Fea in Birmania e regioni vicine. XLIV. List of the Carabidae. XLIV. Annali del Museo Civico di Storia Naturale di Genova 32: 267-428.

Battoni F. 1982. Nuovi Sfodrini del Pakistan e del Kaschmir (Coleoptera Carabidae). Bollettino della Società Entomologica Italiana 114: 17-24.

Bedel L. 1902. Catalogue raisonné des coléoptères du Nord de l'Afrique (Maroc, Algérie, Tunisie et Tripolitaine) avec notes sur la faune des Îles Canaries et de Madère. Société entomologique de France, Paris. 402 pp.

Boheman C H. 1858. Coleoptera. pp. 1-112. Virgin C.A. (ed.): Kongliga Svenska Fregatten Eugenies Resa omkring Jorden. Norstedt & Söner, Stockholm. 614 pp.

Bonelli F A. 1810. Observations entomologiques. Premiere partie (cicindeletes et portion des carabiques) [with the "Tabula synoptica exhibens genera carabicorum in sectiones et stirpes disposita"]. Felix Galletti, Turin. 58 pp.

Bouchard J. 1903. Insectes recueillis par M. le Professeur Dr Forster à Bornéo, Java et Sumatra (Palembang). Coléoptères carabiques. Annales de la Société entomologique de France 72: 169-176.

Bousquet Y, Larochelle A. 1993. Catalogue of the Geadephaga (Coleoptera: Trachypachidae. Rhysodidae, Carabidae Including Cicindelini) of America North of Mexico. Memoirs of the Entomological Society of Canada 167: 1-397.

Bousquet Y. 2002. Additions and corrections to the world catalogue of genus-group names of Geadephaga (Coleoptera) published by Wolfgang Lorenz (1998). Folia Heyrovskyana (Supplement) 9: 1-78.

Bousquet Y. 2003. Catalogue of Palaearctic Coleoptera Vol. 1. Archostemata-Myxophaga-Adephaga, pp. 449-469. Löbl and A. Smetana (eds.). Apollo Books, Stenstrup, Denmark. 819 pp.

Bousquet Y. 2012. Catalogue of Geadephaga (Coleoptera, Adephaga) of America, north of Mexico. ZooKeys 245: 1-1722.

Brullé A. 1834. Des Insectes en Général, De leur Division en Ordres. Histoire Naturelle des Insectes, Coléoptères Librarie Encyclopédique de Roret, Paris. 1: 1-497.

Casale A. 1980. The Himalayan ground-beetle genus *Aparupa*

(Carabidae) with three new species. Systematic Entomology 5: 399-403.

Casale A. 1981: Carabidae dell'Himalaya Nepalese. Sphodrini nuovi o poco noti (Insecta: Coleoptera). Senckenbergiana Biologica 61: 383-395.

Casale A. 1982. Nuovi 'Sphodrini' (Sphodrina sensu Habu, 1978) dell'Asia (Col. Carabidae, Pterostichinae). Entomologica Basiliensia 7: 142-155.

Casale A. 1988. Revisione degli Sphodrina (Coleoptera, Carabidae, Sphodrini). Museo Regionale di Scienze Naturali, Torino. 1024 pp.

Casale A, Shi H. 2018. Revision of the Oriental species of *Calleida* Latreille (sensu lato). Part 1: Introduction, groups of species, and species of six species groups (Coleoptera: Carabidae: Lebiini). Zootaxa 4442: 1-42.

Casale A, Heinz W. 2000. Contribution to the knowledge of the genus *Sphodropsis* Seidlitz, 1887, in the Himalayan region, with the description of a new species (Coleoptera, Carabidae, Sphodrina). Entomologische Zeitschrift 110 (6): 166-168.

Casale A, Wrase D W. 2012. New or little known *Laemostenus* species from the near and Middle East (Coleoptera, Carabidae: Sphodrini). Linzer Biologische Beiträge 44(2): 1111-1127.

Casey T L. 1920. A revisional study of the American Platyninae, pp. 1-132. Memoirs on the Coleoptera. IX. The New Era Printing Company, Lancaster. 529 pp.

Chaudoir M de. 1843. Genres nouveaux de la famille des carabiques (Continuation). Bulletin de la Société impériale des naturalistes de Moscou 16: 383-427.

Chaudoir M de 1844. Trois mémoires sur la famille des carabiques. Bulletin de la Société impériale des naturalistes de Moscou 17: 415-479.

Chaudoir M de. 1850. Memoire sur la famille des Carabiques (2e partie, cont.). Bulletin de la Société impériale des naturalistes de Moscou 23: 1-460.

Chaudoir M de 1852. Mémoire sur la famille des carabiques. 3e partie. Bulletin de la Société impériale des naturalistes de Moscou 25: 3-104.

Chaudoir M de. 1854. Mémoire sur la famille des carabiques. 4-e partie. Bulletin de la Société impériale des naturalistes de Moscou 27: 112-144.

Chaudoir M de. 1859. Monographie du genre *Colpodes* MacLeay. Annales de la Société entomologique de France 7: 287-364.

Chaudoir M de. 1878. Révision des genres *Onychopterygia*, *Dicranoncus* et *Colpodes*. Annales de la Société entomologique de France 8: 275-382.

Chaudoir M de. 1879. Révision des genres *Onychopterygia*, *Dicranoncus* et *Colpodes* (suite). Annales de la Société entomologique de France 8[1978]: 337-382 [part].

Clairville J P de. 1806. Entomologie helvétique ou catalogue des insectes de la Suisse rangés d'après une nouvelle méthode. Orell, Fussli et Compagnie, Zürich. 247 pp.

Coiffait H. 1956. Les *Pristonychus* s. str. de la région mediterranéenne occidentale. Archivos del Instituto de Aclimatación de Almería 5: 25-27.

Csiki E. 1931. Carabidae: Harpalinae V (Pars 115), pp. 739-1022. Junk W. & Schenkling S. (eds.). Coleopterorum catalogus. Volume II. Carabidae II. Berlin. 1022 pp.

Darlington P J Jr. 1952. The carabid beetles of New Guinea II. The Agonini (Anchomenini). Bulletin of the Museum of Comparative Zoology 107: 89-252.

Darlington P J Jr. 1971. The carabid beetles of New Guinea IV. General considerations, analysis and history of fauna, taxonomic supplement. Bulletin Museum of Comparative Zoology 142: 129-337.

de Geer C. 1774. Mémoires pour servir à l'histoire des insectes. 4th Volume. P. Hesselberg, Stockholm. 456 pp.

Dejean P F M A. 1821. Catalogue de la collection de coléoptères de M. le Baron Dejean. Crevot, Paris. 136 pp.

Dejean P F M A. 1828. Species général des coléoptères, de la collection de M. le Comte Dejean. Volume III. A Paris, Chez Crevot, Libraire-Éditeur, Paris. 7: 556 pp.

Dejean P F M A. 1831. Species general des Coleopteres de la collection de M. le comte Dejean. Tome cinquieme. Mequignon- Marvis, Paris. 883 pp.

Descourtilz T. 1827. Description de quelques insectes nouveaux découverts en France en 1825. Mémoires de la Société Linnéenne de Paris 5[1825]: 156-163.

Deuve T, Lassalle B, Quéinnec E. 1985. Nouveaux *Pristosia* Motschulsky et *Calathus* Bonelli de la region himalayenne (Coleoptera, Carabidae, Pterostichinae). Entomologica Basiliensia 10: 75-84.

Deuve T. 2006. Nouveaux Carabidae et Trechidae (Coleoptera, Caraboidea). Coléoptères 12: 291-304.

Drapiez P A J. 1819. Description de huit espèces d'insectes. Annales Générales de la Société des Sciences Physiques de Bruxelles 1: 130-138.

Duftschmid C E. 1812. Fauna Austriae, oder Beschreibung der Österreichischen Insekten für angehende Freunde der Entomologie. 2er Teil. Leipzig: Akademie Buchhandlung. 311 pp.

Eschscholtz F. 1829. Zoologischer Atlas, enthaltend Abbildungen und Beschreibungen neuer Tierarten, während des Flottcapitains von Kotzebue zweiter Reise um die Welt, auf der Russisch-Kaiserlichen Kriegsschlupp Predpriaetië in den Jahren 1823-1826. G. Reimer, Berlin. pp. 1-18.

Fabricius J C. 1792. Entomologia systematica emendata et aucta, secundum classes, ordines, genera, species adjectis synonimis, locis, observationibus, descriptionibus. Volume I. Part I. C. G. Proft, Copenhagen. 330 pp.

Fairmaire L. 1862. Miscellanea entomologica. Quatrième partie. Annales de la Société entomologique de France (4) 1[1861]: 577-596.

Fairmaire L. 1889. Descriptions de deux Carabiques du nord de 1'Inde appartenant au Musee de Calcutta. Bulletin des Séances et Bulletin bibliographique de la Société entomologique de France 1889(2): xv-xvii.

Fairmaire L. 1891. Coléoptères de l'intérieur de la Chine (7e partie). Bulletin de la Société entomologique de Belgique 1891: clxxxvii-ccxix.

Fairmaire L. 1901. Matériaux pour la faune coléoptérique de la région malgache. (11e note). Revue d'Entomologie 20: 101-248.

Fedorenko D N. 2011. A new ground-beetle Genus, *Dalatagonum* Gen. n. (Coleoptera, Carabidae, Platynini), Far-Eastern Entomologist 233: 1-23.

Fedorenko D N. 2015. A review of the Oriental genus *Praepristus* (Coleoptera: Carabidae: Platynini). The Canadian Entomologist 1-22.

Fedorenko D N. 2020. New species of *Meleagros* and *Tarsagonum* (Coleoptera: Carabidae: Platynini) from the Oriental region. Russian Entomological Journal 29: 139-147.

Ganglbauer L. 1892. Die Käfer von Mitteleuropa 1. Die Käfer der österreichisch-ungarischen Monarchie, Deutschlands, der Schweiz,

sowie des Französischen und italianischen Alpengebietes. Familienreiche Caraboidea. Carl Gerold, Wien. 557 pp.

Gautier des Cottes C. 1867. Monographie du genre *Calathus*. Mittheilungen der Schweitzerischen Entomologischen Gesellschaft 2[1866-1868]: 235-286.

Gemminger M, Harold B de. 1868. Catalogus Coleopterorum 1 (Cicindelidae Carabidae. E. Deyrolle f. Paris. 424 pp.

Gillet M P T. 2009. Unknown or little-known large ground beetles from the United Arab Emirates (Coleoptera: Carabidae: Scaritinae, Harpalinae, Platyninae). Tribulus 18: 62-64.

Gistel J N F X. 1848. Naturgeschichte des Thierreichs. Für höhere Schulen bearbeitet durch Johannes Gistel. Miteinem Atlas von 32 Tafeln (darstellend 617 illuminirte Figuren) und mehreren dem Texte eingedruckten Xylographien. R. Hoffmann, Stuttgart. 216 pp.

Goeze J A E. 1777. Entomologische beiträge zu des Ritter Linné zwölften ausgabe des natursystems. Erster Theil. Weidmann Erben und Reich, Leipzig. 736 pp.

Gray G, Hatch M H. 1941. The Coleoptera of Washington, Carabidae: Agonini. 10: 7-27, 9 pls.

Guéorguiev B V, Morita S. 2009. Taxonomic note on genus *Rupa* (Coleoptera: Carabidae: Platynini) from Japan. Acta Zoologica Bulgarica. 61: 93-96.

Gyllenhal L. 1810. Insecta Suecica descripta. Classis 1. Coleoptera sive Eleuterata. Tomi I. Pars II. F.J. Leverentz, Scaris. 660 pp.

Habu A. 1955. One new species of *Synuchus* (Coleoptera, Carabidae) from northwest India. The Bulletin of the National Institute of Agricultural Sciences 5: 139-142.

Habu A. 1973a. A new subgenus of *Platynus* and its peculiar tibial characteristic (Coleoptera, Carabidae). The Entomological Review of Japan 25: 11-12.

Habu A. 1973b. On a collection of Carabidae from Nepal made by the Hokkaido University Scientific Expedition to Nepal Himalaya, 1968 (I). The Bulletin of the National Institute of Agricultural Sciences 27: 81-132.

Habu A. 1975. Carabidae taken from the Ryukyus, Japan, mainly by Mr. H. Hasegawa during February and March in 1973 (Coleoptera: Carabidae). Transactions of the Shikoku Entomological Society 12: 63-81.

Habu A. 1978a. Fauna Japonica. Carabidae: Platynini (Insecta: Coleoptera). Keigaku Publishing Co, Tokyo. 447 pp..

Habu A. 1978b. On a collection of Carabidae from Nepal made by the Hokkaido University scientific expedition to Nepal Himalaya, 1968 (II). The Entomological Review of Japan 32: 1-17.

Habu A. 1978c. Notes and descriptions of Formosan Carabidae taken by Dr S.-I. Uéno in 1961 (Coleoptera, Carabidae). VIII. *Synuchus* spp. The Entomological Review of Japan 31: 33-67.

Harold E von. 1878a. Beiträge zur Käferfauna von Japan. (Viertes Stück). Japanische Käfer des Berliner Königliches Museums. Deutsche Entomologische Zeitschrift 22: 65-88.

Harold E von. 1878b. Ueber einige Japanische *Colpodes*-Arten. Deutsche Entomologische Zeitschrift 22: 212-214.

Hatch M H. 1953. The beetles of the Pacific northwest. Part I.: Introduction and Adephaga. University of Washington Publications in Biology 16: 1-340.

Heller K M. 1916. Philippinische Käfer, gesammelt von Prof. C. Fuller-Baker, Los Banos. Deutsche Entomologische Zeitschrift 30: 269-311.

Heller K M. 1923. Some new Malayan Carabidae, especially Philippine. The Philippine Journal of Science 13: 295-307.

Herbst J F W. 1784. Kritisches Verzeichnib meiner Insecten-Sammlung. pp. 1-151. Füessly J C: Archiv der Insectengeschichte. Hefte 4-5. H Steiner, Zürich. 151 pp.

Hope F W. 1831. Synopsis of the new species of Nepal insects in the collection of Major General Hardwicke. Zoological Miscellany 1: 21-32.

Hovorka O, Sciaky R. 2003. Subtribe Pristosiina Lindroth, 1956. pp. 530-531. Catalogue of Palaearctic Coleoptera, Volume 1. Archostemata-Myxophaga-Adephaga. Löbl I, Smetana A (eds). Apollo Books, Stenstrup. 819 pp.

Illiger J K W. 1798. Verzeichniss der Käfer Preussens. Entworfen von Johann Gottlieb Kugelann, Apotheker in Osterode. Ausgearbeitet von Johann Karl Wilhelm Illiger. Mit einer Vorrede des Professors und Pagenhofmeisters Hellwig in Braunscheig, und dem angehängten Versuche einer natürlichen Ordnungs- und Gattungs-Folge der Insekten. J.J. Gebauer, Halle. 510 pp.

Illiger J K W. 1801. Nachtrag und Berichtigungen zum Verzeichnisse der Käfer Preussens. Magazin für Insektenkunde 1: 1-94.

Jeannel R. 1914. Sur la systématique des Sphodrides (Col. Carabidae) (note préliminaire). Bulletin de le Société entomologique de France 1914: 235-240.

Jeannel, R. 1942: Coléoptères carabiques. Deuxième partie. Faune de France 40. Librairie de la Faculté des Sciences, Paris. pp. 572-1173.

Jeannel R. 1948. Faune de l'empire français. X. Coléoptères carabiques de la région Malgache (deuxième partie). Office de la Recherche Scientifique Coloniale 10: 373-765.

Jedlička A. 1932. Carabiden aus Ost-Asien. Entomologisches Nachrichtenblatt 6: 69-76.

Jedlička A. 1934. Monographie der mit *Colpodes* verwandten Gattungen aus China, Formosa und Philippinen. Monografie příbuzných rodů s Colpodes z Číny, Formosy a Filipin. Acta Entomologica Musei Nationalis Pragae 12: 177-205.

Jedlička A. 1935a. Neue Carabiden aus Ostasien. (8. Teil.). Časopis Československé Společnosti Entomologické 32: 31-36.

Jedlička A. 1935b. Noví Carabidi - Neue Carabiden (Col. Carab.). Časopis Československé Společnosti Entomologické 32: 79.

Jedlička A. 1935c. Pterostichinae (Carab., Col.). P. 278. Visser C. & Visser-Hooft J. (eds.): Wissenschaftliche Ergebnisse der niederländischen Expeditionen in den Karakorum und die angrenzenden Gebiete 1922, 1925 und 1929/30. F A Brockhaus, Leipzig.

Jedlička A. 1953. Revise tribu Pterostichini. Reviziya Tribyi Pterostichini. Revision der Tribus Pterostichini (Col., Carabidae). Ročenka Ceskoslovenské Společnosti Entomologické 50: 85-112.

Jedlička A. 1937. Zástupci rodu Calathus z Číny. *Calathus*-Arten und ihre Verwandten aus China. Časopis Československé Společnosti Entomologické 34: 78-83.

Jedlička A. 1955. Noví střevlíci z asijské oblasti. Novye vidy Carabidae iz Azii. Neue Carabiden aus der asiatischen Region. (Col., Carabidae). Ročenka Československé Společnosti Entomologické 51[1954]: 119-128.

Jedlička A. 1960. Neue Carabiden aus dem Sammlungen des Museums Frey (Col.). Entomologischen Arbeiten aus dem Museum G Frey 11: 587-598.

Jedlička A. 1963. Neue Carabiden aus der palaearktischen Region (Coleoptera). Reichenbachia 1[1962]: 303-307.

Jedlička A. 1965. Neue Carabiden aus Nepal (Coleoptera). Khumbu Himal, ergebnisse des forschungsunternehmens Nepal Himalaya 1: 98-107.

Jedlička A. 1969. Neue Carabiden ans der Zoologischen Sammlung

des Bayerischen Staates (Col., Carabidae). Opuscula Zoologica (Muenchen) 108: 1-7.

Jedlička A. 1970. Neue Carabiden aus Nepal (Coleoptera - Carabidae). Khumbu Himal, ergebnisse des forschungsunternehmens Nepal Himalaya 3: 439-440.

Kirby W. 1837. Part the fourth and last. The insects. Richardson J: Fauna Boreali-Americana; or the zoology of the northern parts of British America: containing descriptions of the objects of natural history collected on the late Northern Land Expeditions, under command of captain Sir John Franklin, R.N. J. Fletcher, London. 329 pp.

Kirschenhofer E. 1992. *Agonum (Metacolpodes) buchanani* Hope, 1831 und seine verwandten Arten aus dem östlichen Himalaya (Coleoptera: Carabidae). Koleopterologische Rundschau 62: 13-20.

Kirschenhofer E. 1999. Über neue und wenig bekannte Carabiden Arten und Gattungen aus Südeuropa, Kleinasien, Süd- und Südostasien (Coleoptera: Carabidae: Lebiinae). Annales Historico-Naturales Musei Nationalis Hungarici 9 (1): 67-79.

Kirschenhofer E. 2010. New and little-known species of Carabidae from the Middle East and Southeast Asia (Coleoptera, Carabidae: Lebiini, Brachinini). Annales Historico-Naturales Musei Nationalis Hungarici 102: 25-64.

Klug J C F. 1833. Bericht über eine auf Madagascar veranstaltete Sammlung von insecten aus der Ordnung Coleoptera. Eine in der Königl. Akademie der Wissenschaften am 29. März 1832 gelesene Abhandlung. Mit fünf illuminirten Tafeln. Königliche Akademie der Wissenschaften, Germany. 135 pp.

Klug J C F. 1834. Bericht über eine auf Madagascar veranstaltete Sammlung von Insecten aus der Ordnung Coleoptera. Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin, 1832(1): 91- 223.

Kollar V, Redtenbacher L. 1844. Aufzählung und Beschreibung der von Freiherrn Carl v. Hügel auf seiner Reise durch Kaschmir und das Himaleyagebirge gesammelten Insecten. pp. 395-564, 28 pls. Hügel C.: Kashmir und das Reich der Siek, von Carl Freiherrn von Hügel in vier Banden. Vierter Band. Zweite Abteilung. Hallberger, Stuttgart. pp. 247-581.

Kryzhanovskij O L. 1993. New or poorly known Platynini from SW China (Coleoptera: Carabidae). Zoosystematica Rossica 2(2): 297-305.

Lacordaire J T. 1854. Genera des coléoptères, ou exposé méthodique et critique de tous les genresproposés jusqu'ici dans cet orde d'insectes. Histoire naturelle des Insectes Coléoptères 1: 1-486.

Laporte F L N. 1834. de Caumont [comte de Castelnau]. pp. 1-94. Études entomologiques, ou description d'insectes nouveaux: et observations sur leur synonymie. Méquignon-Marvis, Paris. 159 pp.

Larochelle A, Larivière M C. 2001. Carabidae (Insecta: Coleoptera): catalogue. Fauna of New Zealand 43: 1-285.

Larochelle A, Larivière M C. 2007. Carabidae (Insecta: Coleoptera): Synopsis of supraspecific taxa. Fauna of New Zealand 60: 1-188.

LeConte JL. 1854. Synopsis of the species of *Platynus* and allied genera, inhabiting the United States. Proceedings of the Academy of Natural Sciences of Philadelphia 7[1854-1855]: 35-59.

LeConte J L. 1879. Synopsis of the North American species of *Platynus*, Bon. Bulletin of the Brooklyn Entomological Society 2 [1879-80]: 43-58.

Liang H, Kavanaugh D H. 2005. A review of genus *Onycholabis* Bates (Coleoptera: Carabidae: Platynini), with description of a new species from Western Yunnan, China. The Coleopterists Bulletin 59: 507-520.

Liebherr J K. 1991. Phylogeny and revision of the *Anchomenus* clade: The genera *Tetraleucus, Anchomenus, Sericoda,* and *Elliptoleus* (Coleoptera: Carabidae: Platynini). Bulletin of the American Museum of Natural History 202: 1-163.

Liebherr J K. 1994. Identification of New World *Agonum*, review of the Mexican fauna, and description of *Incagonum*, new genus, from South America (Coleoptera: Carabidae: Platynini). Journal of the New York Entomological Society 102: 1-55.

Liebherr J K. 1998. On *Rembus (Colpodes) brunneus* MacLeay (Coleoptera: Carabidae: Platynini): redescription and relationships. Journal of Natural History 32: 987-1000.

Liebherr J K. 2005. Platynini (Coleoptera: Carabidae) of Vanuatu: Miocene diversification on the Melanesian Arc. Invertebrate Systematics 19: 263-295.

Liebherr J K, Nikitsky N B, Schmidt J. 2003. *Dolichodes geniculatus* Motschulsky is a junior synonym of *Euleptus ooderus* Chaudoir (Coleoptera: Carabidae: Platynini). The Coleopterists Bulletin 57: 457-458.

Liebherr J K, Schmidt J. 2004. Phylogeny and biogeography of the Laurasian genus *Agonum* Bonelli (Coleoptera, Carabidae, Platynini). Deutsche Entomologische Zeitschrift 51(2): 151-206.

Liebherr J K, Will K W. 1996. New North American *Platynus* Bonelli (Coleoptera: Carabidae), a key to species north of Mexico, and notes on species from the southwestern United States. The Coleopterists Bulletin 50: 301-320.

Lindroth C H. 1956. A revision of the genus *Synuchus* Gyllenhal (Coleoptera: Carabidae) in the widest sense, with notes on *Pristosia* Motschulsky (*Eucalathus* Bates) and *Calathus* Bonelli. Transactions of the Royal Entomological Society of London 108: 485-576.

Lindroth C H. 1966. The ground beetles of Canada and Alaska, part 4. Opuscula entomologica and its supplement 29: 409-648.

Linnaeus C von. 1758. Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis. Editio decima, reformata 1: 823.

Löbl I, Smetana A. 2003. Catalogue of Palaearctic Coleoptera. Vol. 1. Archostemata-Myxophaga-Adephaga. Apollo Books, Stenstrup, Denmark. 819 pp.

Löbl I, Löbl D. 2017. Catalogue of Palaearctic Coleoptera. Archostemata-Myxophaga-Adephaga, revised and updated edition, Brill, Leiden, Boston. 1443 pp.

Lorenz W. 1998. Systematic list of extant ground beetles of the world (Insecta Coleoptera "Geadephaga": Trachypachidae and Carabidae incl. Paussinae, Cicindelinae, Rhysodidae). 1st edition, printed by the author, Tutzing. 502 pp.

Lorenz W. 2005. Systematic list of extant ground beetles of the world. 2nd edition, Published by the author, Tutzing. 530 pp.

Lorenz W. 2021. CarabCat: Global database of ground beetles (version Oct 2017). Catalogue of life, [author list in alphabetical order] (ed.) (2021). Species 2000 & ITIS Catalogue of Life, 2021-05-07. Digital resource at - Species 2000: Naturalis, Leiden, the Netherlands. ISSN 2405-8858.

Louwerens C J. 1953. The Oriental species of *Colpodes* Macl. (Col. Carabidae). Treubia 22: 75-151.

Louwerens C J. 1955. New Oriental Agonini (Coleoptera, Carabidae). Tijdschrift voor Entomologie 98: 43-56.

Louwerens C J. 1956. On a collection of Carabidae from the Northern Moluccas (Coleoptera). Treubia 23: 219-243.

Louwerens C J. 1966. Some more Malayan Carabidae in the Stockholm. Museum of Natural History. Tijdschrift voor Entomologie 87: 33-39.

MacLeay W S. 1825. Annulosa Javanica, or an attempt to illustrate the natural, affinities and analogies of the Insects collected in java by Thomas Horsfield and deposited by him in the museum of the Honourable East-India Company. Kingsbury, Parbury, and Allen, Leadenhall Street, London. 1: 50 pp.

Maindron M. 1899. Description d'une espèce nouvelle de *Cardiomera* [Col. Carab.]. Bulletin de la Société entomologique de France 4: 155-156.

Maindron M. 1905. Notes synonymiques sur quelques coléoptères de la famille des Carabidae. Bulletin de la Société Entomologique de France 10: 94-95.

Mäklin F W. 1857. Beitrag zur kenntnis der sogenannten vicarirenden formen unter den Coleopteren des Nordens. Entomologische Zeitung 18: 321-348.

Malkin B, Hatch M H. 1952. A new *Agonum* from Oregon (Coleoptera: Carabidae). The Pan-Pacific Entomologist 28: 107-108.

Malkin B, Hatch M H. 1953. *Colpodes buchanani* in Oregon. The Pan-Pacific Entomologist 29: 134.

Mannerheim C G von. 1853. Dritter nachtrag zur käferfauna der Nord-Amerikanischen Länder des Russischen Reiches. Bulletin de la Société Impériale des Naturalistes de Moscou 26: 95-273.

Makarov K V, Sundukov Yu. N. 2011. First record of *Euplynes batesi* and *Agonum lampros* (Coleoptera: Carabidae, Platynini) from Russia. Far Eastern Entomologist 234: 34-36.

Morawitz A. 1862a. Vorläufige diagnosen neuer Carabiciden aus Hakodade. Bulletin de l'Académie Impériale des Sciences de St.-Pétersbourg 5[1863]: 321-328.

Morawitz A. 1862b. Vorläufige diagnosen neuer Carabiciden aus Hakodade. Mélanges Biologiques tirés du Bulletin de l'Académie des Sciences de St.-Pétersbourg 4: 237-247.

Morvan P [D]. 1973. Nouveaux coléoptères carabiques d'Iran. Bulletin du Muséum National d'Histoire Naturelle, Paris (3e série, N. 110, Zool.) 84: 169-186.

Morvan P [D]. 1978. Ergebnisse der Bhutan-Expedition 1972 des Naturhistorischen Museums in Basel. Coleoptera: fam. Carabidae, tribus Pterostichini und Sphodrini. Entomologica Basiliensia 3: 87-102.

Morvan P [D]. 1979. Ergebnisse der Bhutan-Expedition 1972 des Naturhistorischen Museums in Basel. Coleoptera: Fam. Carabidae, tribus Sphodrini. Entomologica Basiliensia 4: 31-42.

Morvan P [D]. 1992. Contribution à la connaissance des *Colpodes* du Népal (Coleoptera, Caraboidea, Platynina). Description d'un genre nouveau et de dix espèces nouvelles. Bulletin de la Société entomologique de France 96[1991]: 331-345.

Morvan P [D]. 1996. Le genre *Batenus* Motschulsky, 1864, redéfinition; descriptions d'espèces nouvelles d'Asie (Coleóptera, Carabidae, Platynina). Bulletin de la Société entomologique de France, 101: 35-48.

Morvan D mabb. 1997. Genre *Lepcha* Andrewes (Coleoptera, Carabidae, Platynina). Loened Aziad 1: 1-16

Morvan P [D]. 1998. Nouveaux genres et nouvelles espèces de Colpodes de l'Himalaya Oriental. Loened Aziad amprevaned feuraskelleged c'hwiledig 3: 1-52.

Morvan P [D]. 1999a. Nouveaux genres et nouvelles espèces de Platynina de l'Himalaya Oriental. Loened Aziad amprevaned feuraskelleged c'hwiledig 5: 1-31.

Morvan P [D]. 1999b. Nouveaux genres et nouvelles espèces de Platynina et de Sphodrina de l'Himalaya Oriental. Loened Aziad amprevaned feuraskelleged c'hwiledig 4: 1-44.

Morvan P [D]. 2002. Nouveaux genres et nouvelles especes de Platynina de l'Himalaya Oriental. Loened Aziad amprevaned feuraskelleged c'hwiledig 7: 1-32.

Morvan P [D]. 2004. Nouvelle tribu et nouvelles espèces de Platyninae. Nouvelles espèces de Tiruka et de Sphodrini de la région Orientale. Asia. Loened Aziad amprevaned feuraskelleged c'hwiledig 9: 1-65.

Morvan P [D]. 2007. Nouveaux espèces de Platynini de la région Himalayenne. Coleoptera, Caraboidea, Platyninae. Loened Aziad amprevaned feuraskelleged c'hwiledig 11: 1-59.

Morvan P. [D]. 2010. Mise au point sur les *Xestagonum*: nepalense, jannuense Jedlicka, keridwen Morvan. Etrectifications des synonymies des genres: *Deuveius, Batenoplatynus, Kalchtacha*. Loened Aziad amprevaned feuraskelleged c'hwiledig 13: 1-79.

Motschulsky V de. 1850. Die käfer Russlands. W. Gautier, Moscou. iv + xi + 91 pp.

Motschulsky V de. 1859. Entomologie spéciale. Insectes des Indes orientales, et de contrées analogues. 2de série. Études Entomologiques 8: 25-118.

Motschulsky V de. 1862. Entomologie spéciale. Insectes du Japon (Continuation). Études Entomologiques 10[1861]: 3-24.

Motschulsky V de. 1865. Énumération des nouvelles espèces de coléoptères rapportés de ses voyages. 4-ème article (suite). Bulletin de la Société Impériale des Naturalistes de Moscou 37[1864]: 297-355.

Muller J. (G.). 1926. Coleotteri della Venezia Giulia. Parte I. Adephaga. Studi entomologici Trieste I: 1-306.

Nietner J. 1858. Descriptions of new Ceylon Coleoptera. The Annals and Magazine of Natural History 2:175-183, 418-431.

Osculati G. 1844. Coleopterorum species novae quae in ista enumeratione commemoratae sunt disgnosibus atque observationibus illustrate. Note d'un viaggio nella Persia e nelle Indie orientali negli anni 1841-1842. Edizione fuori di commercio. L. Corbetta, Monza. 72 pp.

Panzer G W F. 1793. Faunae Insectorum Germanicae initia; oder Deutschlands insecten. [Heft 11]. Felsecker, Nürnberg. 24 pp.

Panzer G W F. 1796. Faunae Insectorum Germanicae Initia; oder Deutschlands insecten. [Heft 30.] Felsecker, Nürnberg. 24 pp.

Paykull G von. 1790. Monographia caraborum Sueciae. J.F. Edman, Upsaliae. 138 pp.

Péringuey L. 1896. Descriptive catalogue of the Coleoptera of South Africa. Part II. Cicindelidae supplement. Carabidae. The Transactions of the South African Philosophical Society 7: 99-623

Peyron E. 1856. Description de deux genres et de quatre espèces de coléoptères provenant d'Orient. Annales de la Société entomologique de France 3: 715-725.

Putzeys J A A H. 1873. Monographie des Calathides. Annales de la Société entomologique de Belgique 16: 19-96.

Putzeys J A A H. 1875. Notes sur les Carabiques recueillis par M. Jean van Volxem à Ceylan, à Manille, en Chine et au Japon (1873-1874). Annales de la Société entomologique de Belgique 18: 45-55.

Putzeys J A A H. 1877. Carabiques nouveaux du nord de l'Inde (Darjeling). Stettiner Entomologische Zeitung 38: 100-103.

Reichardt H. 1977. A synopsis of the genera of Neotropical Carabidae (Insecta, Coleoptera) Quaestiones Entomologicae 13: 346-493.

Reitter E. 1907. Übersicht der mir bekannten Arten des Coleopteren-Genus *Agonum* Bon. Wiener Entomologische Zeitung 26: 63-72.

Reitter E. 1908. Fauna Germanica. die käfer des Deutschen Reiches. I. Band. Schriften des Deutschen Lehrervereins für Naturkunde 22. K.G. Lutz, Stuttgart. 248 pp.

Rossi P. 1790. Fauna Etrusca sistens insecta quae in provinciis Florentina et Pisana praesertim collegit. Tomus primus. Thomae Masi & Sociorum, Liburni. 272 pp.

Ruiz C, Jordal B, Serrano J. 2009. Molecular phylogeny of the tribe Sphodrini (Coleoptera: Carabidae) based on mitochondrial and nuclear markers. Molecular Phylogenetics and Evolution 50: 44-58.

Sasakawa K, Kim JL, Kim J K., Kubota K. 2006. Descriptions of two new species of *Pristosia* (Coleoptera: Carabidae) from South Korea. Annals of the Entomological Society of America 99: 1006-1011.

Schaufuss L W. 1861. Die europäischen ungeflügelten Arten der Gattung *Sphodrus* Dej. Stettiner Entomologische Zeitung 22: 240-258.

Schaufuss L W. 1862. Diagnosen neuer *Sphodrus* und *Pristonychus* Arten. Sitzungsberichte und Abhandlungen der Naturwissenschaftlichen Gesellschaft Isis zu Dresden 1862: 66-67.

Schaufuss L W. 1865. Monographische bearbeitung der Sphodrini. Sitzungsberichte und Abhandlungen der Naturwissenschaftlichen Gesellschaft Isis zu Dresden 1865: 69-196.

Schaum H R. 1858. Naturgeschichte der insecten Deutschlands begonnen von Dr W F Erichson, fortgesetzt von Prof Dr H Schaum, Dr G Kraatz und H V Kiesenwetter. Erste abtheilung. Coleoptera. Erster Band. Nicolai, Berlin. pp. 353-552.

Schmidt J. 1998. Beschreibungen neuer arten der Carabidae aus Nepal (5): Gattungen *Trechus* Clairv., *Rupa* Jedl. und *Aparupa* Andr. (Insecta: Coleoptera). Reichenbachia 32: 197-208.

Schmidt J. 2000a. Ein vorschlag zur lösung nomenklatorischer probleme der Gattung *Platynus* Bonelli, 1810 (Coleoptera, Carabidae). Entomologische Blätter 96: 9-23.

Schmidt J. 2000b. Revision der Gruppe des *Colpodes lucens* Andrewes, 1947 (Coleoptera, Carabidae, Platynini). Coleoptera, Schwanfelder Coleopterologische Mitteilungen 4: 25-53.

Schmidt J. 2001. Die *Xestagonum*- Fauna des Emei Shan Gebirges (Sichuan) und beschreibungen der Gattungen *Dinocolpodes* gen. n. und *Chaetosaurus* gen. n. (Coleoptera, Carabidae, Platynini). Coleoptera, Schwanfelder Coleopterologische Mitteilungen 5: 13-40.

Schmidt J. 2003. Neue und interessante laufkäferarten der Gattung *Xestagonum* Habu, 1978 aus dem Himalaya (Insecta: Coleoptera: Carabidae). pp. 85-106. Biodiversität und naturausstattung im Himalaya. (Hartmann M, Baumbach H. (eds.). Verein der Freunde und Förderer des Naturkundemuseums Erfurt, Erfurt. 391 pp.

Schmidt J. 2008. Two new species of platynine carabid beetles from the Indian subcontinent, and remarks on synonymy and systematics of the genus *Orthotrichus* Peyron, 1856 (Coleoptera: Carabidae: Platynini). Annals of Carnegie Museum 77: 195-203.

Schmidt J. 2009a. Taxonomie und verbreitung von arten der Gattung *Lucicolpodes* Schmidt, 2000, stat. n. (Insecta: Coleoptera: Carabidae: Platynini), pp. 141-161. Biodiversität und naturausstattung im Himalaya III. (Hartmann M, Weipert J (eds.)). Verein der Freunde und Förderer des Naturkundemuseums Erfurt, Erfurt. 477 pp.

Schmidt J. 2009b. Diagnosen neuer und wenig bekannter arten der Gattung *Platynus* Bonelli, 1810 (Insecta: Coleoptera: Carabidae: Platynini). Vernate (Naturkundemuseum, Erfurt) 28: 197-224. (in German)

Schmidt J, Kabak I. 2016. Additions on synonymy and distribution of *Sericoda quadripunctata* ('de Geer', 1774) (Coleoptera: Carabidae: Platynini). Nachrichtenblatt der Bayerischen Entomologen 65: 31-34.

Schmidt J, Hartmann M. 2009. *Pristosia* Motschulsky, 1865 from the Nepal Himalaya: taxonomy and biogeography (Coleoptera: Carabidae: Sphodrini). Zootaxa 2009: 1-26.

Schmidt-Göbel H M. 1846. Faunula Coleopterorum Birmaniae, Adjectis Nonnulis Bengaliae Indigenis. Gottlieb Hasse Söhne, Prague. 94 pp.

Seidlitz G K M von. 1887. Fauna Baltica. Die kaefer (Coleoptera) der deutschen Ostseeprovinzen Russlands. Zweite neu bearbeitete Auflage. Hartung, Königsberg. 96 pp.

Serrano A R M, Capela R A, Santos C V N. 2017. Biodiversity and notes on carabid beetles from Angola with description of new taxa (Coleoptera: Carabidae). Zootaxa 4353: 201-256.

Sloane T G. 1903. Studies in Australian Entomology, New Carabidae (Panagaeini, Bembidiini, Pogonini, Platysmatini, Platynini, Lebiini, with revisional lists of genera and species notes on synonymy, etc.). Proceedings of the Linnean Society of New South Wales 28: 566-642.

Sloane T G. 1910. Revisional notes on Australian Carabidae. The Proceedings of the Linnean Society of New South Wales 35: 435-458.

Sloane T G. 1920. A list of the species of Australian Carabidae which range beyond Australia and its dependent Islands). Proc eedings of the Linnean Society of New South Wales, 45: 320-323.

Stork N. 1986. An annotated checklist of the Carabidae (including Cicindelinae, Rhysodinae and Paussinae) recorded from Borneo. Occasional Papers on Systematic Entomology 2: 1-24.

Sturm J. 1824. Käfer. Die Insecten. Deutschlands fauna in abbildungen nach der natur mit beschreibungen. V Abteilung, J Sturm, Nürnberg. 220 pp.

Tanaka K. 1960. On the genus *Sericoda* from Japan. Kontyû 28: 90-96.

Terada K, Yeh L W, Wu W J. 2016. Notes on Taiwanese Caraboidea (Coleoptera) VI. Redescriptions of three species of the genus *Colpodes* MacLeay (Carabidae: Platynini). Collection and Research 29: 1-18.

Walker F. 1858. Characters of some apparently undescribed Ceylon insects. The Annals and Magazine of Natural History 2: 202-209.

Wiedemann C R W. 1823. Zweihundert neue Käfer von Java, Bengalen und dem Vorgebirge der guten Hoffnung. Zoologisches Magazin 2: 1-135, 162-164.

Zhu P, Kavanaugh D H, Liang H. 2021. Notes on the genus *Xestopus* from China, with description of a new species (Carabidae, Sphodrini, Dolichina). ZooKeys 1009: 139-151.

(Manuscript Received: July, 2021; Revised: August, 2021;
Accepted: September, 2021; Online Published: September, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21199

Indian Journal of Entomology 84(1): 213-222 (2022) DoI.: 10.55446/IJE.2021.117

MYCOPHAGOUS PHLAEOTHRIPIDAE (THYSANOPTERA: TUBULIFERA) IN THE INDIAN SUBCONTINENT#

R Varatharajan

Department of Zoology, Centre of Advanced Study in Life Sciences
Manipur University, Imphal 795003, Manipur, India
Email: rvrajanramya@gmail.com

ABSTRACT

Mycophagous Phlaeothripidae (Thysanoptera: Tubulifera:) are recognizable as (a) fungal-hyphae-feeding mycetophagous Phlaeothripinae, living on fungi that infest dry twigs and (b) fungal-spore-feeding sporophagous Idolothripinae, usually present on leaf litter. In the Indian subcontinent, out of 765 species of known Thysanoptera, nearly 152 species in 66 genera fall within the mycophagous group of the Phlaeothripidae with 54 idolothripine and 98 phlaeothripine species. Taxonomic diversity of these species in bamboo- and oak-leaf litter and pine forests in the sub-Himalayan ecosystems of North-Eastern India are discussed in this article, along with the diversity that is apparent in their developmental patterns, thrips-plant-fungus association, and phenotypic plasticity, supplemented with a note on their ecological implications.

Key words: Phlaeothripidae, bamboo, pine, plant fungus, association, development, ecological implications, fungal spores and mycelia, taxonomic diversity, leaf litter, phenotypic plasticity, oak leaf litter

Thrips (Thysanoptera) are relatively small insects with asymmetrical mouthparts bearing fringed wings and protractible, adhesive pre-tarsal bladders. The term *thrips* denotes both singular and plural forms, meaning 'woodworm' in ancient Greek, besides other commonly used terms, such as the thunderflies, storm flies, thunderblights, storm bugs, thunderbugs, corn fleas, corn flies, corn lice, freckle bugs, harvest bugs and physopods (Kirk, 1996; Marren and Mabey, 2010; Kobro, 2011). Most of them feed on plant sap (e.g., *Ananthakrishnana euphorbiae* (Priesner), and some of them on floral nectar and pollen (e.g., *Dichromothrips nakahari* Mound, Thripidae), fungal spores (e.g., *Holurothrips manipurensis* Varatharajan and Chochong) and mycelia (e.g., *Adraneothrips okajimai* (Muraleedharan and Sen)), further to a few species being predatory (e.g., *Androthrips ramachandrai* Karny (all Phlaeothripidae except *D. nakahari*) feeding on other smaller soft-bodied insects and mites. Feeding niches of the Phaleothripidae vary highly, most feed on plants, and many others feed on pollen, fungal filaments and spores, and some of them feed on other arthropods. Thysanoptera comprises two suborders, the Terebrantia and Tubulifera, of which the body length of those belonging to Terebrantia are always <1 mm, while those of the Tubulifera can be from 1.1 to 15 mm, such as the spore-feeding taxa of the Phlaeothripidae, viz., *Bactrothrips* Karny, *Elaphrothrips* Buffa, *Mecynothrips* Bagnall, *Meiothrips* Priesner, *Oidanothrips* Moulton, and *Tiarothrips* Priesner (Ananthakrishnan, 1973; Eow et al. 2011; Mound and Tree, 2011) with the exception of the smallest leaf-litter inhabiting *Preeriella* Hood (Phlaeothripinae) being <1 mm (Okajima, 1998). Although considerable volume of information on fungus-feeding Thysanoptera has been documented, the present article refers to the diversity and dynamics of mycophagous Phlaeothripidae of the Indian subcontinent, drawing examples from the North-Eastern Himalayan parts of India.

A. Diversity of the mycophagous Thysanoptera

ThripsWiki (2021) lists 6312 extant taxa under 785 genera and 175 extinct taxa under 65 genera (Mound and Vesmanis, 2021), of which a little >50% utilize fungi as their source of food (Morse and Hoddle, 2006; Mound, 2005). Among the mycophagous Thysanoptera, >700 spore-feeding idolothripines are known worldwide (Eow et al., 2011). In the Neotropics, mycophagous Thysanoptera occupy 50% of the total numbers of thrips known (Mound, 2002). The Uzelothripidae, Merothripidae, and Idolothripinae are primarily fungal-spore feeders, whereas half of the world's known Phlaeothripidae are mycelial feeders. In the Indian subcontinent out of 765 known taxa (Tyagi and Kumar, 2016; Rachana and Varatharajan, 2017), 152 are mycophagous including 54 species of spore-

#Invited Review: Courtesy Review Editor– Dr. A. Anantanaryanan Raman, CSIRO, Australia.

feeding idolothripines and 98 species of mycetophagous phlaeothripines (Table 1, 2). On extrapolating this statistic, we can assume that close to 1400 species of mycetophagous Thysanoptera occur in the world, since *c*. 700 Idolothripinae are known (Mound et al., 2013). Although the Paraneoptera (Thysanoptera) has been categorized into 15 families including that of the fossil-spore feeding Uzelothripidae (Mound, 2013), members of Phaleothripidae include *c*. 3500 species (ThripsWiki, 2021), of which approximately 2100 belong to fungus-feeding *Phlaeothrips* lineage (Dang et al., 2014).

In oak-leaf litter

The Sub-Himalayan region stretching from Jammu and Kashmir to Manipur (24º-34ºN, 93º-95ºE) is the *Quercus* (Fagaceae)-belt of the Indian subcontinent (Negi and Naithani, 1995). *Quercus*-leaf litter harbours at least 14 species of mycophagous Phlaeothripidae, of which five are idolothripines and the remainder are phlaeothripines, which dominate both in density and taxonomic diversity (Chochong and Varatharajan, 2004). The species composition and mean percentage of their occurrence in Chochong and Varatharajan's (2004) study indicates the following sequence: *Urothrips tarai* (Stannard) - 20%, *Apelaunothrips madrasensis* (Ananthakrishnan) - 18%, *Adraneothrips okajimai* (Muraleedharan and Sen) - 12%, *Apelaunothrips consimilis* (Ananthakrishnan) and *Mecynothrips simplex* Bagnall - 10% each, *Elaphrothrips spiniceps* Bagnall, *Xylaplothrips debilis* Ananthakrishnan and Jagadish, and *Holurothrips manipurensis* Varatharajan and Chochong - 5% each, *Meiothrips menoni* Ananthakrishnan, *Bradythrips hesperus* Hood and Williams, and *Tylothrips indicus* Sen and Muraleedharan - 3% each, *Adraneothrips disjunctus* Ananthakrishnan, *Preeriella formosana* Okajima, and *Bactrothrips idolomorphus* Karny - 2% each (all Phlaeothripidae). Although the above information pertains to the *Quercus* forests of Manipur (24°44'N, 93°58'E), *U. tarai* (Phlaeothripidae) was first collected and described by Lewis Judson Stannard of the University of Illinois-Champaign, Illinois, in 1970, from the *Quercus* regions of the Tarai (29º22'N, 79º27'E). But the distribution of *U. tarai* from 24°44'N, 93°58'E to 28°2'N, 96°E of the north-eastern region of India confirms their occurrence throughout the *Quercus* belt of the Sub-Himalayan region. Similarly, species such as *T. indicus* and *H. manipurensis* are known only from Manipur, but the remaining 10 mycophagous Phlaeothripidae known earlier from the biodiversity-rich Western Ghats (Ananthakrishnan, 1973) are presently known to be occurring in north-eastern India as well. Further, the minute leaf-litter inhabiting *P. formosana* (~950 μm) is a new record for India, which was previously known only from Taiwan (23°41'N, 120°57E) (http://anic.ento.csiro.au/thrips/resources/ Taiwan.htm). The presence of these 14 species especially in the *Quercus* belt reiterates that the thrips composition in the north-eastern India is a 'mixed bag' with species known previously from the Western Ghats, some from the Sub-Himalayan region, and some from the Indo-Myanmar bioregion (Varatharajan et al., 2010).

In bamboo forests

Nearly 125 native and 11 exotic species of bamboos (Poaceae) belonging to 23 genera are known from India, of which more than 50% occur in north-eastern India (fsi.nic.in/isfr2017/isfr-bambooresource). The overall bamboo-growing area in the Indian subcontinent has been estimated at *c*. 9.6 m ha. Thysanoptera are key inhabitants of bamboo litter (Ananthakrishnan, 1973; Varatharajan, 2005). The litter-inhabiting Thysanoptera of the Western Ghats and north-eastern India include five species of idolothripines and 10 of phlaeothripines. The species recorded thus far include *Acallurothrips amplus* (Faure), *Allothrips bicolor* Ananthakrishnan, *A. montanus* Ananthakrishnan, *Elaphrothrips curvipes* Priesner and *Nesothrips brevicollis* (Bagnall) (all Idolothripinae). On the other hand, members of the Phlaeothripinae include species such as *Ablemothrips maxillatus* Ananthakrishnan, *Adraneothrips bambusae* (Ananthakrishnan), *A. limpidus* Ananthakrishnan, *Apelaunothrips madrasensis* (Ananthakrishnan), *Karnyothrips melaleucus* (Bagnall), *Margaritothrips flavus* Bhatti, *M. sumatrensis* Priesner, *Mystrothrips dammermani* (Priesner), *Ocythrips rarus* Ananthakrishnan, and *Stephanothrips occidentalis* Hood and Williams (Ananthakrishnan and Sen, 1980; Sen et al. 1988; Varatharajan, 2005).

In pine forests

A dozen mycophagous Phlaeothripidae occurs in association with the dry needle litter of *Pinus kesiya* Royle ex Gordon (Pinales: Pinaceae), of which *Apelaunothrips consimilis* (Ananthakrishnan), *Ecacanthothrips tibialis* (Ashmead), *Karnyothrips melaleucus* (Bagnall), *Hoplandrothrips corticis* Ananthakrishnan,, *Hoplothrips fungosus* Moulton, *Hoplothrips orientalis* (Ananthakrishnan), *Macrophthalmothrips splendidus* Ananthakrishnan, *Streptothrips orientalis* (Ananthakrishnan) (Phlaeothripinae) are more dominant than the spore-feeding thrips such as *Ethirothrips longisetis* (Ananthakrishnan and Jagdish), *Holothrips minor*

Table 1. List of Idolothripinae recorded in India

1. *Acallurothrips amplus* (Faure)	16. *Ethirothrips anacardii* (Ananth.)	30. *Elaphrothrips notabilis* Ananthakrishnan	43. *Meiothrips menoni* Ananthakrishnan
2. Aesthesiothrips jatrophae Ananthakrishnan	17. *Ethirothrips beesoni* (Moulton)	31. *Elaphrothrips procer* (Schmutz)	44. *Meiothrips nepalensis* Kudo & Ananthakrishnan
3. *Allothrips bicolour* Ananthakrishnan	18. *Ethirothrips brevisetosus* (Ananthakrishnan & Jagadish)	32. *Elaphrothrips spiniceps* Bagnall.	45. *Neosmerinthothrips fructuum* Schmutz
4. *Allothrips indicus* Ananthakrishnan	19. *Ethirothrips brevis* (Bagnall)	33. *Gastrothrips acuticornis* (Hood)	46. *Neosmerinthothrips inquilinus* Ananthakrishnan
5. *Allothrips montanus* Ananthakrishnan	20. *Ethirothrips indicus* (Bagnall)	34. *Gastrothrips falcatus* (Ananthakrishnan)	47. *Neosmerinthothrips robustus* (Ananthakrishnan)
6. *Allothrips watsoni* Hood	21. *Ethirothrips longisetis* (Ananthakrishnan & Jagadish)	35. *Gastrothrips turbinatus* (Ananthakrishnan)	48. *Nesidiothrips alius* (Ananthakrishnan)
7. *Bactrothrips idolomorphus* (Karny).	22. *Ethirothrips obscurus* (Schmutz)	36. *Holurothrips manipurensis* Varatharajan & Chochong	49. *Nesothrips brevicollis* (Bagnall)
8. *Bactrothrips luteus* Ananthakrishnan	23. *Ethirothrips uredinis* (Ananthakrishnan & Jagadish)	37. *Ischyrothrips crassus* Schmutz	50. *Nesothrips lativentris* (Karny)
9. *Compsothrips congoensis* (Hood).	24. *Ethirothrips vitreipennis* (Priesner)	38. *Loyolaia indica* Ananthakrishnan	51. *Ophthalmothrips breviceps* (Bagnall)
10. *Compsothrips ramamurthii* (Ananthakrishnan)	25. *Ethirothrips tirumalaiensis* (Ananthakrishnan)	39. *Machatothrips corticosus* Ananthakrishnan	52. *Ophthalmothrips faurei* (Ananthakrishnan)
11. *Diaphorothrips unguipes* Karny	26. *Elaphrothrips curvipes* Priesner	40. *Machatothrips indicus* Ananthakrishnan and Jagadish	53. *Priesneriana kabandha* (Ramakrishna)
12. *Dinothrips juglandis* Moulton	27. *Elaphrothrips denticollis* (Bagnall)	41. *Machatothrips silvaticus* Ananthakrishnan	54. *Tiarothrips subramanii* (Ramakrishna)
13. *Dinothrips longicauda* (Ananthakrishnan)	28. *Elaphrothrips greeni* (Bagnall)	42. *Mecynothrips simplex* Bagnall	
14. *Dinothrips spinosus* (Schmutz)	29. *Elaphrothrips insignis* Ananthakrishnan		
15. *Dinothrips sumatrensis* Bagnall			

(Hood), *Machatothrips indicus* Ananthakrishnan, and *Mecynothrips simplex* Bagnall (Idolothripinae). Among these, the bark-dwelling *Hoplandrothrips corticis* were apparently restricted to dry fallen bark pieces of *P. kesiya* that grow above 1500 masl, whereas the other species such as *H. fungosus* and *H. orientalis* inhabit the dry, fungus-infested needle litter. The density and diversity of Thysanoptera collected from the needle litter of *P. kesiya* was lesser than the other plantation sectors such as bamboo and oak (Table 3).

B. Thrips-plant-fungus association

Mycophagous Thysanoptera feed on fungal spores and hyphae and use dry leaves and twigs for egg laying and colony establishment. The mycophagous Phlaeothripidae mostly show a pattern in their colonization behaviour and feeding on fungal spores. For instance, the spore feeder *Tiarothrips subramanii* (Idolothripinae) occurs closely associated with three species of *Anthostomella* (Ascomycota: Xylariales: Xylariaceae), that usually grows on dry fronds of *Borassus flabellifer* L. (Arecaceae). Similarly, *Mecynothrips hardyi* (Phlaeothripidae) feeds on the spores of *Dothiorella thripsita* Shivas and Tree (Ascomycota: Botryosphaeriales: Botryosphaeriaceae) (Shivas et al., 2009). Species of *Pestalotia* (47.44%) (Ascomycota: Xylariales: Amphisphaeriaceae) have been found in the dissected gut of *B. idolomorphus* indicate the preference between *B. idolomorphus* and the species of *Pestalotia*. Further, *B. idolomorphus* also appear to prefer spores of the Coelomycetes, Ascomycetes, and Hyphomycetes, but not those of the Basidomycetes (Ananthakrishnan and Dhileepan, 1984). Such a pattern is evident in sporo- and mycetophagous species (Table 4), based on field observations and laboratory evaluation of spores of the gut contents.

Table 2. List of fungal-hyphae feeding Phlaeothripinae in India

1. Ablemothrips *maxillatus* Ananthakrishnan
2. *Adraneothrips bambusae* (Ananthakrishnan)
3. *Adraneothrips disjunctus* Ananthakrishnan
4. *Adraneothrips elegans* Ananthakrishnan
5. *Adraneothrips infirmus* (Ananthakrishnan)
6. *Adraneothrips limpidus* (Ananthakrishnan)
7. *Adraneothrips madrasensis*Ananthakrishnan
8. *Adraneothrips nilgiriensis* (Ananthakrishnan)
9. *Adraneothrips okajimai* (Muraleedharan & Sen)
10. *Adraneothrips pteris* (Ananthakrishnan)
11. *Adraneothrips stannardi* Ananthakrishnan
12. *Apelaunothrips bhowalii* (Ananthakrishnan)
13. *Apelaunothrips consimilis* (Ananthakrishnan)
14. *Apelaunothrips indicus* (Ananthakrishnan)
15. *Apelaunothrips lucidus* (Ananthakrishnan)
16. *Apelaunothrips madrasensis* (Ananthakrishnan)
17. *Apterygothrips fungosus* (Ananthakrishnan & Jagadish)*
18. *Apterygothrips jogensis* (Ananthakrishnan& Jagadish)*
19. *Apterygothrips rubiginosus* (Ananthakrishnan & Jagadish)*
20. *Azaleothrips amabilis* Ananthakrishnan
21. *Azaleothrips aspersus* Bhatti
22. *Azaleothrips bhattii* Vijay Veer & Chauhan
23. *Azaleothrips lineus* Bhatti
24. *Baenothrips asper* (Bournier)
25. *Baenothrips indicus* (Ananthakrishnan)
26. *Baenothrips minutus* (Ananthakrishnan)
27. *Bradythrips hesperus* Hood & Williams
28. *Bunothrips cruralis* Ananthakrishnan.
29. *Ecacanthothrips tibialis* (Ashmead)
30. *Glubothrips mucidus* Ananthakrishnan
31. *Habrothrips curiosus* Ananthakrishnan
32. *Holothrips andamanensis* (Sen)
33. *Holothrips ananthakrishnani* Okajima
34. *Holothrips cracens* (Ananthakrishnan)
35. *Holothrips fumidus* (Ananthakrishnan)
36. *Holothrips indicus* (Ananthakrishnan)
37. *Holothrips minor* (Hood)
38. *Holothrips mirandus (*Ananthakrishnan)
39. *Holothrips nepalensis* (Pelikán)
40. *Holothrips quadrisetis* Okajima
41. *Holothrips ruidus* (Ananthakrishnan)
42. *Holothrips stannardi* (Ananthakrishnan)
43. *Holothrips subtilis* (Ananthakrishnan)
44. *Holothrips typicus* (Ananthakrishnan)
45. *Hoplandrothrips corticis* Ananthakrishnan
46. *Hoplandrothrips flavipes* Bagnall
47. *Hoplandrothrips kudoi* Muraleedharan
48. *Hoplandrothrips nobilis* Priesner
49. *Hoplothrips dubius* (Bagnall)
50. *Hoplothrips fungosus* Moulton
51. *Hoplothrips nemorius* Ananthakrishnan
52. *Hoplothrips orientalis* (Ananthakrishnan)
53. *Hoplothrips transvaalensis* (Hood)
54. *Idiothrips bellus* Faure
55. *Karnyothrips melaleucus* (Bagnall)*
56. *Karnyothrips mucidus* (Ananthakrishnan & Jagadish)*
57. *Macrophthalmothrips splendidus* Ananthakrishnan
58. *Malacothrips natalensis* (Trybom)
59. *Margaritothrips flavus* Bhatti
60. *Margaritothrips longus* Bhatti
61. *Margaritothrips sumatrensis* Priesner
62. *Mesandrothrips emineus* (Ananthakrishnan & Jagdish)**
63. *Mesandrothrips pictipes* (Bagnall)**
64. *Mesandrothrips pusillus* (Ananthakrishnan & Jagdish)**
65. *Mesandrothrips tener* (Ananthakrishnan & Jagdish)**
66. *Mystrothrips dammermani* (Priesner)
67. *Neothrips lepidus* Ananthakrishnan
68. *Ocythrips rarus* Ananthakrishnan
69. *Oidanothrips enormis* (Ananthakrishnan)
70. *Oidanothrips megacephalus* (Ananthakrishnan)
71. *Opidnothrips corticulus* Ananthakrishnan
72. *Phiarothrips reperticus* Ananthakrishnan
73. *Phlaeothrips nilgiricus* Ananthakrishnan
74. *Phylladothrips karnyi* Priesner
75. *Plectrothrips corticinus* Priesner
76. *Plectrothrips eximius* Ananthakrishnan
77. *Plectrothrips pallipes* Hood
78. *Preeriella formosana* Okajima
79. *Priesneria insolitus* (Ananthakrishnan)
80. *Psalidothrips ascitus* (Ananthakrishnan)
81. *Pygmaeothrips angusticeps* (Hood)
82. *Socothrips verrucosus* Ananthakrishnan
83. *Sophiothrips nigrus* Ananthakrishnan
84. *Sophiothrips typicus* (Ananthakrishnan)
85. *Stannardothrips longirostris* Ananthakrishnan
86. *Stephanothrips adnatus* Ananthakrishnan
87. *Stephanothrips occidentalis* Hood & Williams
88. *Strepterothrips orientalis* Ananthakrishnan
89. *Symphyothrips aberrans* Ananthakrishnan
90. *Tamilthrips pini* (Ananthakrishnan)*
91. *Trichinothrips breviceps* (Bagnall)
92. *Tylothrips indicus* Sen & Muraleedharan
93. *Tylothrips samirseni* Varatharajan, Singh & Bala
94. *Urothrips tarai* (Stannard)
95. *Veerabahuthrips bambusae* Ramakrishna
96. *Xylaplothrips debilis* Ananthakrishnan & Jagadish*
97. *Xylaplothrips ligs* Ananthakrishnan & Jagdish*
98. *Xylaplothrips micans* Ananthakrishnan & Jagdish*

*Species under Haplothripini and the rest come under *Phlaeothrips* lineage; ** *Mesandrothrips* (=*Xylaplothrips*)

Table 3. Thrips diversity and density in the leaf litters of natural and human-made forests of Manipur (24°44'N, 93°58'E)

Plantation type with altitude	Number of thrips species collected			Mean No.*
	Idolo-thripinae	Phlaeo-thripinae	Total	
Pine forest (1500-2100 m)	4	8	12	9.3[a]
Bamboo forest (900 - 1600 m)	5	10	15	17.4[b]
Oak forest (900-1300 m)	5	9	14	27.0[c]
Polyculture forest (900-1800 m)	12	30	42	33.0[d]
CD at p=0.01=4.6				

Each value mean of seven replications*; Alphabets followed by each figure in the last vertical column different from each other at 1% level (ANOVA p=0.01); *No. collected using Tullgren funnel method

But, in Nature, a chance of more than one fungal taxon co-occurring at the same feeding site is highly likely. If this were proved right, then the spore-feeding thrips show no specificity to any particular fungal taxon.

Morphotaxonomy distinguishes members of the Phlaeothripidae into spore-feeding Idolothripinae and the fungal-hyphae-feeding Phlaeothripinae, based on the width of maxillary stylets: 2-3 μm in the fungal-hypha feeders and 5-10 μm in spore feeders (Mound and Palmer, 1983). This classification gains in validity by the correlation of the width of maxillary stylets of *Mecynothrips hardyi* (Priesner) (Phlaeothripidae) and fungal spore size of *Dothiorella thripsita* (Ascomycota: Botryosphaeriales: Botryosphariaceae). For example, the mean width of the maxillary stylet of *M. hardyi* (body length - 15 mm) is 13.9± 0.2 μm and the mean width of the ingested spore of *D. thripsita* is 10.9± 0.3 μm. This observation along with the spores extracted from the gut confirmed the spore feeding habit of *M. hardyi* (Tree et al., 2010; Eow et al., 2011). This example serves well to illustrate mycophagous habit of the other Idolothripinae.

The mutualistic relations between insects and fungi in terms of dispersal, nutrition, mechanical protection and antimicrobial defence has been elaborately explained (Bidermann and Vega, 2019). Considering that in the context of Phlaeothripidae and fungi, the mutualism between them can be described in terms of dispersal and nutrition of the involved thrips. Nearly 2100 species of the Phlaeothripidae feed on fungal hyphae and spores (Dang et al., 2014; Eow et al., 2011). Some evidences also exist to indicate that the Thysanoptera act as mechanical vectors and disseminate fungal spores on plants (Ananthakrishnan, 1980; 1993). Mechanical dispersal of fungal spores is a strong possibility because of their numerous body setae that facilitate the attachment of fungal spores to their body surfaces similar to that of pollen grains transmitted mechanically

Table 4. Thrips, plants and fungi

Thrips (Tubulifera: Idolothripinae)	Plant	Fungus
Loyolaia indica (Ananthakrishnan)	Dry leaves and leaf sheaths of *Cynodon dactylon* (L.) Pers. (Poaceae)	*Lojkania cynodontifolii*[++] (Fenestellaceae)
Tiarothrips subramanii (Ramakrishna)	Dry leaves of *Borassus flabellifer* L. (Arecaceae)	*Anthostomella consanguinea, A. phoenicicola, A. sepelibili*[++] (Xylariaceae)
Mecynothrips simplex Bagnall	Dry leaves of *Areca catechu* L. (Arecaceae)	*Pestalotia* sp.[++] (Amphisphaeriaceae)
Mecynothrips hardyi (Priesner)	*Acacia harpophylla* F. Muell. ex Benth. (Fabaceae)	*Dothiorella thripsita*** (Botryosphaeriaceae).
Priesneriana kabandha (Ramakrishna)	*Eucalyptus globulus* Labill. (Myrtaceae)	*Rhytidhysterium rufula** (Patellariaceae) and *Cytospora** (Phyllostictaceae)
Elaphrothrips denticollis (Bagnall)	*Tectona grandis* L. f. (Lamiaceae)	*Pestalotia* sp.* (Amphisphaeriaceae) *Phomopsis tectonae* (Diaporthaceae)
Nesothrips indicus Ananthakrishnan	Decaying scape of *Agave americana* L. (Asparagaceae)	*Anthostomella sphaeroidea** (Xylariaceae)
Dinothrips sumatrensis Bagnall	Dry bark of *Piper nigrum* L. (Piperaceae)	*Lasiodiplodia theobromae** (Botryosphaericeae)

Source: [++]Ananthakrishnan and James, 1983; **Tree et al. (2010) *Ananthakrishnan et al. (1984)

by certain species of the Thysanoptera, such as *Thrips hawaiiensis* (Morgan), *Frankliniella schultzei* (Trybom), and *Microcephalothrips abdominalis* (Crawford) (Thripidae) (Varatharajan et al., 2016).

C. Developmental pattern

A comparison of breeding behaviours and developmental durations of different life stages of five species each of the mycetophagous and sporophagous thrips is available (Ananthakrishnan et al., 1984) (Table 5). The duration of development from egg to adult for the above 10 species was between 15 and 28 d, but the type of reproduction varied between the mycetophagous and sporophagous thrips (Ananthakrishnan et al., 1983; 1984). For instance, the mycetophagous Phlaeothripinae were oviparous and oviposited in greater numbers during moist months (July-December) when fresh fungi were abundantly available, whereas the sporophagous Idolothripinae reproduced by either oviparous or ovoviviparous or viviparous mode influenced by fungal density and environmental factors such as temperature, rainfall, and humidity. Field observations of the idolothripines such as *T. subramanii* and *B. idolomorphus* indicated viviparous mode of reproduction especially when the fungal density was less due to seasonal dryness. This has been confirmed by rearing *B. idolomorphus* at 30ºC and 80% RH, wherein they reproduced either ovoviparously or viviparously (Ananthakrishnan and Dhileepan, 1984). In *Ethirothrips,* another idolothripine, Ananthakrishnan et al. (1984) have observed that among the females of a natural population inhabiting the dry, fungus-infested leaves of a species of *Zizyphus* (Rhamnaceae), oviparous females formed 60% of that population, followed by viviparous and ovoviparous females, 20% each. Similar to *B. idolomorphus*, *Bactrothrips* (= *Caudothrips*) *buffai* (Karny) (Idolothrpinae) also reproduces ovoviviparously (Bournier, 1957). This behaviour has been interpreted as an adaptation wherein few larvae and eggs are laid in different batches possibly to make use of available fungal material for the development of the juveniles (Bournier, 1957; 1966). But a comparison between oviparous and viviparous females in terms of eggs-larvae output revealed that the fecundity was less during the viviparous phase (7-11 larvae/ female) compared with the oviparous phase (25-33 eggs/ female) of *T. subramanii*. Whatever is the type of reproduction, from the perspective of their breeding behaviour, the mycophagous Phlaeothripidae inhabit fungus-rich parts of the litter and lay eggs in such a way that the fungal spores are accessible to the emergent larvae. In species such as *T. subramanii*, both adult males and females exhibit parental care by guarding rows of eggs until hatching (Ananthakrishnan et al., 1983; Ananthakrishnan and Suresh, 1983).

Table 5. Mycophagous Phlaeothripidae

Mycetophagous (Phlaeothripinae)	Sporophagous (Idolothripinae)
Adraneothrips limpidus Ananthakrishnan	*Bactrothrips idolomorphus* (Karny)
Azaleothrips amabilis Ananthakrishnan	*Elaphrothrips denticollis* (Bagnall)
Ecacanthothrips tibialis (Ashmead)	*Elaphrothrips procer* (Schmutz)
Holothrips cracens (Ananthakrishnan)	*Meiothrips menoni* Ananthakrishnan
Hoplandrothrips flavipes Bagnall	*Tiarothrips subramanii* (Ramakrishna)

Populations of mycophagous Phlaeothripidae are regulated by the richness of fungi. The density of litter-inhabiting Phlaeothripidae is a useful, although indirect, measure to estimate fungal density: i.e., larger the thrips colony, greater is the diversity and density of the fungal flora, and the vice versa (Mound, 1974; 1977). In the mycophagous Phlaeithripidae, more apterous individuals than alates occur in the first 4-5 wk. With the dwindling of the availability of fungal spores, the situation reverses with more of alates, as shown in *Priesneriana kabandha* (Ramakrishna) (Idolothripinae) feeding on the spores of a species of *Cytospora* (Ascomycota: Sordariomycetes: Valsaceae). Thus, the abundance and depletion of fungal spores not only reveal the high and less abundance of the Phlaeothripidae, but also reflect the proportions of apterous and alate individuals within a colony (Ananthakrishnan et al., 1983). Between the two extremes, brachypterous individuals occur in many bark-dwelling Phlaeothrpidae. Brachypterae (apterous) arise when the fresh fungi are available, whereas the macropterae (alates) occur more in numbers when fungal density declines (Hood, 1940; Bournier, 1961). Influence of food in alary polymorphism can be understood with *Hoplothrips fungi* Zetterstedt (Phlaeothripidae) feeding on a species of *Stereum* (Agaricomycetes: Russulales: Stereaceae) on dead wood. Apterous individuals were abundant as long as *Stereum* populations were high and when *Stereum* was replaced by a species of *Mucor* (Mucoromycota: Mucorales: Mucoraceae), a large number of winged males and females of *Hoplothrips fungi* arose (Mound, 2005). This example highlights not only the significance of fungi as food in the production and maintenance of apterous individuals, but indirectly highlights the specificity of *H. fungi* to a species of *Stereum*.

Although alary polymorphism occurs among the mycophagous Phlaeothripidae (Figs. 1a, b), the development of apterous individuals seems to be an adaptation in the leaf-litter habitat for the following reasons:

(a) Abundance of fungi enables the Phaleothripidae to feed and breed. For instance, *Loyolaia indica* consumes 47,600 spores of *Fusarium oxysporum* f. sp. *cubense* Smith, Snyder and Hansen (Sordariomycetes: Hypocreales: Nectriaceae) per adult and lays 4-6 eggs/ female on clumps of *Cynodon dactylon* Pers. (Poaceae). The total development time is 13-18 d when reared at 30± 2ºC and 72% RH (Ananthakrishnan et al., 1984).

(b) In the fungus-feeding *Suocerathrips linguis* Mound and Marullo (1994) in Germany, occurrence of either partial or completely de-alate adult females was common in the colony and the process of wing shedding occurred immediately after mating (Moritz, 2002; Mound, 2005). This feature was explained as *S. linguis*'s commitment to establish the colony and parental care.

(c) The mycophagous Phlaeothripidae utilize the conducive semi-permanent niche endowed with abundant fungi to their advantage and produce more apterous adults as in *H. fungi* on the fungus-infested dead wood (Mound, 2005).

(d) The juvenile hormone (JH) titre will be higher in apterous insects than the alates in general (Roff, 1991). Higher JH titre would mean that the duration on insect development will be longer in apterous than alates. For example, the total duration of development in *Loyolaia indica* was reported to be 13-18 d when reared at 30± 2ºC and 72% RH, but the study did not mention it for alate or apterus individuals (Ananthakrishnan et al., 1984). Although the bioassay on thrips's hormone levels has not been attempted so far, considering the role of JH, it is presumed that the extended duration of 5 d of development may refer to the duration of apterous and the short duration of 13 d may reflect the developmental period of winged individuals, since all the rearing conditions stated above were the same.

(e) Periodical collection and enumeration of field populations of litter-inhabiting thrips also reflected the presence of alates, apterous, normal males and females, besides large and small males reflecting morphological variation (Ananthakrishnan, 1969; 1979; Mound and Palmer, 1983; Tree et al., 2010). As a result, in a colony, it is possible to observe

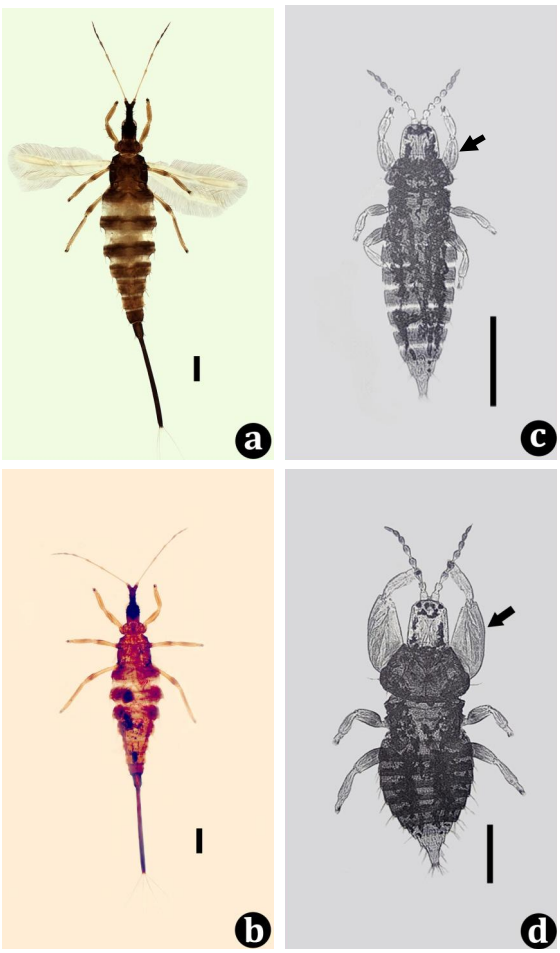


Fig. 1. a, b: Alate and Apterous *Holurothrips manipurensis*; c, d: small and large individuals of *Hoplothrips fungosus* (Scale bar = 500 μm). Arrows indicate size variation of fore-femora. (Source: c, d. Ananthakrishnan, 1973).

a small proportion of large and small males, in addition to dominant population of normal-size males and females of the same species. Size variation among them is distinct as in *T. subramanii*, in which the length of third antennal segment of the small, normal, and large individuals of *T. subramanii* were 80, 160 and 240 μm, respectively (Ananthakrishnan, 1973; 1979). Similar variations on the size of forefemora of *H. fungosus* (Fig. 1c and 1d) (Ananthakrishnan, 1973), two fold long preocular projection on the heads of large males of *T. subramanii*, three-fold increased width of the fore-femora of large males of *E. tibialis* (Ananthakrishnan, 2005) and thorn-like cheek setae of large males of *Mecynothrips kraussi* Palmer and Mound, (Mound, 2005) are a few notable examples of intraspecific variation in comparison with the respective species of their smaller males. Based on the available data pertaining to representative

examples of mycophagous Thysanoptera mentioned here, a general pattern of their development has been reconstructed (Fig. 2).

D. Phenotypic plasticity

Phenotypic plasticity is a kind of intraspecific variation among individuals belonging to same species, in which, some members of a population exhibit considerable morphological variations (Ananthakrishnan, 2005). Such a plasticity is common among the mycophagous Phlaeothripidae. As of the present, only observational evidences exist in support of the prevalence of phenotypic plasticity among the Thysanoptera, and experimental verifications are necessary to strengthen the phenotypic-plasticity theory (Mound, 2005). The literature abounds with many observational reports that many species of mycophagous Phlaeothripidae exhibit wide-ranging morphological traits, such as alary polymorphism, sexual dimorphism, and intra-specific variation of body organs. Ananthakrishnan (1979; 1984; 2005) and Mound (2005) have elaborately discussed this aspect based on morpho-taxonomy. The following remarks highlight some of the prominent features noticed among selected mycophagous Phlaeothripidae:

- Alary polymorphism refers to either apterous or brachypterous or alate individuals. As evident in *H. manipurensis,* populations from *Quercus*-leaf litter in summer months (April-June) included more of alates, whereas in winter and spring months (November-March), *H. manipurensis* populations included more of apterous individuals in Manipur (24°44'N, 93°58'E). *Quercus griffithii* Hook f. et Thomson ex. Miq., and *Q. serrata* Murray (Fagaceae) being deciduous, accumulation of leaf litter is appreciably more in late autumn and winter compared with summer. Dense leaf litter coupled with low temperature, dampness, and short photoperiods facilitates the growth of fungus, which highly likely lead to the production of apterous individuals (Fig. 1a, b).
- In *Loyolaia indica,* reproductive diapause occurs in June-September on dry grass clusters, and the dispersal of alates take place later leading to the production of apterous individuals through oviparous mode of reproduction in Chennai (13º4'N,80º14'E) climate. Variation in climatic conditions along with food scarcity results in the production of alates and with the arrival of north-east monsoon in October-November, fungal growth is activated, which in turn, facilitates the population build-up of apterous individuals (Ananthakrishnan, 1984).
- The large and small individuals within the male populations of *Ecacanthothrips tibialis, Elaphrothrips denticolis, M. simplex, T. subramanii,* are a few examples showing striking intraspecific structural variations within one population. Their allometric data show considerable differences between the large and small individuals. For instance, in *E. tibialis*, the width of fore-femora in large males is (1600-1800 μm) three times more than that of small male (400-600 μm). Similarly, the presence of fore-femora inner tooth (400-550 μm) can be observed in large males of *E. tibialis* and that will be almost invisible in small males of the same species (Ananthakrishnan, 1971). Although Ananthakrishnan (1971) has elaborately described this phenomenon in many a thrips species from a taxonomic perspective, Bernard Crespi (1986) conceptualized their functional dynamics and has explained such variations within the same colony. According to Crespi (1986), in a large congregation of fungus-feeding male *Hoplothrips pedicularius* Haliday (Phlaeothripinae) competitive infighting occurs resulting in the death of the weaker individuals. The successful males of *H.*

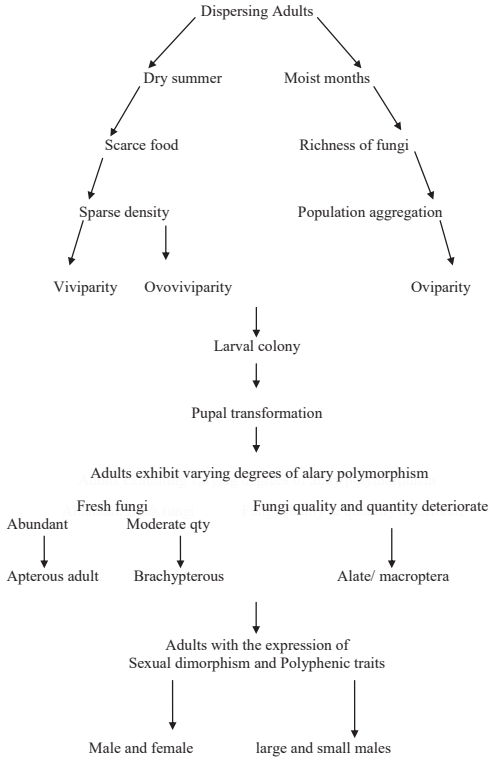


Fig 2. Developmental pattern in certain fungal spore feeding thrips

pedicularius feed voraciously and breed to protect their eggs and siblings (Crespi, 1988). Similar to other subsocial insects such as termites (Isoptera) and fig wasps (Hymenoptera) with traits to achieve the maximum level of inclusive fitness (Hamilton, 1978; 1979), spore-feeding thrips as well, display a range of features such as parental care, sexual dimorphism and other allometric variations among the individuals of a colony, possibly with the purpose to enhance their survival fitness.

E. Ecological implications

The taxonomic diversity of litter-inhabiting Thysanoptera is *c*. 2100 species feeding solely on fungal spores and hyphae (Dang et al., 2014; Eow et al., 2011). Not only their diversity, but their density are high, similar to populations of *Preeriella jacotia* Hartwig (Phlaeothripinae) with 2500 individuals collected from forest litter in South Africa (Hartwig, 1978). Such a diversity of species coupled with dense population possibly contributes to the overall ecological services to the concerned ecosystem. By virtue of occupying the litter habitat, the mycophagous Phlaeothripidae involve themselves in the decomposition and recycling of leaf litter, either directly or indirectly. Among the litter-inhabiting arthropods, the Phlaeothripidae occupy at least a third of the soil fauna. Although the Acarina are the most abundant (55.7%) soil arthropods, the Collembola and Thysanoptera standing second (14.7%) and third (6.5%), respectively, and the remainder including species of the Coleoptera, Hymenoptera, and the Lepidoptera (Wang and Tang, 2012). The role of litter-inhabiting thrips in forest floor is known to some extent (Mound, 1974; 1977; Ananthakrishnan, 1996), but, not many studies have been attempted to know the abundance and vertical distribution of insects in general and thrips in particular and such studies will certainly contribute substantially in understanding the role of litter-inhabiting Thysanoptera.

ACKNOWLEDGEMENTS

The Author thanks the Department of Science &Technology, New Delhi for financial support. This article is dedicated to N. Muraleedharan, former Director of the UPASI Tea Research Institute, Coimbatore & the Tocklai Tea Research Institute, Assam and Samir Sen, formerly Zoologist at the Zoological Survey of India, Calcutta for their contribution to the systematic studies of thrips of NE India. I am grateful to the Head, Department of Zoology and the Coordinator, Centre of Advanced Study in Life Sciences, Manipur University for the facilities. Thanks are due to L A Mound, CSIRO Entomology, Canberra, Australia for comments and suggestions.

REFERENCES

Ananthakrishnan T N. 1969. Indian Thysanoptera. Council of Scientific & Industrial Research Zoological Monograph 1: 1-171.

Ananthakrishnan T N. 1971. Trends in intraspecific sex-limited variation in some mycophagous Tubulifera (Thysanoptera). Journal of the Bombay Natural History Society 67: 481-501.

Ananthakrishnan, T N. 1973. Mycophagous Tubulifera of India. Occasional Publications of the Entomology Research Institute, No. 2. 144 pp.

Ananthakrishnan T N. 1979. Biosystematics of Thysanoptera. Annual Review of Entomology 24: 159-183.

Ananthakrishnan T N. 1980. Thrips. Harris K F, Maramorosch K (eds.). Vectors of plant pathogens. Academic Press Inc., New York, 149-164 pp.

Ananthakrishnan T N. 1984. Bioecology of thrips. Indira Publishing House, Michigan. 233 pp.

Ananthakrishnan T N. 1993. Bionomics of thrips. Annual Review of Entomology 38: 71-92.

Ananthakrishnan T N. 1996. Forest litter insect communities: Biology and chemical ecology, Oxford & IBH Publishing Co. Pvt. Ltd, New Delhi. 174 pp.

Ananthakrishnan T N. 2005. Perspectives and dimensions of phenotypic plasticity in insects. Ananthakrishnan T N, Whitman D (eds.). Insect phenotypic plasticity - diversity of responses. Science Publishers, Inc., Enfiled. pp. 1-23.

Ananthakrishnan T N, Dhileepan, K. 1984. Thrips-fungus association with special reference to the sporophagous *Bactrothrips idolomorphus* (Karny) (Tubulifera: Thysanoptera). Proceedings of the Indian Academy of Sciences (Animal Sciences) 93: 243-249.

Ananthakrishnan T N, James P W. 1983. Feeding preferences in some sporophagous Idolothripinae (Thysanoptera: Tubulifera). Proceedings of the Indian Academy of Sciences (Animal Sciences) B 49: 86-92.

Ananthakrishnan T N, Sen S. 1980. Taxonomy of Indian Thysanoptera. Zoological Survey of India, Handbook Series No. 1, 234 pp.

Ananthakrishnan T N, Suresh G. 1983. Patterns of fungal resource utilization and feeding range in some mycetophagous Tubulifera (Insecta: Thysanoptera). Proceedings. Indian Academy of Sciences (Animal Science) 92: 285-291.

Ananthakrishnan TN, Dhileepan K, Padmanabhan B. 1983. Reproductive strategies and behavioural attributes in some sporophagous Idolothripinae (Tubulifera: Thysanoptera). Proceedings. Indian Academy of Sciences (Animal Sciences) 92: 95-108.

Ananthakrishnan T N, Padmanabhan B, Dhileepan K, Suresh G. 1984. Ecological interactions, species dynamics and reproductive biology of some mycophagous Thysanoptera. Occasional Publication No.5, Entomology Research Institute, Loyola College, Chennai. pp. 1-37.

Bidermann P H W, Vega F E. 2020. Ecology and evolution of insect-fungus mutualisms. Annual Review of Entomology 65: 22.1-22.25.

Bournier A. 1957. Un deuxièmecasd'ovoviviparité chez les Thysanoptères, *Caudothrips buffai* Karny (Tubulifère, Megathripidae). Comptes rendus de l, Academie des Sciences, Paris 244: 506-508.

Bournier A. 1961. Remarques au sûjet du brachypterisme chez certainesespèces de thysanoptères. Bullétin de la Société de Entomologique de France (NS) 3: 173-179.

Bournier A. 1966. L`embryogenèse de *Caudothrips buffai* Karny (Thysanoptera: Tubulifera). Annales de la Société entomologique de France (NS) 2: 415-435.

Chochong V S, Varatharajan R. 2004. Faunistic diversity of thrips (Thysanoptera) inhabiting the oak leaf litters of plantation and natural habitats. Rajmohana K, Sudheer, K, Girish Kumar P, Santhosh S. (eds.). Perspectives on biosystematics and biodiversity, Prof T C Narendran commemorative volume, Systematic Entomology Research Scholars Association, Department of Zoology, University of Calicut, Calicut. pp. 119-127.

Crespi B J. 1986. Territoriality and fighting in a colonial thrips, *Hoplothrips pedicularius*, and sexual dimorphism in Thysanoptera. Ecological Entomology 11: 119-130.

Crespi B J. 1988. Adaptation, compromise and constraint: the development, morphometrics and behavioural basis of a fighter-flier polymorphism in male *Hoplothrips karnyi*. Behavioural Ecology and Sociobiology 23: 93-104.

Dang L, Mound L A, Qiao G X. 2014. Conspectus of the Phlaeothripinae genera from China and Southeast Asia (Thysanoptera: Phlaeothripidae). Zootaxa 3807 (1): 1-82.

Eow L X, Mound L A, Ng Y F. 2011. Genera of spore feeding Thysanoptera from Southeast Asia (Phlaeothripidae: Idolothripinae), with a species checklist from Peninsular Malaysia. Zootaxa 2928: 1-19.

Hamilton W D. 1978. Evolution and diversity underbark, Mound LA, Waloff N (eds.). Diversity of insect faunas. Symposia of the Royal Entomological Society of London No 9, Oxford: Blackwell Scientific. pp. 154-175.

Hamilton W D. 1979. Wingless and fighting males in fig wasps and other insects, Blum M S, Blum N A (eds.). Reproductive competition, mate choice and sexual selection in Insects, London, Academic Press. pp. 167-220.

Hartwig E K. 1978. A new species of *Preeriella* (Thysanoptera: Phlaeothripidae) from South Africa with comments on Hydiothripini characters. Journal of Entomological Society of South Africa 41: 259-264.

Hood J D. 1940. The cause and significance of macropterism and brachypterism in certain Thysanoptera, with description to a new Mexican species. Anales de la Escuela de Ciences Biologicas 1: 497-505.

Kirk W D J. 1996. Thrips: Naturalists' handbook. The Richmond Publishing Company 25: 1-70.

Kobro S. 2010. Checklist of Nordic Thysanoptera. Norwegian Journal of Entomology 58: 21-26.

Marren P, Mabey R. 2010. Bugs Britannica. Catalogue No.17419, Random House, London. 500 pp.

Moritz G. 2002. The biology of thrips is not the biology of their adults: a developmental view. Marullo R, Mound L A (eds.). Thrips and tospoviruses, Proceedings. 7th International symposium on Thysanoptera. pp. 259-267.

Morse J G, Hoddle M S. 2006. Invasion biology of thrips. Annual Review of Entomology 51: 67-89.

Mound L A. 1974. Spore feeding thrips (Phlaeothripidae) from leaf litter and dead wood in Australia. Australian Journal of Zoology 27: 1-106.

Mound L A. 1977. Species diversity and the systematics of some New World leaf litter Thysanoptera (Phlaeothripinae: Glyptothripini). Systematic Entomology 2: 225-244.

Mound L A. 2002. Thysanoptera biodiversity in the Neotropics. Revista de Biologia Tropical 50: 477-484.

Mound L A. 2005. Thysanoptera: diversity and interactions. Annual Review of Entomology 50: 247-269.

Mound L A. 2013. Order Thysanoptera Haliday, 1836, in Animal biodiversity: an outline of higher-level classification and survey of taxonomic richness (Addenda 2013). Zootaxa 3703 (1): 49-50

Mound L A, Palmer J M. 1983. The generic and tribal classification of spore-feeding Thysanoptera (Phlaeothripidae: Idolothripinae). Bulletin of British Museum (Natural History), Entomology 46: 1-174.

Mound L A, Tree D J. 2011. Australian spore-feeding Thysanoptera of the genus *Bactrothrips* (Phlaeothripidae: Idolothripinae). Zootaxa 3087: 56-65.

Mound L A, Vesmanis A H. 2021. All genera of the world: Order Thysanoptera (Animalia: Arthropoda: Insecta), Megataxa 006 (1): 002-069.

Mound L A, Dang, Li Hong, Tree D J. 2013. Genera of fungivorous Phlaeothripinae (Thysanoptera) from dead branches and leaf litter in Australia. Zootaxa 3681 (3): 201-224.

Negi S S, Naithani H B. 1995. Oaks of India, Nepal and Bhutan. International Book Distributors, Dehradun. 266 pp.

Okajima S. 1998. Minute leaf-litter thrips of the genus *Preeriella* (Thysanoptera, Phlaeothripidae) from Asia. Species Diversity 3: 301-316.

Rachana R R, Varatharajan R. 2017. Checklist of terebrantian thrips (Insecta: Thysanoptera) recorded from India. Journal of Threatened Taxa 9: 9748-9755.

Roff D A, 1991. Life history consequences of bio-energetic and biomechanical constraints on migration. American Zoologist 31: 205-215.

Sen S, Pramanik N K, Sengupta C K. 1988. Thysanoptera fauna of North Eastern India, Records of the Zoological Survey of India, ZSI Occasional Paper No. 100. 123 pp.

Shivas R G, Tree D J, Tan Y P, Ballard E L. 2009. *Dothiorella thripista*. Persoonia 22: 168-169.

ThripsWiki, 2021(http://thrips.info/wiki/classification_overview) accessed on 17-5-2021.

Tree D J, Mound L A,Walter G H. 2010. Fungal spore-feeding by adult and larval *Mecynothrips hardyi* (Priesner) (Thysanoptera: Phlaeothripidae: Idolothripinae). Journal of Natural History 44: 307-316.

Tyagi K, Kumar V. (2016) Thrips (Insecta: Thysanoptera) of India - an updated checklist. Halteres 7: 64-98.

Varatharajan R. 2005. Faunistic diversity of thrips (Thysanoptera) of north-eastern India. Silver Jubilee Publication, Manipur University. 74 pp.

Varatharajan R, Tarunkumar O, James Keisa, T, Chochong V S,Taptamani H. 2010. Thysanoptera fauna of the oak fields of Manipur and Nagaland, north-eastern India. Entomon 35: 139-142.

Varatharajan R, Shyam Maisnam, Chochong V S, Rachana R R. 2016. Pollination potential of thrips (Insecta: Thysanoptera)-an overview. Zoo's Print XXXI: 6-12.

Wang J, Tang X L. 2012. Species diversity, species dynamics and vertical distribution of litter dwelling thrips in an urban forest remnant of South China. Journal of Insect Science 12: 1-12.

(Manuscript Received: July, 2021; Revised: July, 2021;
Accepted: July, 2021; Online Published: September, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e21200

Indian Journal of Entomology 84(1): 223-236 (2022) DoI.: 10.55446/IJE.2021.42

WHY INSECT POLLINATORS IMPORTANT IN CROP IMPROVEMENT?

Amarjit S Tanda

School of Horticulture University of Western Sydney Richmond Australia
Current Address 2/49 Arthur Street Rose hill NSW 2142 Australia
Email: drtanda101@gmail.com

ABSTRACT

Three out of four plants provide fruits or seeds for human consumption as crops rely on insect pollinators across the world. Many fruit and vegetable crops such as almonds, apples, cranberries, melons, broccoli, cherries and blueberries are dependent upon insect pollinator services. Thus, healthy and nutritious diet to humans is offered by the bee pollinators. These natural servants help in the fertilization and seed setting of 87 major food plants. Crop pollinators are in danger, and modern agronomic practices can minimize the threat to flower foragers by changing the landscape and redesigning the ecological procedures. Safeguarding over 20000 wild bee pollinators will be of great importance as these have enhanced the economic value of crops up to $235- 577 billion. Herein, emphasized are the questions, why insect pollinators are significant in crop improvement technology? and how this is improving the quality and quantity in food production.

Key words: Insect, pollinators, apiculture, honeybees, crop improvement, production seed fertilization, agriculture, behaviour, decline, challenges, sustainability

On the biodiversity in agricultural systems and ecological services of insect pollinators, intensive agriculture has unfavorable effects. To transfer pollen as they forage, many crop plant species rely upon many animals, among them insects are the great champions. Plants, offering the natural food gifts of pollen or nectar and they give them directions towards the crop flowers. Plants attract pollinators by their vibrant colors and alluring fragrances. This floral biotechnology has brought about strong relationships between flowers and the animals that pollinate them. Modern agribusinesses depend on bee pollinator's services globally. Honey bees, native wild bees, and flies offer billions of dollars (about $235 and 577 billion U S) in economic value in every pollination season and serve a significant role in the world economy (FAO, 2018; Tanda, 2019; 2021).

Because of the high scale and homogeneity of current agriculture industry, the majority of crops requiring pollination, rely upon managed pollinators, especially on managed services (Aizen et al., 2008). No other group of insects are more helpful to humans than bees. The world's most staple nourishments, including wheat, corn, and rice (comprising 65% of global food production) reproduce without insect pollination, still leaving as much as 35% depending on pollinating insects (Klein et al., 2007). Besides this most meat and dairy too rely on bees for pollination which play significant role in the pollination of clover and Lucerne (Dias et al., 1999). Numerous crops and the majority of wild plants are dependent on animal pollination through insects, birds, bats and others, with insects playing the major role for sexual reproduction. Hence, among the insect pollinator's solitary and social bees, help in crop production both in managed and natural ecosystems. World's most economic crops such as apple, citrus, tomato, melon, strawberry, apricot, peach, cherry, mango, grape, olive, carrot, potato, onion, pump-kin, bean, cucumber, sunflower, various nuts, a range of herbs, cotton, alfalfa and lavender rely upon insect bee pollination services (Tanda, 2019, 2020 a, b). The European honeybee (*Apis mellifera* Linnaeus) rules crop pollination worldwide, but native bee species also play a significant role. Crop pollination system is a biological management, food security and key to sustainable environment. Crops that do not even require pollination for seed setting such as those producing fibre or timber, still require pollination to produce further, and harvests, such as cotton that do not require pollination to produce more prominent yields when pollinators are accessible (Tanda, 2019; 2020 a-c; Tanda and Goyal, 1979). Bees are the key pollinators for many fruit and vegetable crops. In farming, particularly among pollen-limited crops is a method for expanding profitability without resorting to expensive agricultural inputs such as insecticides or herbicides. Bee pollination bolster efficiency in numerous crops without farmers even acknowledge it, so long as habitat and alternative pollinator forage are readily available as they often are in little holder agroecosystems. By creating bigger

fields and landscapes for agriculture, the living space that pollinators may need becomes limited or finished. Expanding over-dependence on pesticides for pest and disease control is also highly destructive to beneficial insects such as pollinators, except if arranged and embraced with outrageous consideration (Tanda, 2019; 2021).

Crop pollination is a valuable insect service and we often do little to encourage them. As traditional faming systems are being changed to more man uses to meet out the increasing need of food security, we should know what pollination services are most significant for food security, and how we can protect bee services in sustainable farming systems. Bee pollinator varies from crops and cultivars. Numerous crops do not require insect pollinator, however may give rise to better quality fruit and seed if pollinated, and a number of others are strictly self-pollinated or cross-pollinated. Some flowers require specific pollinators while others are pollinated by a variety of foragers, and many crops are wind or water pollinated. Effective pollinators of the same crop may vary from one site to another. Honey bees (*Apis* spp.) alone pollinate crops that have an added economic value of over $14 billion to the agriculture (FAO, 2018; da Silva, 2018; Tanda, 2019, 2020 a, b, 2021). Honey bees are indispensable for the production of almond, alfalfa and sunflower seed, apple, cherry, melon, and berries. Only a few species of bees can be used for commercial pollination services, health and improved management is critical for agricultural productivity (da Silva, 2018; Tanda, 2019). Entpollinatology (from ancient Greek ἔντομον (entomon or ent), meaning 'insect', +pollination or pollinate, act of transferring pollen grains and -λογία (-logia), meaning 'study of') is the first time proposed technical term describing as branch of biology in which insects are involved or used to transfer pollen grains to the stigma of the flower for pollination which is very critical process in the fruit production of crop plants. Pollinatechnology is described as pollina= pollen + technology= the techniques or methods used in to transfer pollen grains from the male anther of a flower to the female stigma.

Apiculture in crop improvement

Apiculture industry is significant because it offers honey bees with a shielded place to work and make a colony to live. It's important to maintain the bee population healthy, as bees pollinate many of our food crops. Beekeeping also gives an environment in which to study bee habitat and their behaviour. US Department of Agriculture (2019) provided land managers and scientists with methods to evaluate the relationship between bees and the landscape. It offers a basis for making decisions about where to put their apiaries for the summer and fall after crop pollination ends so that the colonies will be in a position to build up strong healthy and in numbers in time for migration to California for almond pollination. As it produces honey, a unique product that is the honey bee is the most versatile commercial pollinator. By puzzling declines of honey bee colonies throughout the world, the impudence of honey bees for agroecosystem was severely challenged in the past several years (Aizen and Harder, 2009; van Engelsdorp et al., 2007). The chronic exposure to acaricides is required to control the parasitic mite *Varroa destructor*. Such uses negatively affects agriculture (Barnett et al., 2007; Desneux et al., 2007; Karise, 2007). Any decline of supervised honey bees and the loss of wild pollinators are of increasing concern as there exists a relationship between insect pollinators and food security. The global health of honey bees is at a great risk, doubtlessly. Significant negative effects on honey bees and other insect pollinators are there by the destruction and fragmentation of natural and seminatural habitats as well as land use escalation in agro-environment (Rathcke and Jules, 1993; Tscharntke et al., 2005; Kremen et al., 2004, 2007; Steffan-Dewenter and Westphal, 2008;). Honey bees are attacked by parasitic mites (*Varroa destructor, Acarapis woodi, Tropilaelaps* spp.), fungi (*Nosema* spp., *Ascosphaera apis*), bacteria (*Paenibacillus* larvae, *Melissococcus plutonius*), numerous viruses, and scavengers from beetles and mice to bears during life stages that is most important issue. While for others they remain elusive, but some of these parasites and pathogens the consequences for individual bees and colonies are known.

Non-Apis bees too need a particular crop species or can be manipulated in greenhouse agroindustry. Hence, the practices and techniques that support the commercialization of wild non-*Apis* pollinators are also in high demand. The most important requirements are the conservation and restoration of their habitat including managed farms, urban parks, and golf courses because many bees can nest in small habitat patches, in the natural areas, wild lands,Bottom of Form and human-dominated areas. These bees are threatened by shrinking habitat necessary for their biological requirements, or parasites and brood diseases. If they can be produced in adequate large populations and managed for pollination services, native species will be better used to enhance the pollination in crops. Since flower guests gain no direct benefit by pollinating flowers, rewards must draw

them. The most widely recognized way plants draw in creatures to visit their flowers is by giving sustenance, for example, nectar, pollen or oils. While looking for these prizes in the flower, dust from the flower's anthers may adhere to the body of the creature. At the point when the creature visits consequent flowers looking for more rewards, pollen from its body may hold fast to the stigma of these flowers and once more, new dust may adhere to the body of the creature. Pollination is a basic need in the sexual reproduction of crop flowering plants. Majority of the flowering plants dependent upon bees for the transfer of pollen dust (Nabhan and Buchmann, 1997; Renner, 1988). Pollination is a basic need for sexual proliferation in seed delivering plants (spermatophytes), taking into consideration hereditary recombination and the development of a hereditarily exceptional seed. This mingling of genetic material expands the capacity of probably a portion of a plant's posterity to get by in a universe of erratic ecological changes. Maintenance of this genetic variability in a population is necessary for Evolution by natural selection process to occur, and therefore is the ability of a plant population to adapt to changing environmental influences. The genetic variation in the next generation is larger by cross-pollination, in which pollen from the flower of one plant is transferred to the stigma of another flower plant. Reshuffling of genetic material also occurs in meiosis, to produce gametes. So even self-pollination, in which pollen grains are transferred from the stamens to the stigma of a same flower (or from one flower to another on the same plant) permits the maintenance of crop genetic variations (Tanda, 2019; 2021).

For some plants it has demonstrated invaluable to depend on pollination via animals. Numerous plants depend on wind or water resources for pollination, but must deliver a lot of pollen grains to ensure the chances of interception by the receptive stigma. By depending upon pollination by animals, the plant wastes less pollen as compared to pollination by wind or water. Then again, the plant may exhaust extra vitality to advance pollination by creatures; one model is the generation of nectar to remunerate pollinating creatures. Likewise, insect pollinators can transfer disease organisms from one plant to another along with pollen grains. Flowers contrast colossally in shading, aroma, size and shape; and they are visited by an equally diverse morphological and taxonomic array of creatures. Most common flower visitors are insects belonging to Hymenoptera, Lepidoptera, Diptera and Coleoptera orders. Yet, several species of birds, bats, and other mammals also regularly visit and pollinate flowers (da Silva, 2018; Tanda, 2019).

In pollination biology, a typical perspective is that plants should specialize on a small subset of these visitors in order to ensure effective pollination. Furthermore, undoubtedly, regardless of the enormous morphological and taxonomical diversity of potential interaction partners, flowers show trait combinations that seem to reflect the morphology, behaviour and physiology of certain pollinator types (Faegri and van der Pijl, 1979). Red coloured, odourless flowers with deeply hidden and dilute nectar seem to be adapted to hummingbirds or perch-ing birds; blue coloured bilaterally symmetric flowers with moderately hidden and relatively concentrated nectar combined with a pleasant odour are thought to be adapted to bees (Baker, 1975). Pollination syndromes are found across diverse taxonomic groups of plants and seem to be a consequence of specialization and convergence in evolution. Plants and animals have coevolved over millions of years, since the Cretaceous time frame. Plant pollination depends on the behaviour of many species of animals, from insects to birds to mammals, which transport pollen from stamens to pistils, a key step in the seed reproduction of most flowering plants. Pollinators provide a crucial ecosystem service that results in the out-crossing and sexual reproduction of many and improving livelihoods and by the role they play in conserving biological diversity in agricultural and natural community of living organisms. Lowered agricultural yields and deformed fruit often result from insufficient pollination rather than from a deficiency of other agrochemicals. In common biological systems, the visual clues of insufficient pollination are more unobtrusive than in agriculture, but the consequences can be as severe as the disappearance of a plant species. A perceptible reduction in fruit and seed eating animals, the loss of vegetation cover and ultimately, if keystone species are involved, the demise of healthy ecosystems and their services.

Natural eco environments and agricultural systems rely upon pollinator diversity to maintain overall biological diversity. A variety of materials, including dry wood (especially wood with empty beetle burrows), bare ground, vegetation-free embankments, mud, resins, sand (for some bees), carrion (for certain flies), host plants (for bees, moths and beetles) and caves (for certain bats) contribute to the diverse environment needed to maintain pollinator diversity. Pollinator diversity is gigantic which contain, more than 20,000 pollinating bee species in the world, as well as numerous insects and vertebrates. Pollinators differ from many other suppliers of essential ecosystem services because

they are often part of highly specific pollinator-plant relationships. Where there are very specific niche requirements for the plants and their pollinators, loss of the pollinator can have falling effects across the agroecosystem. A few bees that pollinate small herbaceous plants depend on openings in dry wood to nest, and when the wood is removed plant fruitfulness is reduced (FAO, 2018).

Significance of honey bees

Managed honey bees are the most profitable pollinators as far as agricultural financial matters. All these hyper-efficient insects can provide pollination to virtually any crop. Almonds are almost entirely dependent upon honey bee cross pollination for better seed setting. The production of blueberries, squash, watermelon, and other fruits without honey bees, would be greatly lowered, driving up prices and disrupting the marketplace. According to the USDA, a honey bee colony is worth 100 times more to the community than to the beekeeper- meaning the value they deliver extends well beyond their actual price. Honey bee pollination has helped make fruits, nuts, and vegetables more accessible to consumers (USDA, 2018). The importance of pollination in agribusiness has been perceived for centuries (Kevan and Phillips, 2001), with male flowers to ensure that dates would form on their trees, ancient Assyrian temple carvings depict winged deities pollinating female date palms (Buchmann and Nabhan, 1996). To manage and propagate captive colonies of stingless bees in logs, is mentioned in Maya of Mesoamerica. In the history, the mechanism of flower pollination was investigated by Koelreuter (1733-1806) and Sprengel (1750-1815) in pollination ecology.

The irony, however, is that although the importance, and fragility, of pollination for agriculture and Nature conservation has been known for a long time, there appears to have also been a popular belief that flowering plants always somehow seem to get pollinated and bear fruits and seeds and carry on into the next generation. Thus, the science of pollination ecology has not advanced adequately, and this makes ample room for new and established researchers to contribute to knowledge about pollinators and the plants they pollinate, whether in natural or agroecosystems. Surprisingly, even the identities of major and minor pollinators for many major crops plants worldwide remain unknown. Pollination refers to the transfer of pollen from the male parts of the flower to the female parts. This is especially critical in plants where different sexes are found in different plants or flowers. Pollination is a resource that is vital to agricultural productivity. Insect pollinators for example are practically essential in fruit and vegetable crop production. This is especially because pollinators increase or enhance seed set, improve seed and fruit quality, as well as improve genotype progeny (Fig. 1).

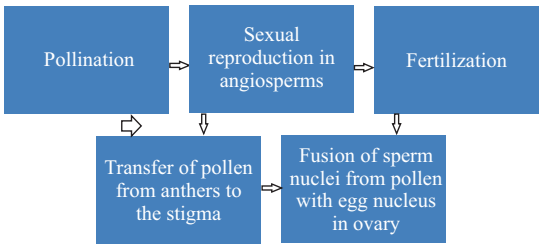


Fig. 1. A schematic model on sexual reproduction in angiosperms (designed by A S Tanda)

Pollination may be indispensable when all the other conventional inputs of water, fertilizer and pest control are taken into consideration. The pollinators however are currently under threat arising from: agricultural development, habitat fragmentation, agricultural chemicals (pesticides and herbicides), destruction of foraging and nesting sites, spread of pests and diseases. In USA, bee poisonings from pesticides result in annual losses of $14.3 million. We have a chance to avert a huge biological disaster - the large-scale loss of pollinator abundance as nature is rapidly disappearing all over the planet due to biological and climatic disturbances. All this is well known to apiculturists, biologists, ecologists, entomologists and other environment experts from many fields. Owing to a serious decline of bee pollinators, mostly decision makers are badly enlightened about the huge bio-ecological catastrophe worldwide. To eradicate utmost poverty in developing countries, recognition of the significance of bee pollination services will be an important ethical and practical drive in the world. Honey bees contribute fairly in rural development to secure and sustainable livelihoods, in addition to offering a critical role in crop pollination and thus improving the quality and yields (FAO, 2018).

Buzz pollination

Buzz pollination or sonication is a mechanism of vibrations performed by social /or solitary bees to release pollen which is firmly held by the anthers. Pollen can only be free when the stamens are shaken by vibrating movement of bees in many flowering plants. Not by the honey bees, buzz-pollination is carried out by bumblebees, carpenter bees and by the *Melipona* stingless bees. There implies a new dimension for the application of bees as pollinators crops that need to be

pollinated in greenhouse environment in the absence of natural pollinators. For seed production in crops the honey bees are considered to be the most significant tool. For the pollination of greenhouse crops and ornamental plants, bumble bees and solitary bees are being utilized (Estes et al., 1983). Due to the habitat loss by land use changes, more monoculture practices and, ill effects of pesticides and herbicides, despite more recognition of their important role in pollination, the population abundance and biodiversity of honey bees is declining (Fig. 2).

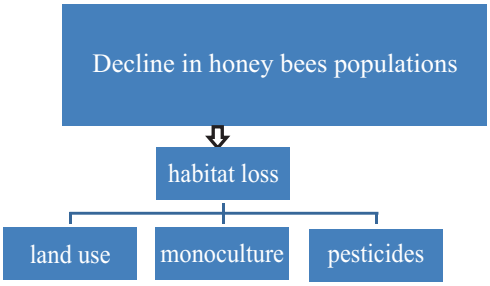


Fig. 2. Schematic decline in honey bee populations and diversity (designed A S Tanda)

Modern intensive agriculture and certain ways for managing our environment may have important consequences for the ecological position and the conservation of bees in this environment. Pollination is a threatened system from highly managed agriculture to uncultivated wilderness. Pesticides take their toll, insecticides directly killing pollinators and herbicides indirectly by reducing insect pollinators (Fig. 3). Certain improvements, the use of agro-chemicals and of genetically modified crops are considered to be detrimental for beekeeping (da Silva, 2018; Tanda, 2019). There are several reasons why honey bees are perhaps one of the most studied insects probably next to Drosophila. The value of crops that require pollination

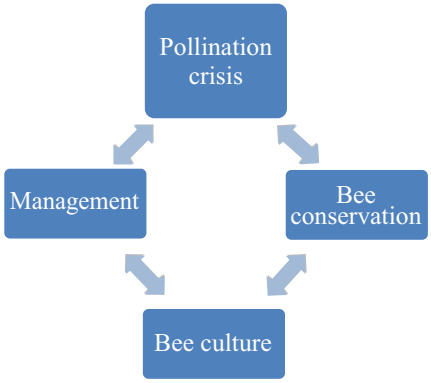


Fig. 3. Schematic model on bee pollination crisis solution (designed A S Tanda)

by honey bees, in the United States alone, is estimated to be around $24 billion each year and commercial bee pollination was valued around $10 billion (FAO, 2018; da Silva, 2018). There is a tendency to consume more bee-pollinated crops, making honey bees more and more important in agriculture. The honey bees are not domesticated in true sense but one had to understand and adjust his methods to gain maximum from the hard labor of honey bees. Contribution of bee keeping to agriculture and horticulture is very valuable. Over 50 million hectares under crops are benefited by the bee pollination services in India (da Silva, 2018; Tanda, 2019). Due to pollination services by bee's yields are enhanced in oilseeds, pulse crops, vegetables and fruits. Considering the recurring shortages of edible oils, pulses and other food crops, the significance of pollination can be acknowledged (FAO, 2018). An ancient coevolved practice involving animals and plants in mutualism, bee pollination is basic to agricultural crop production.

To change the demography of beekeeping and availability of crop pollinators honey bee diseases are a big threat to the industry. As a part of conservation, forestry, agroforestry, sustainable agriculture and development, significant assistance of wild natural pollinators, domestication of unused potential pollinators, and more environmentally sensitive human exploitation of the biodiversity are urgently required. As reciprocal selective factors, pollinators and crop flowers, have been closely and mutually interrelated for 200 million years. To produce some amazing inventive pollination mechanisms, they have developed together. For example, figs to a wasp, *Blastophaga*; *Phlox* to a diurnal butterfly, *Hemoris*; Yucca to a tineid moth, *Pronuba*; red clover to bumble bees;Trollius to a blade fly, *Chiastochaeta*; etc, several entomophilous species of crops are adapted to certain insects for seed setting. The flowers have very striking resemblances with the females of certain wasp species of *Scolia,* in some orchids, eg. *Ophrys insectifera*. For the visual simulation of flowers resembling their females, thus pollinating them incidentally, male wasps visit the blossoms not for nectar or pollen. In organic evolutionary development, this considerable relationship between plants and their pollinators is one of the most important occurrences. To the agriculture world about 200 billion US dollars/ year is the added potential economic value of insect crop pollination. On our planet in pollinating the 250,000 kinds of wild flowering plants, more than one lakh different animal pollinator species are valuable (FAO, 2018). As many as 1,500 species of birds and

mammals give out the services as the flower pollinators in addition to bees, wasps, moths, butterflies, flies and beetles. Globally, perching birds, flying foxes, fruit bats, snails, slugs, possums, lemurs and a gecko serve as efficient crop pollinators, however, hummingbirds are the effective flower pollinators in many states of the US (Bartomeus and Dicks, 2019). At a very alarming rate, the population level of wild and domesticated bee pollinators is decreasing worldwide.

Globally they are about 500 insects including butterflies, moths, bees, wasps, ants, beetles are an important source of calories and proteins as natural supplements. Leading to death of nearly 20% of the caterpillars, in the U.S.A. at Cornell University, it was observed that monarch butterfly caterpillars eating Bt corn toxic pollen blown on to milkweed plants near Bt corn fields had suffered significant adverse effects. For moths and butterflies, and deplete nesting materials for bees, these toxins can finish nectar sources for pollination and affect larval host plants adversely. To minimize pollinator's exposures to poisoning chemicals, farmers can move to more insect pollinator-friendly practice of agriculture (da Silva, 2018). In India, due to the indiscriminate application of chemicals as well as environmental pollution, the abundance of approximately 1,500 butterfly species, is alarmingly fluctuating. By the eradication of larval as well as adult food sources, feeding areas and nesting sites, other human alterations such as deforestation, and extension of farming and unrestricted urbanization are also a challenge to butterfly species to extinction. Due to the wanton eradication of living habitats in many areas of the subcontinent, the Travancore Evening Brown, the Malabar Tree Nymph, Bhutan Glory and Kaiser-I-Hind Butterfly are under near elimination.

Under local law, most spectacular and endangered species have various levels of protection and safety measures. For the survival of human and animal bioecology, next to bees and moths only butterflies are most effective pollinators of crops to help turn flowers into seeds, food, fruits and fibers. To save endangered species like butterflies and their habitats, based on sustainable exploiting wild creatures, wildlife farming can assist. Over the past decade, the growers of the Himalayan region have been complaining about the reduction in apple fruit production and quality due to bee pollination difficulties (van der Sluijs and Vaage, 2016). During the apple flowering season they have all disappeared now, there used to be a lot of wild bees, butterflies and moths in the past. The shortage of insect pollinators has, therefore, become an evaluative factor in insufficient crop pollination. Augmenting the populations of honey bees, bumblebees, sting less bees, and solitary bees, the pollination problem can be solved. In Maoxian County of Sichuan, China, hand pollination of apples is a common procedure (van der Sluijs and Vaage, 2016; da Silva, 2018; Bartomeus and Dicks, 2019; Tanda, 2019, 2020 a, b). At all levels among policy makers, planners, bee-keepers and growers, the awareness about the value of honeybee pollinators has to be put up. For pollination of different crops growers are already utilizing honey bees and solitary bees in western countries. From conventional honey production to crop pollination, the center of attention of beekeeping requires to change (da Silva, 2018).

Recognition of insect pollinators

Pollination by insect's supplies basic support of the structure and function of a wide range of natural communities, and it increases aesthetic, recreational, and cultural aspects of human activity, its direct economic value to humans. Taking into consideration that economic and ecological importance, there is a need to identify species for which there is evidence of decline, analyzes the supposed causes of those declines, and discusses their potential consequences, need of monitoring, conservation and their restoration. The planet's most successful life forms are among angiosperms that produce seeds often enclosed within an edible fruit. Flower reproductive systems differ considerably among insect species, but two mechanisms are significant for sexual reproduction in all flowering plants: firstly the transfer of pollen from the anthers of a stamen to the stigma of a pistil (Fig. 4), secondly the fertilization, the blending of the sperm nuclei from pollen grains with the egg nucleus in the ovary to

Fig. 4. Raspberry flowers and sexual reproduction (Photo A S Tanda)

produce an embryo. Many crop plants self-pollinate, implies that pollen transfer occurs within the same flower or among the flowers on a single plant, usually because the anthers touch the adjacent stigma. However, majority of the flowering plants, depend on the transfer of pollen from other individuals known as cross-pollination. Over 200,000 species of insect pollinators to various extents to meet their reproductive necessities. More than three-fourths of the planet's angiosperms depend on wind and water for pollen transfer. The fossil records are the evidences, angiosperms underwent a remarkable diversification between 130 million and 90 million years ago.

Self-seed fertilization barricades

In different taxa, adaptations that decrease the likelihood of selfing is found. Dioecy and monoecy promote outcrossing, and that they achieved ecological dominance 100 million to 70 million years ago (Davies et al., 2004). For the dispersal of pollen dust, main among the various explanations provided for their spectacular ascendancy is the evolution of mutualistic associations among animal species (Labandeira et al., 1994) and seed formation (Herrera, 1989; Kevan, 1984). Mutualistic associations among creatures provide mobility of gametes to otherwise predominantly sessile terrestrial plants, which allows for greater genetic variation in crop plants as well as access to a wider range of bioecological opportunities through seed dispersal mechanism. For flowering plants, use of an insect partner to transport pollen increases the area in which potential mates can be found and promotes outcrossing, the merger of gametes from genetically distinct individuals. By increasing genetic variability through recombination associated with outcrossing is key although monoecious plants can receive self-pollen from male flowers on the same plant. Monoecious plants give rise to male and female flowers at different stages, and thus the chances of selfing is reduced. When the male and female flower parts mature at different times in hermaphrodite flowers, self-pollination within flowers is failed. Because the male and female parts of the same flowers are isolated, the probability of self-pollination in some plants, is minimized. Allowing self-pollination before the flower is too old to set fruit, the male and female parts of the flower come closer together as the flower ages in those species. Several angiosperms are self-incompatible, means pollen that is transferred on a stigma within the same flower (or another flower on the same plant) deterrent to selfing, is unable to succeed fertilization. Self-incompatibility is under jurisdiction in complex and variable ways, and it involves the interplay of incompatibility alleles (of which there may be many) and their effects in the two parent plants (Matton et al., 1994).

Mechanisms to stop up self-fertilization can suddenly cease to function as a result of aging or environmental factors, especially temperature, the efficacy of self-incompatibility processes ranges from absolute to weak. Even when cross-pollination is not possible, shattering barricades down assures sexual reproduction in plants. Several species persevere exclusively and successfully live with self-pollinating and self-fertile flowers in spite of the omnipresence of outbreeding. In agriculture, few self-fertile species that can self-pollinate are of great significance. Where their native bee pollinators are not present many can set-up themselves in non-indigenous crop regions. In detail, the nature and evolutionary biology of crop-breeding systems are demonstrated by Richards (1997). Genetic variability in crop populations could ease the resistance to pathogens and herbivores, by permitting animals to adjust spatially and temporally in variable environments. It may contain hundreds of ovules and give rise to a fruit bearing hundreds of seeds as in tomato, kiwi fruit, cucumber, watermelon, or squash, or an ovary may have a single ovule and produce a fruit that bears only a single seed as in almond, avocado, coconut, plum, or cherry fruit plants. Some plants need many hundreds of pollen grains to fertilize all the egg cells to form seed as each seed results from the union of a sperm cell from a pollen grain and an egg cell. Some of the egg cells will not be fertilized and seeds will not set if a flower gets insufficient amount of pollen grains. Undersized fruits which have less value in the market are developed due to the result of incomplete pollination and fertilization. Individual flowers be foraged by several pollinators or that one too many pollinators make multiple visits to the same flower, the sufficient pollination often requires this. That would not be sustainable in natural environment, as few fruits are generally the outcome of selective breeding or genetic manipulations (Schery,1972). Seedless bananas are the results of clean triploid plants emerging either suddenly or because of hybridization of diploid and tetraploid people and are proliferated vegetatively. Parthenocarpic natural products, for example, seedless tangerines, are those in which organic products create without effective fertilization treatment could fall flat in light of the fact that these self- incompatible cultivars are developed in monoculture plantations. Seedless grapes, interestingly, are stenospermocarpic; fertilization happens, however

the subsequent natural product is seedless because the immature embryo fails to develop (Schery,1972).

Bioenvironment and crop foragers

Deguines et al., (2016) indicated that benefits from agricultural intensification may be offset by depletion in pollination services, and supports the need for an ecological intensification of agriculture through optimization of ecosystem. Flower foragers and plant interactions have been approximated to 400,000 species, exceptionally the nature of relationship between plant and pollinators differs. Though some foragers visit flowers for nectar or pollen, but all pollinators never help in pollination as they do not touch the male parts. Efficient bee pollinators often have behavioral and anatomical traits that greatly enhance the effectiveness and precision of pollen transfer (Barth 1991; Proctor et al., 1996; Lewinsohn et al., 2006). Crop pollination, in general, is a beneficial relationship for each other pollinating insects get some form of nutritional food and transfer pollen. For some flies, butterflies, birds, and bats, pollen itself is a gift, helping as the primary food necessity for bee larvae and as a rich source of protein (Roulston and Cane, 2000). Many plants offer nectar, oils, resins, fragrances, pheromone precursors, and other assets to prompt foraging and pollen dissemination (Barth, 1991; Dafni et al., 2005; Roulston and Cane, 2000; Roulston et al., 2000). Degree of interdependence differ in pollinators and flowers. Some crops rely on a single species or genus of insect pollinator, which in turn has limited sources of pollen or nectar.

The mutualism between plants in the genus *Yucca* (Agavaceae) and their pollinators, the aptly named yucca moths of the genus *Tegeticula*, is an important example of a close relationship (Pellmyr, 2003). In developing yucca seeds, adult yucca moth is the main pollinator as the main food source for the caterpillar, this relationship is 40 million years old. To gather and compact big amount of pollen grains even up to 10% of the moth's weight from yucca blossoms, female moths have tentacles, utilized for this activity. After collecting a pollen load, the moth flies off and forage at other plant, in which eggs are laid by female moth. Female transfer part of the pollen on the stigma for cross pollination and fertilization, also as a nutritious food for the offsprings, showing a unique biofloral behavioural activity. In plant-pollinator mutulism, such sterotyped associations are unusual. Similar relationships exploiting immediate opportunities are found in many cases, if not most. At least, 45 species of insects in 5 orders foraged on *Geranium thunbergii* Sieb. et Zucc. plants in a natural environment; of these, 11 species in 3 orders worked as key pollinators (Kandori, 2002). In its native Rocky Mountains is fertilized mainly by bumble bees at heights and by flies at low altitudes (Galen et al., 1987). Plants need pollen deposit on receptive stigma to set seed and develop fruits, it is well known now in the agricultural industry for pollination process. Till the seventeenth century and even after that mechanism was recognized slowly, that the seeds are developed from the transfer of pollen on stigmatic surfaces, was not well eloquent. Sexual organs of plants are significant components of classification. The natural niche associations design a platform for the plant hybridization among closely associated crop plants. By evolving a new methodology of artificial pollination and developed the first cross-hybrid from two flower species for seed development in many economic fruits, vegetables, and ornamental flowers (Mayr, 1986). A new era of experimental bee pollination biology was documented in 'The origin of species by means of natural selection or the preservation of favoured races in the struggle for life' in 1859.

Crop pollinators' management

Prasifka et al. (2018) reported related difference in bee foraging with specific floral traits, measured advantages of pollinators to hybrid crops, and used genetic assets in sunflower and other plants to find markers connected with principal floral characteristics. A model for using nectar-related traits to increase flower pollinator interactions, future work to enhance pollinator rewards should enable sunflower. Management of bee pollinator species allowed for increasing crop yield and for financial gain of crops exhibition of biotic pollination techniques showed direction to significant agricultural technology, with extensive economic results (Fig. 5). Worldwide the western honey bee, *Apis mellifera* L., is the leading domesticated pollinator, for its great efficiency as a pollinator, and wax, honey producer (Delaplane and Mayer, 2000; Free, 1993; Kearns et al., 1998; McGregor, 1976).

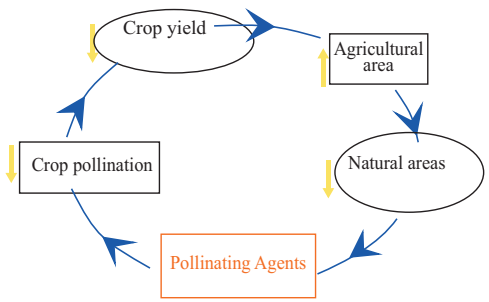


Fig. 5. Pollinating agent's role in agricultural crop entpollinatological system (drawn A S Tanda)

In the 1600s, first in North America with European colonists, *A. mellifera* rapidly became the key pollinator for advance agro industry, and managed hives were transferred worldwide (Sheppard, 1989). Flower pollinators for which effective management process have been evolved constitute many bumble bee species (*Bombus*), for tomato pollination in greenhouses mostly (de Ruijter, 1997; Hughes 1996; Kevan et al., 1991; Macfarlane et al., 1994; Plowright, 1996; van Heemert et al., 1990), and leafcutting bees (Megachile rotundata) (Bohart, 1972a; Frank, 2003), and in arid Pacific Northwest for alfalfa crop pollination. For alfalfa pollination, Alkali bees (*Nomia melanderi*) (Bohart, 1972a) are also used (Stephen, 2003). In the eastern United States, the Japanese horn-faced bee, Osmia cornifrons, mostly Mason bees, are domesticated in apple orchards for pollination (Batra, 1982; Bohart, 1972b), though in Japan these bees are utilized for pollinating the entire apple crop on a larger area. In the northwestern United States, *O. lignaria* is employed to pollinate apple plantations (Bosch et al., 2000; Bosch and Kemp 2002) and in eastern Canada (Sheffield, 2006) and for cherry fruit fertilization (Bosch and Kemp, 1999, 2000, 2001). For breeding this species advance procedures are available (Griffin, 1993; Torchio, 2003). For multiplication and management of various crop pollinators methods are accessible (Batra, 1994a, b; Bosch and Kemp, 2001; Free, 1970; Kevan et al., 1990; Shepherd et al., 2003; Torchio,1990, 2003). Except honey bees, for many crop pollination, more effective pollinators such as bumble bees, megachilids, and other wild bees are available (Cane, 2002; Javorek et al., 2002; Tepedino 1997). As an alternative flower pollinators *Osmia* spp. work in almond orchards (Bosch et al., 2000; Bosch and Kemp, 2000; Torchio, 2003), red raspberries and blackberries (Cane, 2005), pears (Maeta et al., 1993), blueberries (MacKenzie et al., 1997) and for sweet clover fields (Richards, 2003).

Commercial and ecological significance

Agroindustry comprises one of the most important economic sectors. The yield of most crop species is boosted by bee pollination services. Pollination has both commercial and ecological importance in crop production. In the context of agriculture, pollination supplies a wide range of benefits to a broad diversity of commodities across the world. Production of the fruit itself brings about directly from the bee pollination action for fruit formation in some cases. In other cases, although pollination does not result in productivity of the produce itself, the procedures contribute production of seeds used to grow a root crop such as carrots or quality, as size of tomatoes has been linked to repeated pollination (da Silva, 2018; Tanda, 2019) (Fig. 4).

Through food chain associations there are indirect advantages there as well. Directly, an annual value of $109 million, alfalfa seed crop is produced, along with hay valued at $4.6 billion per year for livestock forage indirectly by bee-pollination services (Morse and Calderone, 2000). Though indirect results overemphasize the economic value of crop pollination, the findings have been utilized in many research programs. To the U.S. agriculture, annual value of honey bee pollination has been estimated at $150 million (Rucker et al., 2005), $1.6-5.7 billion (Southwick and Southwick, 1992), $9 billion (Robinson et al., 1989a, b), $14.6 billion (Morse and Calderone, 2000), and $18.9 billion (Levin 1983). In Canada, honey bee pollination annual profits had been reported as $443 million (Scott-Dupree et al., 1995). As alfalfa leaf cutting bees and bumble bees also pollinate crops, the role of *A. mellifera* is not distinctive. In annual bee pollination, about $2 billion to $3 billion benefits can be ascribed to the role of wild bees and other insect species (Losey and Vaughan, 2006; Prescott-Allen and Prescott-Allen, 1986; Southwick and Southwick, 1992).

As plant pollinators of economically significant crops, many vertebrates also work. Species utilized for timber, silk, cotton, balsa wood, and other products, depend mainly on bats for pollen transfer in tropical trees of Bombacaceae family (Bawa, 1990; Watson and Dallwitz, 1992). Also rely on bats and birds for seed fertilization-related activities which are main origin of alcoholic beverages (tequila, mescal) cacti and agaves, and several other valuable products such as sisal fibers (Arizaga and Ezcurra, 2002; Arizaga et al., 2002; Fleming et al., 2001a, b; Grant and Grant, 1979; Rocha et al., 2005; Valiente-Banuet et al., 1996; Slauson, 2000, 2001). Than estimating their economic significance in agriculture sector, the contribution of bees and natural pollinators, and forecasting the results of their deprivation are more demanding. Both the number of species engrossed and the scarcity of details obtainable for most of those species, such approximates are more intricate. Losey and Vaughan (2006) did not try to calculate a dollar value of the plant pollinators in their role to estimate the economic importance of their eco-services given by pollinators. Further for maintenance of natural crop ecosystems, it is practicable to presume that an important number of flowers in uncultivated terrestrial environment rely

on bee pollinators. Valuable to humans, for example water filtration, carbon sequestration, floods and soil erosion control, all these cropping systems offer a lot of environmental jobs (Daily et al., 1997). Other than flower pollination in their immature stages, the difficulty is that crop pollinators may contribute many environmental services. The significance of these jobs is equally complicated to estimate, especially without a full understanding of all aspects of pollinators' biological systems. Honey bee (*A. mellifera*) is the main pollinator that applies a strong effect on its population through their enlarged phenotypes that connects to disease resistance traits (Easton-Calabria et al., 2019). Honey bees confirm resistance to pathogens and pests in its enlarged phenotypes such as honey, propolis, venom, beeswax, bee bread and royal jelly etc. To show antipathogenic properties and to play as a hive level defensive tool against diseases, each of these enlarged phenotypes have proved.

Crop pollination catastrophes

About one million species now face extinction, according to a major new UN report. Scientists warn that this is not only a crisis for nature, but for humanity all over the world (Howard and Johnson, 2019). Why they so feared are and what does it mean for our life systems? Localized bee population diminishing and a global decrease in the number and survival of insect pollinating agent, the concept of a pollinator crisis contributing to trophic collapse (Dobson et al., 2006) was noted in 1990s. About this crucial crop pollinator, big losses in honey bee colonies were found in the United States (Watanabe, 1994). As a fundamental ecoservice system a stress on insect pollination (Daily et al., 1997) brought about an outburst of interest in the international policy arena (Allen-Wardell et al., 1998; Costanza et al., 1997; Eardley et al., 2006). In conservation of biodiversity, the science of insect pollination ecology and floral biology has now been well established. Worldwide scientists and agriculturists were worried about a decline of bee pollinators and ill effects on biodiversity globally occurring in the mid-1990s. In 2000, at the Fifth Meeting of the Conference of Parties (COP) of the Convention on Biological Diversity (CBD) to establish an International Initiative for the Conservation and Sustainable use of pollinators (also referred to as the International Pollinators Initiative, or IPI), concerned policymakers. Within the program of work on agricultural biodiversity to encourage coordinated program globally Fifth Meeting of the Conference of Parties (COP) contemplated this to be an alternate initiative, and appealed for the development of an Action Plan for the IPI. In 2002, Action Plan developed on the São Paulo Declaration on Pollinators recommendations was embraced at COP 6 (decision VI/5). All the conservationists, growers, landscape architects, town planners and other stakeholders are required to follow policy designers and perform for the significance of crop pollinators and sustainability of biodiversity around the world (Eardley et al., 2006; Howard and Johnson, 2019).

Conclusions: challenges and threats

To conclude, bees are well established as efficient crop pollinators, domesticated bumble bees and solitary bees are also important for the prosperous fertilization of many crop plants, while native bees offer a voluntary service. For the conservation of wild flora, insect pollination is significant for natural ecosystem sustainability. It is very complicated to understand the history of insect pollination or entpollinatology, bee behaviour and their management for crop pollination services. Bees perform a big job in the agro-ecosystem resilience, though they are little in size. Of a big mutual connection between humans and the natural environment, the relationship between bees and humankind is figurative. The role of insect pollinator's attempt;

- To fill the gap by offering the evaluative analysis of different management strategies in agriculture sustainability and environment protection
- Pollination needs of various field crops in enhancing quality and quantity
- Why insect pollinators or entpollinatology important in crop improvement programs?
- Global agro industry in the absence of bee pollinators
- Insect pollination in hybrid seed production system of entomophilous crops
- Sustainability of natural bio-ecosystem
- Improvement in pollinators density and diversity boosting crop yields
- Current threats to pollinator populations and sustainable food productivity
- Overuse of insecticides and safety to flower foragers
- Crop pollinators, conservation and strategies
- Importance of non-insect pollinators in crop improvement
- Important issues and future of entpollinatology

- New advances in pollination materially engineered artificial pollinators
- Assessment of pollinators, bee management and crop services
- Adaptive management of crop plants and wildlife
- How pollination biotechnology may be main-streamed into policy decisions for global food sustainability.

REFERENCES

Aizen M, Harder L D. 2009. The global stock of domesticated honey bees is growing slower than agricultural demand for pollination. Current Biology 19: 915-918.

Aizen M, Garibaldi L, Cunningham S, Klein A. 2008. Long-term global trends in crop yield and production reveal no current pollination shortage but increasing pollinator dependency. Current Biology 18:1572-1575.

Arizaga S, Ezcurra E. 2002. Propagation mechanisms in *Agave macroacantha* (Agavaceae), a tropical arid-land succulent rosette. American Journal of Botany 89: 632-641.

Arizaga S, Ezcurra E, Peters E, de Arellano F R, Vega E. 2002. Pollination ecology of *Agave macroacantha* (Agavaceae) in a Mexican tropical desert. I. Floral biology and pollination mechanisms. American Journal of Botany 87:1004-1010.

Baker H G.1975. Sugar concentrations in nectars from hummingbird flowers. Biotropica 7: 37-41

Barnett E A, Charlton A J, Fletcher M R. 2007. Incidents of bee poisoning with pesticides in the United Kingdom, 1994-2003. Pest Management Science 63: 1051-1057.

Barth F G. 1991. Insects and flowers: the biology of a partnership (trans: Biederman-Thorson MA). Princeton University Press, Princeton. 408 pp.

Batra S W T 1982. The horn faced bee for efficient pollination of small farm orchards. Research for small farms. In: Kerr WH and Knutson LV (eds) Research for small farm, USDA Miscellaneous Publication 1422. pp. 116-120.

Batra S W T 1994a. *Anthophora plumipes villosula Sm*. (Hymenoptera: Anthophoridae), a man- ageable Japanese bee that visits blueberries and apples during cool, rainy, spring weather. Proceedings of the Entomological Society of Washington 96: 98-119.

Batra S W T 1994b. Diversify with pollen bees. American Bee Journal 134: 591-593.

Bawa K S 1990. Plant-pollinator interactions in tropical rain forests. Annual Review of Ecology, Evolution, and Systematics 21: 399-422

Bartomeus I, Dicks, L V. 2019. The need for coordinated transdisciplinary research infrastructures for pollinator conservation and crop pollination resilience. Environmental Research Letters. doi:10.1088/1748-9326/ab0cb5.

Bohart G E 1972a. Management of wild bees for the pollination of crops. Annual Review of Entomology 17: 287-312.

Bohart G E 1972b. Management of habitats for wild bees. Proceedings. Tall timbers conference on ecological animal control by habitat management no. 3, Tallahassee. pp. 253-266.

Bosch J, Kemp W P. 1999. Exceptional cherry production in an orchard pollinated with blue orchard bees. Bee World 80(4): 163-173.

Bosch J, Kemp W P. 2000. Development and emergence of the orchard pollinator *Osmia lignaria* (Hymenoptera: Megachilidae). Environmental Entomology 29: 8-13.

Bosch J, Kemp W P. 2001. How to manage the blue orchard bee as an orchard pollinator. Sustainable agriculture network handbook series book 5. National Agricultural Library, Beltsville. 88 pp

Bosch J, Kemp W P 2002. Developing and establishing bee species as crop pollinators: the example of *Osmia* spp. (Hymenoptera: Megachilidae) and fruit trees. Bulletin of Entomological Research 92(1): 3.

Bosch J, Kemp W P, Peterson S S. 2000. Management of *Osmia lignaria* (Hymenoptera: Megachilidae) populations for almond pollination: methods to advance bee emergence. Environmental Entomology 29(5): 874-883.

Bromenshenk J J, Smith G C, Smith G C, Watson V J. 1995. Assessing ecological risks in terrestrial systems with honey bees. Butterworth F M (ed.). Biomonitors and biomarkers as indicators of environmental change. Plenum Press, New York. pp. 9-30.

Bromenshenk J J, Henderson C B, Seccomb R A, Rice S D, Etter R T, Bender S F A, Rodacy P J, Shaw Wilson J J. 2003. Can honey bees assist in area reduction and landmine detection? Journal Mine Action 7(3): 24-27.

Buchmann S L, Nabhan G P. 1996. The forgotten pollinators. Island Press, Washington DC.

Cane J H. 2002. Pollinating bees (Hymenoptera: Apiformes) of U.S. alfalfa compared for rates of pod and seed set. Journal of Economic Entomology 95(1): 22-27.

Cane J H. 2005. Pollination potential of the bee *Osmia aglaia* for cultivated red raspberries and blackberries (Rubus: Rosaceae). HortScience 40(6): 1705-1708.

Charlesworth D, Charlesworth B 1987. Inbreeding depression and its evolutionary consequences.Annual Review of Ecology, Evolution, and Systematics 18: 237-268.

Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin R G, Sutton P, van den Belt M. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253-260.

Crane E. 1983. The archaeology of beekeeping. Duckworth, London, Crane E (1990). Bees and beekeeping. Comstock, Ithaca. 260 pp.

Crane E. 1999. The world history of beekeeping and honey hunting. Routledge, London

Dafni A, Kevan P G, Husband B (eds). 2005. Practical pollination biology. Enviroquest Ltd., Cambridge.

Daily G C, Matson P A, Vitousek PM 1997. Ecosystem services supplied by soil. In: Daily G (ed) *Nature*'s services: societal dependence on natural ecosystems. Island Press, Washington DC. pp. 113-132.

da Silva J G. 2018. Why bees matter. The importance of bees and other pollinators for food and agriculture. fao.org. First observance of world bee day. 20 May Žirovnica, Republic of Slovenia.

Davies T J, Barraclough T G, Chase M W, Soltis P S, Soltis D E, Savolainen V. 2004. Darwin's abominable mystery: insights from a supertree of the angiosperms. Proceedings of the National Academy of Sciences USA 101(7): 1904-1909.

Dedej S, Delaplane K S, Scherm H. 2004. Effectiveness of honey bees in delivering the biocontrol agent *Bacillus sutilis* to blueberry flowers to suppress mummy berry disease. Biological Control 31: 422-427.

Delaplane K S, Mayer D F. 2000. Crop pollination by bees. CAB International, Oxon.

Deguines N, Jono C, Baude M, Henry M, Julliard R, Fontaine, C. 2016. Large-scale trade-off between agricultural intensification and crop

pollination services. Frontiers in Ecology and the Environment 12: 212-217.

Dias B S F, Raw A, Imperatri-Fonseca V L. 1999. International pollinators initiative: the Sao Paulo declaration on pollinators. Report on the recommendations of the workshop on the conservation and sustainable use of pollinators in agriculture with emphasis on bees, Brazilian Ministry of the Environment, Brazil. 79 pp.

Dobson A, David L D, Alder J, Cumming G S, Keymer J, McGlade J, Mooney H, Rusak J A, Sala O, Wolters V, Wall D, Winfree R, Xenopoulos M A. 2006. Habitat loss, trophic collapse, and the decline of ecosystem services. Ecology 87(8): 1915-1924.

Eardley C, Roth D, Clarke J, Buchman S, Gemmill B (eds). 2006. Pollinators and pollination: a resource book for policy and practice. African Pollinator Initiative, Pretoria. 77 pp

Easton-Calabria A, Demary K C, Oner N J. 2019. Beyond Pollination: Honey Bees (*Apis mellifera*) as Zootherapy Keystone Species. Frontiers in Ecology and Evolution 6: 161. https://www.frontiersin.org/article/10.3389/fevo.2018.00161

Estes J, Bonnie B, Amos J, Sullivan R. 1983. Pollination from two perspectives: the agricultural and biological sciences. Jones C E, Little R J (eds). The handbook of experimental pollination biology. van Nostrand Reinhold, New York. pp. 173-183.

FAO. 2018. The Beeconomy: Economics and insect pollination. Biodiversity. April 27, https://modernag.org/biodiversity/beeconomy-economic-value-pollination/

Fleming T H, Sahley C T, Holland J N, Nason J D, Hamrick J L. 2001a. Sonoran desert columnar cacti and the evolution of generalized pollination systems. Ecological Monographs 71: 511-530.

Fleming T H, Tibbitts T, Petryszyn Y, Dalton V. 2001b. Current status of pollinating bats in the southwestern United States. In: O'Shea T, Bogan M (eds) Monitoring bat populations in the United States. U.S. Geological Survey, Fort Collins.

Frank G (ed.) 2003. Alfalfa seed and leafcutter bee production and marketing manual. brooks. Irrigated Alfalfa Seed Producers Association, Alberta. 160 pp.

Free J B. 1993. Insect pollination of crops, 2nd edn. Academic Press, San Diego. 684 pp.

Galen C, Zimmer K A, Newport M E. 1987. Pollination in floral scent morphs of *Polemonium viscosuma* mechanism for disruptive selection on flower size. Evolution 41: 599-606.

Grant V, Grant K A. 1979. The pollination spectrum in the southwestern American cactus flora. Plant Systematics and Evolution 133: 29-37.

Griffin B L. 1993. The orchard mason bee. Knox Cellars Publishing, Bellingham, Washington DC.

Herrera C M. 1989. Seed dispersal by animals: a role in angiosperm diversification? American Naturalist 133: 309-322.

Howard E, Georgie J. 2019. We are losing the web of life': why the global nature crisis is as dangerous as climate change. https://unearthed.greenpeace.org/2019/05/06/nature-crisis-biodiversity-dangerous-climate-change-extinction/

Hughes M J. 1996. Commercial rearing of bumble bees. Matheson A (ed). Bumble bees for pleasure and profit. International Beekeeper Research Association, Cardiff. pp. 40-47.

Javorek S K, Mackenzie K E, Vander-Kloet S P. 2002. Comparative pollination effectiveness among bees (Hymenoptera: Apoidea) on lowbush blueberry (Ericaceae: *Vaccinium angustifolium*). Annals of the Entomological Society of America 95(3): 345-351.

Kandori I. 2002. Diverse visitors with various pollinator importance and temporal change in the important pollinators of *Geranium thunbergii* (Geraniaceae). Ecological Research 17(3): 283-294.

Karise R. 2007. Foraging behaviour and physiology of bees: impact of insecticides. Ph D thesis, Estonian University of Life Sciences, Tartu, Estonia. pp. 1-123.

Kearns C A, Inouye D W, Waser N M. 1998. Endangered mutualisms: the conservation of plant- pollinator interactions. Annual Review of Ecology, Evolution, and Systematics 29: 83-112.

Kevan P G. 1984. Pollination by animals and angiosperm biosystematics. Grant W F (ed) Plant biosystematics. Academic, Toronto. pp. 271-292.

Kevan P G, Clark E A, Thomas V G. 1990. Insect pollinators and sustainable agriculture. American Journal of Alternative Agriculture 5: 13-22.

Kevan P G, Straver W A, Offer M, Laverty T M. 1991. Pollination of greenhouse tomatoes by bumble bees in Ontario. Proceedings of the Entomological Society of Ontario 122: 15-19.

Kevan P G, Shipp V L, Kapongo J P, Al-mazra'awi M S. 2005. Bee pollinators vector biological control agents against insect pests of horticultural crops. Guerra-Sanz M, Roldán Serrano A, Mena Granero A (eds). First short course on pollination of horticulture plants. CIFA, La Mojonera, Spain. pp.77-95.

Klatt B K, Holzschuh A, Westphal C. 2013. Bee pollination improves crop quality, shelf life and commercial value. Proceedings of the Royal Society B: Biological Sciences 2013; 281(1775): 20132440.

Klein A M, Vaissiere B E, Cane J H, Steffan-Dewenter I, Cunningham S A, Kremen C, Tscharntke T. 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B: Biological Sciences 274: 303-313.

Knuth P. 1912. Handbook of flower pollination, vol 2 (trans: Ainsworth Davis J R). Clarendon Press, Oxford.

Kovach J, Petzoldt R, Harman G E 2000. Use of honey bees and bumble bees to disseminate *Trichoderma harzianum* 1295-22 to strawberries for *Botrytis* control. Biological Control 18: 235-242.

Kremen C, Williams N M, Aizen M A, Gemmill-Herren B, LeBuhn G. 2004. The area requirements of an ecosystem service: crop pollination by native bee communities in California. Ecology Letters 7: 1109-1119.

Kremen C, Williams N M, Aizen M A, Gemmill-Herren B, LeBuhn G. 2007. Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. Ecology Letters 10: 299-314.

Labandeira C C, Dilcher D L, Davis D R, Wagner D L. 1994. Ninety-seven million years of angiosperm-insect association: paleobiological insights into the meaning of coevolution. Proceedings of the National Academy of Sciences USA 91: 12278-12282.

Levin M D. 1983. Value of bee pollination to U.S. agriculture. Bulletin of the Entomological Society of America 29: 59-51.

Lewinsohn T M, Prado P I, Jordano P, Bascompte J, Olesen J M. 2006. Structure in plant-animal interaction assemblages. Oikos 113: 174-184.

Losey J E, Vaughan M. 2006. The economic value of ecological services provided by insects. Bioscience 56: 311-323.

Macfarlane R P, Patten K D, Royce L A, Wyatt B K W, Mayer D F. 1994. Management potential of sixteen North American bumble bee species. Melanderia 50: 1-12.

MacKenzie K E, Javorek S, Richards K W. 1997. The potential of alfalfa leafcutter bees (*Megachile rotundata* L.) as pollinators of cranberry (*Vaccinium macrocarpon* Aiton). Acta Horticulturae 437: 345-351.

Maeta Y, Goukon K, Tezuka T. 1993. Utilization of *Osmia cornifrons* as a pollinator of Japanese pears (Hymenoptera, Megachilidae). Chugoku Kontyu 7: 1-12.

Mayr E. 1986. Joseph Gottlieb Köreuter's contributions to biology. Osiris 2(2): 135-176.

McGregor S E. 1976. Insect pollination of cultivated crop plants. USDA Handbook 496. Department of Agriculture, Agricultural Research Service, Washington DC. 411 pp.

Molnar S. 2004. Plant reproductive systems. http://www.geocities.com/we_evolve/Plants/ breeding_sys.html. Accessed 10 Mar 2006.

Morse R A, Calderone N W 2000. The value of honey bees as pollinators of U.S. crops in 2000. Bee Culture 128(3): 1-15.

Nabhan G P, Buchmann S L. 1997. Pollination services: biodiversity's direct link to world food stability. Daily G C (ed). Nature's services: societal dependence on natural ecosystems. Island Press, Washington DC. pp. 133-150.

Prasifka J R, Mallinger R E, Portlas Z M. 2018. Using nectar-related traits to enhance crop-pollinator interactions. Frontiers in Plant Science 9: 812.

Pellmyr O. 2003. Yuccas, yucca moths, and coevolution: a review. Annals of the Missouri Botanical Garden 90: 35-55.

Plowright C. 1996. Bumble bee rearing. Melissa 9: 10-12.

Prescott-Allen C, Prescott-Allen R. 1986. The first resource: wild species in the North American economy. Yale University Press, New Haven. 529 pp.

Proctor M, Yeo P, Lack A. 1996. The natural history of pollination. Timber Press, Portland Rathcke B J, Jules E S 1993. Habitat fragmentation and plant-pollinator interactions*:* from specialization to generalization. Waser N, Ollerton J (eds). The University of Chicago Press, Chicago and London. pp. 173-199.

Renner S S. 1988. Effects of habitat fragmentation on plant-pollinator interactions in the tropics. Newbery D M, Prins H H T, Brown N D (eds). Dynamics of tropical communities. Blackwell Science, Oxford. pp. 339-360.

Richards A J. 1997. Plant breeding systems. 2nd edn. Garland Science, London

Richards K W. 2003. Potential use of the alfalfa leafcutter bee *Megachile rotundata* to pollinate sweet clover. Journal of Apicultural Research 42(1/2): 21-24.

Robinson W S, Nowogrodzki R, Morse R A. 1989a. The value of honey bees as pollinators of U.S. crops. Part I of a two-part series. American Bee Journal 129: 411-423.

Robinson W S, Nowogrodzki R, Morse R A. 1989b. The value of honey bees as pollinators of U.S. crops. Part II of a two-part series. American Bee Journal 129: 477-487.

Rocha M, Valera A, Eguiarte L E. 2005. Reproductive ecology of five sympatric *Agave littaea*(Agavaceae) species in Central Mexico. American Journal of Botany 92: 330-341.

Roubik D W (ed). 1995. Pollination of cultivated plants in the tropics. Food and Agriculture Organization Agricultural Services Bulletin 118, Rome. 196 pp.

Roulston T H, Cane J H. 2000. Pollen nutritional content and digestibility for animals. Plant Systematics and Evolution 222(1-4): 187-209.

Roulston T H, Cane J H, Buchmann S L. 2000. What governs the protein content of pollen grains: pollinator preferences, pollen-pistil interactions, or phylogeny? Ecological Monographs 70: 617-643.

Rucker R R, Thurman W N, Burgett M. 2005. Internalizing reciprocal benefits: the economics of honeybee pollination markets. North Carolina State University, Department of Agricultural and Resource Economics, Raleigh, NC, Unpublished manuscript http://legacy.ncsu.Âedu:8020/classes/ecg701001/personal/Internalization_of_Reciprocal_Benefits-full_March_2005.pdf. Accessed 6 Mar 2005.

Schery R W. 1972. Plants for man, 2nd edn. Prentice-Hall, Englewood Cliffs NJ.

Scott-Dupree C, Winston M, Hergert G, Jay S C, Nelson D, Gates J, Termeer B, Otis G. 1995. A guide to managing bees for crop pollination. Canadian Association of Professionals Apiculturists. Canadian Department of Agriculture, Aylesford. 41 pp.

Shepherd M D, Buchmann S L, Vaughan M, Black S H. 2003. Pollinator conservation handbook: a guide to understanding, protecting, and providing habitat for native pollinator insects. The Xerces Society in association with the bee works. The Xerces Society, Portland. 45 pp.

Slauson L A. 2000. Pollination biology of two chiropterophilous agaves in Arizona. American Journal of Botany 87: 825-836.

Slauson L A. 2001. Insights on the pollination biology of *Agave* (Agavaceae). Haseltonia 8: 10-23.

Southwick E E, Southwick L Jr. 1992. Estimating the economic value of honey bees (Hymenoptera: Apidae) as agricultural pollinators in the United States. Journal of Economic Entomology 85: 621-633.

Steffan-Dewenter I, Westphal C. 2008. The interplay of pollinator diversity, pollination services and landscape change. Journal of Applied Ecology 45: 737-741.

Stephen W P. 2003. Solitary bees in North American agriculture: a perspective. Strickler K V, Cane J H (eds). For non-native crops, whence pollinators of the future? Thomas Say Publications in Entomology, Entomological Society of America, Lanham. pp. 41-66.

Tanda A S. 2021. Insect pollinators matter in sustainable world food production. Indian Journal of Entomology.

Tanda A S. 2020a. Biogenetic engineering in developing insect resistant crops: constraints and applications. 5th Edition. Global congress on plant biology and biotechnology (GPB 2020)' during November 11-13, 2020 at Valencia, Spain.

Tanda A S. 2020b. An Assessment of honey bee (*Apis mellifera*) foraging activity and pollination efficacy in Australian raspberry *Rubus parvifolius* at Rose hill. Australian Journal of Entomology (submitted)

Tanda A S. 2020c. Entpollinatology is for sustainable Agroecosystems and Global Agroindustry. Indian Journal of Entomology.

Tanda A S. 2019. Entomophilous crops get better fruit quality and yield: An appraisal. Indian Journal Entomology 81(2): 227-234.

Tanda A S, Goyal N P. 1979. Insect pollination in Asiatic cotton (Gossypium arboreum). Journal of Apicultural Research 18(1): 64-72.

Tepedino V J. 1997. A comparison of the alfalfa leaf cutting bee (*Megachile rotundata*) and the honey bee (*Apis mellifera*) as pollinators for hybrid carrot seed in field cages. Richards K W (ed). Proceedings. 7th International symposium on pollination, Lethbridge, Alberta. International Society for Horticultural Science, Leiden, the Netherlands. pp. 457-461.

Torchio P F. 1990. Diversification of pollination strategies for U.S. crops. Environmental Entomology 19(6): 1649-1656.

Torchio P F. 2003. The development of *Osmia lignaria* Say (Hymenoptera: Megachilidae) as a managed pollinator of apple and almond crops: a case history. Strickler K, Cane J H (eds). For nonnative crops, whence pollinators of the future? Proceedings, Entomological Society of America. Thomas Say Publications in Entomology, Lanham. pp. 67-84.

Tscharntke T, Klein A M, Kruess A, Steffan-Dewenter I, Thies C. 2005. Landscape perspectives on agricultural intensification and biodiversity- ecosystem service management. Ecology Letters 8: 857-874.

US Department of Agriculture 2018. The Beeconomy: Economics and insect pollination. Biodiversity. April 27. https://modernag.org/biodiversity/beeconomy-economic-value-pollination/

US Department of Agriculture 2019. Honey bee colonies more successful by foraging on non-crop fields Public Release: 20-Mar-https://www.eurekalert.org/pub_releases/2019-03/udoa-hbc031619.php

Valiente-Banuet A, Arizmendi MC, Rojas-Martínez A, Domínguez-Canseco L 1996. Ecological relationships between columnar cacti and nectar feeding bats in Mexico. Journal of Tropical Ecology 12: 103-119.

van der Sluijs J P, Vaage, N S. 2016. Pollinators and global food security: the need for holistic global stewardship. Food Ethics 1: 75-91.

van Heemert C, de Ruijter A, van den Eijnde J, van der Steen J. 1990. Year-round production of bumble bee colonies for crop pollination. Bee World 71(2): 54-56.

van Engelsdorp D, Underwood R, Caron D, Hayes J Jr. 2007. An estimate of managed colony losses in the winter of 2006-2007: a report commissioned by the apiary inspectors of America. American Bee Journal 147: 599-603.

Vaughan M, Shepard M, Kremen C, Black S H. 2004. Farming for bees: guidelines for providing native bee habitat on farms. The Xerces Society for Invertebrate Conservation, Portland.

Watanabe ME (1994) Pollination worries rise as honey bees decline. Science 265: 1170.

Watson L, Dallwitz M J. 1992. The families of flowering plants: descriptions, illustrations, identification, and information retrieval. http://delta-intkey.com/. Version: 2 June 2006

(Manuscript Received: November, 2020; Revised: September, 2021;
Accepted: September, 2021; Online Published: October, 2021)
Online published (Preview) in www.entosocindia.org Ref. No. e20370

Indian Journal of Entomology 84(1): 237-239 (2022) DoI.: 10.55446/IJE.2022.457

FIELD ENTOMOLOGISTS IN PUBLIC HEALTH?

P K Rajagopalan

Former Director, Vector Control Research Centre (ICMR)
2E Lakshmi Apartments, Ist Seaward Road, Valmiki Nagar, Chennai 600041, Tamil Nadu, India
Email: leelaraj2004@gmail.com

Mosquito-borne disease research in India has remained stagnant for decades, and will continue to remain. This is so as the hard work in the field by entomologists has given way to comfortable work in air-conditioned laboratories, with computer as the main tool. Critical reviews are being written by men not of science, and also others, but our government totally ignores them.

There are many vector-borne diseases (VBD) prevalent in India apart from malaria and filariasis, such as the Kyasanur-forest disease (KFD), Japanese encephalitis, scrub typhus, dengue and chikungunya. The control of all of them depends on an understanding of the natural cycles and epidemiology of their vectors. Malaria, for example, is ideal model system for explaining VBDs, because quite a lot of fieldwork was done by scientists all over the world. Notable among them were Fred Soper, Paul Russell, Thammajirao Ramachandra Rao, and several others in preindependent India. Their endeavours had led to a clear understanding of the ecology and behaviour of the vectors involved, which helped in devising appropriate management measures.

The most important landmark in malaria control was achieved by biologists and naturalists with a deep understanding of the environment. The first and foremost among them was Ronald Ross, who discovered that mosquitoes transmitted malaria in 1897, who showed that the transmission was very significantly influenced by many factors, including human activity. The relationships between vector control and transmission among the mosquito vector, the parasite, the environment, and the behaviour of human carriers have been extensively studied by many in the preindependence days. They laid emphasis on the environment and how it contributed to malaria, as indeed all the other vector-borne diseases. The studies covered local vectors, ecology, demography, agriculture, and so on. They found that local environmental conditions contributed to the disease, especially in specific zones and the link between parasite transmission and vector control predicated a need to understand the other factors that led to malarial transmission. Paul Farr Russell was one of the pioneers, who studied malarial transmission. Nicolaas Hendrik Swellengrebel coined the term 'species sanitation' to link the carrier anopheline species with specific habitats, which explained the connection between ecology and malaria. Factors such as availability of local vectors, ecology, demography, race and culture of humans were identified as key players in the transmission of the disease. According to Ross, what was required was not the total elimination of mosquitoes, but a reduction in their numbers below a threshold, now referred as 'critical density'. Ross also identified the 'human factor' in the transmission. Malcolm Watson of the Federated Malay States (presently Malaysia), Paul Russell and T Ramachandra Rao in India demonstrated for the first time the validity of critical density of the vector.

In preindependent India, most of the notable contributions were made by scientists such as Muirhead Thomson in Assam, Robert Knowles Ronald Senior-White and colleagues in Orissa (now Odisha), Mandayam Osuri Tirunarayana Iyengar and R N Sen in Bengal, Russell and Ramachandra Rao in South India, D K Viswanathan and Ramachandra Rao in the old Bombay State, and B Ananthasamy Rao in the erstwhile Mysore State. They contributed considerably to our understanding of the bionomics and ecology of vectors such as *Anopheles culicifacies*, *A. stephensi*, *A. minimus*, *A. fluviatilis*, *A. philippinensis*, and *A. sundaicus* (Diptera: Culicidae). In India, the time between 1930 and 1945 could be regarded as the golden era of studies on the bionomics and ecology of malaria vectors. The work by the Malaria Institute of India under the leadership of Gordon Covell needs to be remembered in this context. During the late 1930s, Russell and Ramachandra Rao used pyrethrum as a space-spray against anophelines in the malaria-affected areas of Pattukkottai (Thanjavur district, Tamil Nadu) where irrigation practices were defective. Pyrethrum sprays were used within human residences against the

adult *A. culicifacies*. Spraying of pyrethrum extracts as mist inside human dwellings during daytime killed the resting adult mosquitoes. They extended their work to North Kanara district of the old Bombay State in 1945, a high malaria-prone area. Then DDT appeared on the scene and revolutionized malaria management when it was sprayed on the walls and ceilings of human dwellings because the vector mosquito rested there after an infected blood meal. This method was successfully used to protect civilian populations by Viswanathan and Ramachandra Rao in North Kanara in 1945 and Senior-White in Odisha. Almost simultaneously, B A Rao and his team trialled it successfully in other parts of the country. In 1946, Viswanathan and Ramachandra Rao launched one of the largest malaria control projects in the rural India, seeking to protect over a million humans in the North Kanara and Dharwar Districts in the erstwhile Bombay State, and it proved a crashing success. DDT sprays were ineffective here, because the vector *A. fluviatilis* usually rested outsided human residences.

During the initial years, the control programme was a tremendous success, and was hailed all over the world. All other methods of mosquito larval control, such as the use of *Gambusia affinis* (Cyprinodontiformes: Poecilidae), larvicides such as the Paris green, and environmental management were given up as they did not seem necessary. But in the mid-1960s, malaria came back with a bang. Owing to the euphoria created by the success of vector management of the early 1960s, malaria research, which should have been continued, had practically come to a standstill. The Indian Journal of Malariology, a well-respected professional journal, had apparently lost its relevance and ceased publication.

Work of Amar Prasad Ray, the architect of India's successful malaria control programme, matched the classic work of Fredrick Lowe Soper, American epidemiologist, who led the successful malaria control programme in the Panama Canal zone in the pre-DDT era. But Ray failed us in the most important aspect. He relied much on the efficacy of DDT and could not foresee vector adaptation to the chemical's pressure. But insect resistance to synthetic chemicals was not known then. The initial success of DDT made him think that there would be no further need for entomologists in mosquito control work. Many were either diverted to family-planning operations or had their services terminated. Only the junior-support field staff were continued with DDT-spraying programme. For this policy decision, India paid a heavy price. There were no trained scientists left to quantify the extent of damage done by DDT-resistant vectors and reinstate a policy to minimize damage.

As Ray himself pointed out, all major malaria vectors in the country became resistant to the two commonly used and comparatively inexpensive insecticides, the DDT and benzene hexachloride (BHC). When the incidence of the disease was at its lowest in 1964-1966, slackness in the allocation of funds and procurement of insecticides strongly prevailed, leading to inadequate and untimely spraying in India. India, like many other developing countries, almost and always followed the advice of the World Health Organization (WHO). The WHO recommended organochlorine insecticides (e.g., DDT, BHC) first, then organophosphorous insecticides (e.g., malathion), then carbamates, followed by synthetic derivatives. Newer methods of application were suggested with the existing insecticides. Use of insecticide-impregnated nets (IIN) or variations of it were recommended by the WHO. These were supplied by multinational companies, enabling them to make big profits. However they financed research projects in India through the WHO. Many foreign universities sought collaborations with Indian institutions. There were also field trials with different kinds of prophylactic drugs. The present-day malarial mosquito research has been going on for the last two or three decades, with scarcely anything of significance coming out of it.

Vaccine for malaria? How do we vaccinate our rural populations, about 300 million of who live in areas where they are exposed to infection? How long will it take for the best of vaccines to provide even partial immunity to our vulnerable population? Why do we find mixed infections with two or three species of parasites in the blood of the same individual? Immunity from the malarial parasite is incomplete, so the vaccine has to be excellent. Even the most severe case of naturally acquired malaria does not protect most people from a second round of infection. In 1980s, Adetokunbo Oluwole Lucas of Nigeria, then Director of the WHO Tropical Diseases Programme, in an informal discussion with the WHO Expert Committee on Vector Biology and Control in Geneva, commented that a "malaria vaccine was just round the corner, and the committee will be able to concentrate on the problems of the other vector-borne diseases within a foreseeable future or the committee can wind up their effort and simply go home". Lucas was well aware how much money was being invested on this research worldwide, especially in the United States, which had an abundance of expertise

and resources. More than 50 years later, we are no nearer a breakthrough, despite many of the world's leading institutions working towards a vaccine. It is possible that the microbiologists and immunologists will ultimately be able to produce such a vaccine but, highly likely we may need to wait for many more years. Undoubtedly, research on this subject has to be greatly accelerated and financially supported. But the interest of governments and public health professionals in effective malaria management has waned, same with Japanese encephalitis, dengue, and chikungunya, whereas recently the pandemic of Covid-19 has caught up with everyone's attention!

Lack of a trained humanpower to execute any meaningful research is the stark reality of the day. The work culture almost everywhere in India, including in research institutions specially created for research on vector-borne diseases, has lost its momentum owing to neglect, ignorance, and poor planning. Medical entomology in early days was pioneered by trained personnel equipped with instinctive knowledge on developing tools to prevent the spread various vector-borne diseases. Their expertise was critical in guiding vector management. Scientists toiled in the field, in rain and shine, to gather most-essential and basic information on mosquito behaviour and which anti-mosquito tools to be applied. The late T Ramachandra Rao wrote the trailblazing Anophelines of India.

Lack of appropriate measures to management of many of the Indian endemic diseases because of the ineffective application of known procedures and unwillingness to address the root causes of failure. Our management efforts need focus on operational investigations. Prompt diagnosis, immediate hospitalization, and supportive treatment of the afflicted are direly necessary. The WHO has to take the major blame for the failure of mosquito management over the years. There was a Vector Biology and Control (VBC) division with the WHO, which did high quality work in the past. This was renamed the Division of Molecular Entomology, presumably with vaccine development in view. The outcome changed unfortunately from the field-oriented work to a laboratory-oriented work. In many medical research institutions, the entomology division has been either progressively downgraded or systematically disbanded.

The National Vector Borne Disease Control Programme in India has been facing a staff crunch—many positions of entomologists remain unfilled. In 1985, the Vector Control Research Centre in Pondicherry started a 2-year master programme in Medical Entomology, initially supported by the WHO. The programme generated many well-trained entomologists. But it was discontinued in the late 1990s, because the graduates hardly found jobs in India. Another master programme in Public Health Entomology, was started a few years ago in the same institute. This programme may also be abandoned soon as the awarded title has not yet been recognized by any of the potentially employing institutions.

The epidemiology of any vector-borne disease is complex. The parasite or pathogen (be it a virus, a bacterium, a protozoan or a helminth), the mosquito, the human victim, and the environment are intimately interconnected. In the instance of malaria, four (now five) species of human plasmodia with differing biologies are involved, and so are the vectoring anophelines, each with its own peculiar bionomics and ecology. Human susceptibility to the disease also varies with the environment, race, and culture. And finally, the environment has an infinite variety of features. Most of the arbovirus diseases are zoonotic in their origin. The latter does not figure in today's research priorities in India. In the instance of two common vector-borne diseases, dengue and chikungunya, although there is evidence of a zoonotic cycle, no meaningful work has been done. The KFD-transmitted by ticks-and the scrub typhus-transmitted by mites-are reemerging in India. Birds and bats, both small and large, and wild and domestic, are involved in the transmission. The forest is one environment with many-unknown-vectors.

We can only aim at managing VBDs because their total eradication is almost impossible. The key is to hold the vector population below a threshold. To do this, we must know all aspects of the vector populations and their buildup, their drivers, further to the environment and human ecology. The role of field entomologists is absolutely crucial in VBD management. But it looks like field entomologists have lost their criticality in modern India, where they are subjugated by medical professionals and microbiologists, to whom 'field work' is an anathema!

Indian Journal of Entomology 84(1): 240 (2022)

Corrigendum on 77(4) 2015: page no. 406

In Indian Journal of Entomology volume 77 issue 4 of 2015 page no 406 Materials and Methods

para 2 the following statement "Five concentrations (5, 10, 15, 20 and 25ppm) were prepared in acetone" to be replaced with the following

Ten concentrations of 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 ppm were prepared in acetone.

para 2 the following statement "200 larvae for each concentration, with control" to be replaced with the following

"100 larvae for each concentration"

The error is regretted.

Indian Journal of Entomology 84(1): 241-243 (2022)

LIST OF REVIEWERS FOR INDIAN JOURNAL OF ENTOMOLOGY VOLUME 83, 2021

A Kalaisekar, Hyderabad
drkalaisekar@rediffmail.com

Abhishek Rana, Palampur
abhir1392@gmail.com

Ajay Sharma, Solan
ajaydivyam@rediffmail.com

Akash Nikoshe, New Delhi
akashnikoshe1596@gmail.com

Altaf H Mir, Kashmir
draltaf_786@yahoo.com

Amandeep Kaur, Ludhiana
amankaur17@pau.edu

Anil Jaiswal, Lucknow
jaiswalak59@gmail.com

Anil Kumar, Samastipur
agri_anil@rediffmail.com

Ankita Gupta, Bangalore
ankitagupta.nbaii@gmail.com

Anooj S S, Pathanakad
anooj227@gmail.com

A P Padmakumari, Hyderabad
padmakumariento@gmail.com

Aparna Kalawate, Poona
aparna_ent@yahoo.co.in

Arulprakash, Coimbatore
avrarulprakash@gmail.com

Arun Baitha, Lucknow
arun.baitha@icar.gov.in

Aruna Sri Issai, Hyderabad
issaiaruna@gmail.com

Arup K Sarma, Jorhat
ak_barbhagia@rediffmail.com

Ashirwad Tripathy, Ranchi
ashirwadaspire351@gmail.com

Avinash Chauhan, Nagaland
avi_shimla@hotmail.com

Ayan Das, Mohanpur
ayandasvb@gmail.com

Azariah Babu, Jorhat
azariah.babu@gmail.com

B Ram Prasad, Warangal
rampi_73@yahoo.com

Badal Bhattacharya, Jorhat
badalassam@gmail.com

Banka Kishore Reddy, Coimbatore
bankakishorereddy@gmail.com

Berin Pathrose, Thrissur
berin.pathrose@kau.in

Bhagyashree S N, New Delhi
bhagyashree.sn@gmail.com

Bhumika Kapoor, Jammu
bhumikakatra.gmail.com

Bindu Panickar, Navsari
bindu.ento@gmail.com

C Sushanth, Thiruvananthapuram
c.susanth@gmail.com

C A Viraktamath, Bangalore
chandrashekara.viraktamath@gmail.com

Chinna Babu Naik, Nagpur
chinnaenton@gmail.com

Chitra N, Coimbatore
chitra.bookworm@gmail.com

C P Srivastava, Varanasi
csrivastava63@gmail.com

D R Kadam, Parbhani
kdhiraj611@yahoo.co.in

D Sagar, New Delhi
garuda344@gmail.com

D Srinivas Reddy, Anantharajupetta
dsr2020@gmail.com

D. Raghavendra, New Delhi
raghuento@gmail.com

David K J, Bangalore
davidento@gmail.com

D B Sisodia, Anand
dbsisodiya@aau.in

Dilip M Damasia, Navsari
dilipdamasia_2008@yahoo.com

Divendar Gupta, Solan
divenderg@yahoo.com

Dushyant Raghav, Jharkhand
dushyantiari@gmail.com

G Anitha, Hyderabad
gorthianitha@gmail.com

G T Behere, Nagpur
ganeshbehere@gmail.com

Gagan Deep, Phagwara
gagandeepkm007@gmail.com

Gaurav Sharma, Dehra Dun
drgaurav.zsi@gmail.com

Gautam Kunal, Nadia
gautamkunalbg@gmail.com

Gavas Ragesh, Thiruvananthapuram
gavas.ragesh@gmail.com

Girish Maheswari, Agra
girish_maheshwari@yahoo.com

G K Mohapatro, Pune
gagan_gk@rediffmail.com

Gundappa B, Lucknow
gundu6100@gmail.com

Guru Pirasanna Pandi, Cuttack
guruagri@gmail.com

Harpal Singh Randhawa, Gurdaspur
harpals_randhawa@pau.edu

Haseena Bhaskar, Thrissur
haseena.bhaskar@kau.in

H K Singh, Nagaland
hemant.singh96@yahoo.co.in

H P Mishra, Bhubaneswar
hara_agri@yahoo.co.in

J Jayaraj, Madurai
vu2jrj@rediffmail.com

J Poorani, Tiruchi
pooranij@gmail.com

Jagdish Jaba, Hyderabad
j.jagdish@cgiar.org

Javaji Chandrasekar, Hyderabad
javajics@gmail.com

Jawala Jindal, Ludhiana
jawalajindal@pau.edu

Jemimah N, Hyderabad
jemimahjems27@gmail.com

Joseph Rajkumar, Kayamkulam
joecpcri@gmail.com

J S Kennedy, Coimbatore
jskennedy@tnau.ac.in

Jugal K Bana, Paria
jugalbana@gmail.com

K Rajmohana, Kolkata
mohana.skumar@gmail.com

K Selvaraj, Bangalore
selvaentomo@gmail.com

K V Raghavendra, New Delhi
raghavendrakv70324@gmail.com

Kailash Naga, Shimla
kailashnaga3j@gmail.com

Kariyanna B Desai, Raichur
kariannabento@gmail.com

Kausik Ghosh, Hooghly-
tokausik@gmail.com

K B Patel, Navsari
ketan_ento@nau.in

K D Prathapan, Thiruvananthapuram
prathapankd@gmail.com

Kesavan Subaharan, Bangalore
subaharan_70@yahoo.com

Kishore C Sahoo, New Delhi
kcsahoo1996@gmail.com

Kuldeep Sharma, Jabalpur
kuldeepagri09@gmail.com

K Vanitha, Puttur
vanis102@gmail.com

Lakshmi Narayanamma, Hyderabad
lakshmipalem9@gmail.com

Laxman C Patel, Burdwan
patel123lakshman@gmail.com

M Abas Shah, Jalandhar
mabas.shah@icar.gov.in

M Jaya Shankar, Bangalore
jay81zoology@gmail.com

M Kandibane, Puducherry
kandibane2015@gmail.com

M Ranjith, Shivamogga
ranjithagriofficial@gmail.com

Mani Chellappan, Vellayani
mani.chellappan@gmail.com

Manisegaran S, Madurai
dr.profsmanisegaran@gmail.com

Manishkumar Joshi, Sardarkrushinagar
mj1107006@gmail.com

Marudathurai, Goa
duraiento@gmail.com

Mayabini Zena, Cuttack
mayabini.jena@gmail.com

Md Golam Ferdous, Bangladesh
ferdous.kyorin@outlook.com

Md. Jafer Palot, Pune
palot.zsi@gmail.com

M J Venkatesha, Bangalore
venkatmelally@gmail.com

N Srinivas, Bangalore
nagappasrinivas@yahoo.com

N Sakthivel, Salem
drnsakthivelcsb@gmail.com

Narendra Kumar, Kolar
jbnarendra@gmail.com

Naresh Meshram, New Delhi
nmmeshram@gmail.com

Naveen Agarwal, Ludhiana
naveen_ag_in@pau.edu

Naveenkumar B Patil, Cuttack
patil2850@gmail.com,
nb.patil@icar.gov.in

Navjot Kaur, Ludhiana
navjotsandhu.pau@gmail.com

Neerja Agarwal, Kanpur
aneerja14@gmail.com

Nithya Chandran, New Delhi
nithyachandran@iari.res.in

N P Trivedi, Anand
nikhil@student.aau.in

N V Chalapathi Rao, Ambajipeta
chalapathirao73@gmail.com

P C Sharma, Palampur
prem_ento@rediffmail.com

P Santhakumar, Gurgaon
spshanthakumar@gmail.com

P Rajanikanth, Hyderbad
panugantirajanikanth@gmail.com

P S Sarao, Ludhiana
preetento@pau.edu

Pardeep Chuneja, Ludhiana
pkchhuneja@pau.edu

P C Rath, Cuttack
pcrath67@gmail.com

P R Shashank, New Delhi
spathour@gmail.com

Pradeeksha Shetty, Bangalore
pradeeksha.shetty@gmail.com

Prasannakumar N R, Bangalore
prasannakumar.nr@icar.gov.in

Pratibha Bhatnagar, Jabalpur
pratibhasfri1@gmail.com

Priyanka Koundal, Varanasi
priyanka10@gmail.com

Punithavalli M, Coimbatore
Punithaentomol@yahoo.co.in

R Ramani, Chennai
ramani_9@scientist.com

R Swaminathan, Udaipur
udaiswami57@gmail.com

Rachna Pande, Umiam
rachna.ento@gmail.com

Ramkumar, Pusa
rk440659@gmail.com

Ramneet Kaur, Patiala
ramneetkaur.in@gmail.com

Ranjeet Kumar, Bihar
rkipm06@gmail.com

Ravindranath, Solan
ravindernath131963@gmail.com

Reena Sinha, Jammu
bkreena12@gmail.com

Renu Gogoi, Guwahati
renugogoi39@gmail.com

Rezina Ahmad, Guwahati
rezina_2008@yahoo.com

R K Gupta, Jammu
rkguptaentoskuast@gmail.com

R M Wadaskar, Akola
rahulwadaskar@gmail.com

R N Borkakoti, Jorhat
rnbk.agri@gmail.com

Rojeet Thangjam, Mizoram
rojeetthangjam@gmail.com

Romila A K, Manipur
romi.ak9@gmail.com

Rubia Bukhari, Srinagar
rubiabukhari@gmail.com

R V Chandel, Palampur
visitrvchandel@yahoo.com

S Mohankumar, Coimbatore
smktnau@gmail.com

S Rajashekara, Bangalore
rajachandra3908@yahoo.co.in

S Ramesh Babu, Udaipur
babuento@yahoo.co.in

S Subramanian, New Delhi
entosubra@yahoo.co.in

S Vennila, New Delhi
svennila96@gmail.com

S M Gaikwad, Kolhapur
smg_zoo@unishivaji.ac.in

Sabu Thomas, Kozhikode
sabukthomas@gmail.com

Sachin Suroshe, New Delhi
sachinsuroshe@gmail.com

Sajad H Mir, Kashmir
drsajadento@skuastkashmir.ac.in

Sajan KC, Nepal
sajankc143@gmail.com

Samuel Tennison, Chennai
samtennyson@gmail.com

Sandeep Singh, Ludhiana
sandeep_pau.1974@pau.edu

Sandip Patra, Umiam
sandippatra47@gmail.com

Sanjeev K Kataria, Jalandh
k.sanjeev@pau.edu

Sankararaman, Annamalainagar
sankararaman05@gmail.com

Sekar J C, Hyderabad
javajics@gmail.com

Shalini Pandey, Jodhpur
pandeyshalini80@gmail.com

Shalini S, Bangalore
shalinis.nilavu@gmail.com

Shankar Ganesh, Coimbatore
shankarento@gmail.com

Shankar M, Nalgonda
shankar.ento2007@gmail.com

Shanowly M Ghosh, Kalyani
shanowly@gmail.com

Sharanabasappa, Shivamogga
sharanu.deshmukh@gmail.com

Shoumitra Das, Jabalpur
shoumitrad@yahoo.com

Shravan Haldhar, Manipur
haldhar80@gmail.com

S M Chavan, Valsad
sachinento@gmail.com

Snehal Chakravarthy, Varanasi
snehel.chak@gmail.com

Sonai Rajan, Coimbatore
snraja_insect@yahoo.co.in

Srinivasa N, Varanasi
srinivasa@bhu.ac.in

S S Hundal, Ludhiana
sshundal@pau.edu

Subash Singh, Ludhiana
subashsingh@pau.edu

Subramanian, Chennai
subbuka.zsi@gmail.com

Suby S B, New Delhi
subysb@gmail.com

Sudeshna Thakur, Ludhiana
thakursudeshna@gmail.com

Suja Srinivasan, Chennai
sujasree07@gmail.com

Sujayanad, Kanpur
sujay2020@gmail.com

Sujithra M, Kasaragod
amitysuji@gmail.com

Sunil Bhalkare, Akola
sunilento@gmail.com

Suresh Nebapure, New Delhi
smnebapure@gmail.com

Sushil Saxena, Navsari
saxenasushil2003@gmail.com

Sushma Deb, S K Nagar
debsushma@gmail.com

S V S Gopala Swamy, Bapatla
paulgopal2003@yahoo.com

T R Ranganath, Shivamogga
trranganath1@gmail.com

T Seenivasagan, Gwalior
seenivasagan@yahoo.com

Timmanna Nayaka, New Delhi
thimsento@gmail.com

V Sridhar, Bangalore
Sridhar.V@icar.gov.in

V U Sonalkar, Akola
vinodsonalkarpdkv@gmail.com

Varatharajan R, Manipur
rvrajanramya@gmail.com

Venkatesan T, Bangalore
tvenkat12@gmail.com

Vikas Jindal, Ludhiana
vikas_ento@pau.edu

Vikas Tandon, Palampur
tandonvikas8763@gmail.com

Vinay Singh, Bhatinda
vinayento@pau.edu

Vipin Chaudhary, Jodhpur
vipin-cima@yahoo.com

Vivek Shah, Nagpur
vivek4256@gmail.com

INDIAN JOURNAL OF ENTOMOLOGY (IJE) & ENTOMOLOGICAL SOCIETY OF INDIA (ESI) PUBLICATION ETHICS AND MALPRACTICE STATEMENT

The journal Indian Journal of Entomology (ISSN 0367-8288 for print and ISSN 0974-8172 for online) is published by the "Entomological Society of India", New Delhi, India and the website is www.entosocindia.org/ www.indianentomology.org

The Indian Journal of Entomology (IJE) strictly adheres to a publication ethics and malpractice statement as given below. It is largely based on the standard guidelines for journal editors developed by the Committee on Publication Ethics (COPE). Entomological Society of India, as a long standing published is committed to meeting high standards of ethical behaviour at all stages of the publication process. The guidelines given herein define the responsibilities of authors, peer reviewers and editors, and are impending by default. Anyone who believes that research published in the IJE is not in line with these principles should raise their concerns with the Chief Editor at email- entosocindia@gmail.com

1. Manuscripts submitted to our journal/s are evaluated entirely on the basis of their scientific content. All possible measures are taken to uphold the highest standards of publication ethics and to prevent malpractices. Authors who submit papers to our Journals attest that their work is original and unpublished and is not under consideration for publication elsewhere. In addition, authors confirm that their paper is their own original work that has not been copied or plagiarized, in whole or in part, from other works and if the authors have used the works of others the same has been appropriately cited or quoted. The submission platform has a statement that requires confirmation by authors that their submissions subscribe to the above requirements, and all authors by default confirm that these are adhered to while submitting a manuscript. Instructions to authors given in the website of the publishers i.e, Entomological Society of India- www.entosocindia.org at URL- http://www.entosocindia.org/instructions-to-authors.html or in the OJMS website: www.indianentomology.org

2. The Indian Journal of Entomology has an Editorial Board supervised/ governed by an Executive Committee of the Entomological Society of India (ESI), who are experienced entomologists who are holding/ held positions in Entomology and its academics/ professions, and are recognised experts. The details of these Executive Committee and the Editorial Board are available in the website of the publishers i.e, ESI - www.entosocindia.org-URL- http://www.entosocindia.org/executive-committee-.html, and http://www.entosocindia.org/ije-editorial-board-.html, respectively for more details; details of the Chief Editor are available in URL- http://www.entosocindia.org/chief-editor-profile-publications.html. These are also available in the OJMS website: www.indianentomology.org

3. Duties / Responsibilities of Editors- The Editorial Team of the ESI/IJE, comprising the Editorial Advisory Committee (EAC) for Publications is responsible for taking a decision as to which of the manuscripts submitted to the IJE are to be published. The members of the EAC have complete discretion to reject/accept an manuscript. The EAC may confer/deliberate with other reviewers/members in arriving at its decisions. The evaluation of manuscripts is made on the basis of their scholarly and intellectual content without having regard to the nature of the authors or the institution including gender, race, religious belief, ethnic origin, citizenship, or political philosophy of the authors. The IJE follows a policy of fair play in its editorial evaluation. The editors are expected to exercise caution and ensure that they have no conflict of interest with respect to the manuscripts they accept/ reject. The members of the EAC follow strict confidentiality and are required not to disclose any information about a submitted manuscript to anyone other than the corresponding author, reviewers and the ESI. Authors are encouraged to correct the errors which are found during the process of review while preserving the anonymity of the reviewers.

4. Duties/ Responsibilities of EAC/ Reviewers- Editorial decisions are based on peer review. The reviewers are expected to maintain absolute confidentiality with regard to the contents of manuscripts. The reviews are conducted objectively and the referees are expected to express their views clearly with supporting reasons. The reviewers should have no conflict of interest with the authors and the subject matter of the research. The reviewers are required to identify relevant published work that has not been cited by the authors. Any observation or argument which has been previously reported should also be accompanied along with the relevant citation. Similarities or overlaps between the manuscript under review and any other published paper of which the reviewer may have personal knowledge, may also be brought to be attention of the members of the EAC. The information or ideas obtained through peer review are of a privileged nature and these are kept confidential and not used for personal advantage. Reviewers are informed not consider manuscripts in which they have conflicts of interest resulting from competitive, collaborative or other relationship with any of authors or institutions connected to the papers.

5. Duties/ Responsibilities of the Authors- Authors are required to present an accurate account of the original research work and also an objective discussion of its significance. Authors are instructed to note that the manuscript should contain sufficient details of the literature and references. It is expected that all the authors have significantly contributed to the research. Fraudulent and knowingly made inaccurate statement constitutes unethical behaviour and would be unacceptable. Authors are required to ensure that the submitted work is original and has not been published elsewhere, and if the authors have used the work of others the same has been appropriately cited or quoted. It is ensured that the applicable copyright laws and conventions are followed.

Copyright materials are reproduced only with permission and due acknowledgement. Authors are not expected to submit manuscripts describing essentially the same research in more than one journal. Submitting the same manuscript to more than one journal concurrently is considered unethical practice and is not unacceptable. It is ensured that proper acknowledgement of the work of others is always made. The format and style to be followed is given in the website of the publishers i.e, ESI- www.entosocindia.org- See URLhttp://www.entosocindia.org/instructions-to-authors.html or in the OJMS website: www.indianentomology.org

Authors are made to know that authorship should be limited to those who have made a significant contribution to the paper which is submitted for publication, and those who have made significant contributions are listed as co-authors; and others who have participated in certain substantive aspects in the development of the paper are acknowledged. The corresponding author is directed to ensure that all co-authors are included in the paper, and that the co-authors have seen and approved the final version of the paper and have agreed to its submission for publication. Authors are suggested to enlist all sources of financial support. Upon discovery of any significant error in the published work, authors are informed that it is their responsibility to promptly notify the editors and cooperate in the retraction or correction of the paper.

Manuscripts published in the IJE report the results of research done by the authors and this is made aware to the authors. Mention of a proprietary product/ commercial formulation/ pesticide does not constitute recommendations/ endorsement by the ESI/ EAC for its use in any form. Use of registered trade names/ trademarks etc., in the manuscripts even without specific indications thereof, unless otherwise stated and solely reflect the individual views of the authors and not necessarily any official view of the IJE/ ESI. The IJE/ ESI assumes no responsibility for the contents/ completeness/ views/ other items/ accuracy of the conclusion reported in the manuscripts by the authors. Any submissions made is subject to the above statement and authors submitting manuscripts are taken as endorsing these.

Any fees or charges that are required for manuscript processing and/or publishing materials in the journal is stated under Instructions to authors/ Article Processing Charges in the website of the publishers under URL- http://www.entosocindia.org/instructions-to-authors.html or in the OJMS website: www.indianentomology.org. Before authors begin preparing their manuscript for submission, authors are instructed to peruse these. The authors are obliged to participate in peer review process. While submitting authors are also made to note that all authors have significantly contributed to the research; are obliged to provide retractions or corrections of mistakes; provide details of list of references, financial support; and are forbidden to publish same research in more than one journal.

6. Peer-review process- The manuscripts published in the IJE are subjected to peer-review through obtaining advice on individual manuscripts from reviewers/ experts in the relevant field of Entomology, in additions to by the subject/ section editors as described in the ESI website www.entosocindia.org- URL- http://www.entosocindia.org/instructions-to-authors.html; - also See URL- http://www.entosocindia.org/executive-committee-.html; http://www.entosocindia.org/ije-editorial-board-.html; http://www.entosocindia.org/chief-editor-profile-publications.html. As stated under Duties/ Responsibilities of EAC/ Reviewers (column 4 above), judgements made are objective, with requirements of reviewers filling up a prescribed manuscript review format; reviewers have no conflict of interest; and it is informed that reviewers should point out relevant published work which is not yet cited, and the reviewed manuscripts are to be treated confidentially.

7. Publication ethics- Publishers, the ESI/ executive committee/ EAC/ editors take reasonable steps to identify and prevent the publication of manuscripts where research misconduct has occurred; in no case encourage such misconduct, or knowingly allow such misconduct to take place. In the event that the publisher ESI/ executive committee/ EAC/ Chief Editors/ Subject Editors are made aware of any allegation of research misconduct, deal with allegations appropriately; also in the event of such allegation follow guidelines for retracting or correcting articles when needed; also always willing to publish corrections, clarifications, retractions and apologies when needed.

8. Copyright and Access- the copyright of the IJE is with ESI and this information is clearly described on the Journal/ web site. - The way(s) in which the Journal and individual articles are available to readers and associated subscriptions, or pay-per-view fees are stated in the Journal/ website prominently.

9. Archiving- the IJE is having its electronic backup in its online platform www.indianjournals.com, and access to the journal content in the event a journal is no longer published shall be clearly indicated in the form of archive therein/ relevant websites.

10. Principles of transparency and best practice in terms of Ownership and management, website, publishing schedule, name of Journal/ other details is indicated in the website of the ESI i.e., www.entosocindia.org in addition to publishing the same in the Journal appropriately. The owner of the Journal is ESI and these ownership and/or management details are clearly indicated on the Journal/ website. This website, including the text that it contains, takes care to demonstrate the high ethical and professional standards, and the periodicity of the Journal i.e. it is quarterly. ESI does not use organizational names that would mislead potential authors and editors about the nature of the journal's owner. The name of the Journal i.e., Indian Journal of Entomology is unique and it is in publication from 1939 onwards, it is unique (ISSN 0367-8288 for print and ISSN 0974-8172 for online), and there exists no confusion with another journal. The Journal's origin is depicted in the ESI website or alternatively in the OJMS website: www.indianentomology.org.

The Entomological Society of India

INSTRUCTIONS TO AUTHORS

(EFFECTIVE 1ST APRIL 2022)

Submit your findings to IJE, refer www.entosocindia.org/ www.indianentomology.org for details

The Entomological Society of India (ESI) was founded in 1938 as a registered society under the Societies Registration Act 1957 as extended to the Union territory of Delhi under Registration No. S. 2434 of 1963-64 dt. 12.3.1964. It is registered with NITI Aayog under unique ID of VO/NGO-DL.2016/0104219. It is one of the largest professional societies in India serving entomologists and researchers in related disciplines.

Indian Journal of Entomology, originated in 1939, is a leading journal in entomological science published quarterly by The Entomological Society of India. The ownership of the Journal is with the Entomological Society of India, and it is solely handled by the Chief Editor. Its ISSN reference number is ISSN 0367-8288 for print and ISSN 0974-8172 for online. The Society invites and accepts contributions from the members. After requisite peer reviewing, it publishes original articles and reviews 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 modelling. The Journal covers mites, ticks, spiders and other arthropods and at thises verteb rate pests as components of Entomology. Review articles, if up to date and current are welcome. Review Editors of the Journal are soliciting reviews exempted from article processing charges and these can follow the journal format as given below:

Type of Articles

- **Research Article:** Report original observations and experiments, the results of the experiment, and a discussion of the significance of the results. There is no word limit for research articles.
- **Research Communication:** Research communications (not exceeding 2000 words) contain important new findings that are novel and of broad interest. They should include a brief abstract and an introductory paragraph. Text should NOT be broken up under subheads like Materials and Methods, Results and Discussion etc., otherwise same as that of Research articles.
- **Review:** The review editors solicit reviews from those who have major contributions in the field of insect science. Although reviews are usually invited, non-solicited reviews will also be considered and authors wishing to present such reviews should contact the Chief Editor/ Review Editors in advance (word count can be 3000 to 7000).
- **Perspective** and **Opinion** are also published occasionally as contributions from industry or experts.

All the research articles/ communications should be original, indicate period (years) of experimentation, based on data of minimum two years, must not be the work of more than 5 years old. Those with one year data in a field trial/ other experiments with limited data (in the form of a research communication) will also be considered by the Journal subject to discretion of the Editorial Board.

The reviews, research articles, and research communications should not be >30, 20 and 7 typed pages including tables and figures, respectively. This page limit is only indicative, and subject to discretion of the Editorial Board. British spellings should be followed. Check adhering to the journal format - ABSTRACT, MATERIALS AND METHODS, RESULTS AND DISCUSSION, separate "Conclusions" NOT allowed. Articles should be computer-typed (Times New Roman, font 12), double spaced throughout on A-4 size, portrait, all around 1" margins, in MS Word. Avoid unnecessary italics (only scientific names in italics, all others normal), unnecessary bold (only title, author names, subheadings like MATERIALS AND METHODS, RESULTS AND DISCUSSION, REFERENCES, ACKNOWLEDGEMENTS, FINANCIAL SUPPORT, AUTHOR CONTRIBUTION STATEMENT, CONFLICTS OF INTEREST / COMPETING INTERESTS in bold). Hardcopies of articles, CD/ floppy are not accepted. Submissions are not accepted solely over email. The hard copy/ CD submissions are now replaced with ONLINE submission of files in the online platform (www.indianentomology.org) of the Society. Immediate charges to the online plateform and submissions are forthcoming and authors are required to peruse these from website before submission. Softcopies of the articles submitted in the online platform may be additionally submitted along with

article submission reference number in email of the Society (entosocindia@gmail.com). Figures which may require a specific resolution in >250 dpi, are to be sent over the above referred email of the Society.

After submissions, authors are necessarily required to look into their email/ society or our OJMS website for communications from the Society, with peer review/ reviewer comments/ online reviews. Online first previews are published as PDFs with eRef. No. and doi number. Authors must peruse such updates and respond promptly. The Journal/ Society will not be responsible if authors fail in this. When revising articles after peer review, all queries marked in the annotated MS by editor/ reviewer(s) must be replied, along with a compliance statement, and returned back promptly within 60 days. If not adhered to this timeline, it will be considered as NEW SUBMISSION. The priority date for publication is the date on which the revised MS is received and date of fulfilling the article processing charges/ membership. Authors are directed to expedite these in the interest of quick publication of their articles.

The Society has a platform of "PREVIEW" for the papers for Online First pdfs with eRef. No. and doi, and on open access. Authors are to keep abreast of the announcements in this regard in the ESI website: entosocindia.org or OJMS website at indianentomology.org. Authors must use this for all purposes as proof of publication and send the corrections/ comments if any, within a fortnight of this online publication. Also, the Journal is making efforts for improvements in these processes which might require authors' response; the authors have to continuously peruse the websites for further details. From 2019 all articles published are subjected to JATS (Journal Article Tag Suite)- an XML format used to describe scientific literature published online. The benefit of XML is that files are machine-readable and searchable. This means that these files can be accessed, read and indexed by the search engines (including Google Scholar, Bing, Google, etc.), which will improve the citation of the Journal.

Each author must be member of the Society (annual subscription fee Rs. 1000/- per member; for new members admission fee of Rs. 100 and membership form duly filled in are required). For each article a processing fee of Rs. 1000/- is to be paid. Overseas articles are encouraged, given priority and a lumpsum processing charge of US $ 100/ paper is charged usually; there are waivers for these, which can be enquired over email after making online submissions. Immediate charges are forthcoming and authors are required to peruse these from website. Watch the website for updates on the membership forms and payments online. These charges may be also paid in exceptional cases by demand drafts/ multicity cheques drawn in favour of "Entomological Society of India." payable at New Delhi. For payments online with credit/debit/NEFT etc. an online link with ICICI EASYPAY is available on the website under membership Tab. The Journal is migrating to a new System of APC (Article Processing Charges) and w.e.f. 1.04.2022 authors are required to peruse these from the websites.

Article Processing Charges (APC)

The following article processing charges (APC) for publication in IJE are effective 1st January/ April 2022. The Journal is transforming into an open access peer-reviewed one from 1st January 2022, and APC will be charged from authors. The APC is estimated on the number of pages of publication, and is based on the standards of income in developing countries. The APC includes an annual membership fee of the Entomological Society of India for first/ corresponding authors (who are presently not members) as preferred by the authors. The Journal is also committing publication of the article (after due peer review etc) within a period of six months of submission/ three months of acceptance with the payment of APC.

The following charges are applicable for the accepted articles in IJE effective 1st January/ April 2022*:

Categories	Charges (Non-members)	Charges (Members)
Full length articles: Research Article, Research Communications and Reviews (< 36 printed pages).	INR 7,000/USD 120	INR 5,000/USD 100
Monographs (Articles of 36 printed pages or more, up to 64 pages). Special issues or larger issues will be calculated on a case-by-case basis.	INR 15,000/USD 300	INR 10,000/USD 250

*Includes an annual membership fee of the Entomological Society of India (ESI) for first/ corresponding author; the rates given in US $ is for the overseas submissions.

The APC are calculated considering various situations, including ability to pay for publication for those who

are unaided or underfunded; also taking into account the production expenses (to break even), and as incurred now. Waiver of APC in full or partially in some cases like those of authors/ students from developing countries/ overseas is under consideration. Please write to the Chief Editor upon acceptance of the article with details. Visit the website of the ESI for details. Invited submissions are exempted from this totally.

Authors have the options to follow the above new system/ continue with existing guidelines until 30th April, 2022.

All submissions are to be made online through online submission system i.e., www. indianentomology.org, which also serves as the online peer review system. Authors to note that www. indianentomology.org and its role stops with online submission. Immediate changes are forthcoming and authors are required to peruse these from website as regards Article Process changes. Authors are directed to use website ESI website: entosocindia.org or OJMS website at indianentomology.org for all purposes. Submissions in the old system at indianjournal.com will not be entertained w.e.f. 1.4.2022 For follow up like membership/ processing fee/ other details the authors are required to refer the website of the Society i.e., www.entoscindia.org. Details, including bank details for payment are available herein. In case of online payment, it is essential to send transaction details along with Membership form (for new members) once payment is done, only then receipt will be sent. These transaction details, membership form etc., can be sent in the email of the Society i.e., entosocindia@gmail.com. The postal address for the sending of DD/ Cheque is Entomological Society of India, Division of Entomology, IARI, New Delhi 110012. Authors to note that a convenient payment gateway with ICICI is now available on the website and authors are urged to use this facility. Immediate charges are forthcoming and authors are required to peruse these from website.

The following are the detailed guidelines for the submissions
Submissions not adhering to these will be summarily rejected

For Research Article

ARTICLE TITLE should be short, specific and informative. It should include the name(s) of author(s), affiliation (institution/ university, and these without abbreviations to be given in full), and mailing address (PIN CODE is must), with Email of corresponding author (other email, fax and phone numbers NOT allowed). Authors are to include their 16-digit ORCID id in the line after email: If authors doesn't have ORCID, register at https://orcid.org/ and get the ID, it is free of cost. Preferably a running short title not >40 characters can be given. By-line should contain the place (organization) where the research was conducted. Author names to be without any titles like Mr. Ms. Dr., etc, and professional affiliations like Professor (official positions NOT to be included). If essential, these can be given as footnotes separately. Must use only superscripts of numerals for indications, no other diacritic marks/ symbols allowed; no foot notes to be used for this purpose, all to be brought along with address. Authors have to refer the recent issue of the Journal for following these carefully and may contact over email for any specific queries. Title and authors' names are to be in uppercase capitals, with corresponding author clearly indicated. Authors are directed to peruse the Online First from the website or current issue of Journal for adhering to the format fully.

ABSTRACT written in complete and simple sentences, should not be >150 words. It must be true summary of what is given in the results as important findings, introductory is not to be part of this. Key words (ten to fifteen) must be given; include only words which are not present in the title and these should appear just beneath the abstract.

INTRODUCTION must be brief and limited to the problem or the aim and scope of the experiment. It has to be without any title heading. No irrelevant/ unwanted things, only one or two sentences on general introduction to be given and straight come to the importance and focus of the article in as less space as possible. Only relevant current references to be cited herein. Must end with a sentence stating the present study- why done, and what is covered.

MATERIALS AND METHODS must include experimental design and the technique(s) used along with appropriate statistical methods used along with the year of experimentation (field and laboratory). More than five years old data not accepted. Must provide where work was conducted (with GPS data), experimental details like treatments, doses, replications, and in field experiments- the plot size, crops' variety, season, spacing etc., design,

statistical analysis and its software version to be included. Check for details like °C (proper use), RH in laboratory experiments, also whether standard methodology is given (But not explained too elaborately - citing standard reference will be enough; formula like the one for working out % to be avoided). Routine/ standard methodologies to be brief. No need of figures for these. Trade names alone are NOT entertained in chemicals/ insecticides. Authors are directed to pay attention to the Disclaimer Statement given in the journal.Subheadings/ Tables NOT allowed herein. The scientific names/ identification of species included in the articles must be authentic. In their own interest authors are instructed to get/ ensure proper identification of species names included in the articles. Ensuring due credit to the experts who assisted in this process is advised. The deposition of voucher specimens in renowned repositories is mandatory and is advised before such submissions are made to the Journal. Articles with new species/ genus/ other taxa descriptions must include Zoo Bank registration details with registration number and date. Authors are directed to not use the common names of insects/ others, except for the first mention is abstract and body of the text, and alongwith full scientific names with author. All subsequent usage should be only scientific names

RESULTS AND DISCUSSION should be combined, to avoid repetition. Results should be supported by brief but adequate tables or graphic or pictorial presentations, wherever necessary. Self-explanatory tables should be typed on separate sheets; tables should fit in the normal page lay-out. All recent relevant literature should be discussed critically. All figures including drawings, graphs and diagrams should be formatted preferably in MS Word. If drawn in Excel, the data file may also be submitted along with graphs. Scanned images of photographs must be on quality glossy paper (if send in hard copy), and softcopy should be in separate file (minimum 300 dpi resolution), in jpeg or tiff format. Hardcopies are to be avoided. Line drawings and photographs should have legends. Figures to be reduced to smallest optimum size, arranged in as less space as possible and continuosly numbered. Use of word PLATE not allowed. Repetition in graphic and tabular matter ought to be avoided. Verbatim reproduction of all data included in Tables in the results is not allowed; only highlights and significant results are to be included in the Results and Discussion. It is advisable to place all tables and figures after the references at the end. While submitting images in soft copy required minimum resolution of 250 dpi must be adhered to.

ACKNOWLEDGEMENTS to follow current style as practiced in the Journal, check for uniformity, and brevity.

FINANCIAL SUPPORT. Authors must acknowledge financial support received in clear terms here under separate heading. This has to be avoided under acknowledgements.

AUTHOR CONTRIBUTION STATEMENT. Authors must provide a short description of the contributions made by each listed author (please use initials). This will be published in a separate section in front of the Acknowledgments. For example: AM and DB conceived and designed research. AM and BB conducted experiments. GR contributed new reagents and/or analytical tools. AM, BB and GR analyzed data. AM wrote the manuscript. All authors read and approved the manuscript.

CONFLICTS OF INTEREST / COMPETING INTERESTS. Authors must declare if any conflict of interest exist as a separate document along with the article. If it does not exist this must be clearly stated herein.

REFERENCES. Journal follows almost the universal style, with journal names given in full as given below: Research article- Khandelwal P, Choudhury D, Ajanta B, Reddy M K, Gupta G P, Banerjee N. 2004. Insecticidal pilin subunit from the insect *pathogen Xenorhabdus nematophila*. Journal of Bacteriology 186(19): 6465-6476. Proceedings/ Seminar/ Conference papers- Rembold H, Forster H, Czoppelt C H. 1987. Structure and biological activity of azadirachtins A and B. Proceedings. Third neem conference, Nairobi, 1986. pp.149-160.

Book and chapters- Painter R H. 1951. Insect resistance in crop plants. McMillan Company, New York. 520 pp. 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, R D Chancellor (eds.). Eagle Studies. World Working Group on Birds of Prey (WWGBP), London. 670 pp.

Internet resources- Author. Year. Title of website, database or other resources, Publisher name and location (if indicated), number of pages (if known). Available from: http://xxx.xxx.xxx/ (Date of access). The authors are required to verify that the included references are cited in the text, and those that are cited are listed alphabetically in the REFERENCES Section. References from the recent five years period should be atleast 25% of all references.

Authors must take enough care to follow spacing, full-stop, colon, semi colon, comma etc., as per journal format. The format and style for listing to be strictly adhered to, for which current issue/ online first published papers from website can be referred. Any submission found lacking in these basics will be summarily rejected.

For Research Communication

Authors to follow the above instructions in full, except that it will have no headings like Materials and Methods and Results and Discussion but these to be provided in separated paragraphs. In all other aspects the format is same as the Research Article.

For Review

Except for Materials and Methods/ Results and Discussion (no such headings will be there) these are same as above. Authors to peruse the Reviews published in the current issue/ online published once from website for strict adherence. Reviews must subscribe to the prerequiste of plagiarism check and a check report to be appended alongwith submission. Invited Reviews also follow these guidelines.

Submissions must adhere to the above instructions. Authors are required to peruse the publication ethics/ essential requirements given under the "Ethics and malpractice statement" of the Journal. This statement covers details about the publisher, nature of manuscripts published, editorial board, executive committee, duties and responsibilities of Chief Editor/ Editorial Board/ Reviewers and Authors, Peer Review process, Publication ethics, Copyright access, Archiving, Principles of transparency, Best practices, Ownership and such aspects of Journal publishing. This statement is published in every issue and also available in the website of the Society. Submissions are acknowledged/ processed with the understanding that authors subscribe to the ethics/ requirements by default. Articles not adhering to the above are liable to be rejected. Authors can contact the Chief Editor for any queries/ grievance etc., at the Email- entosocindia@gmail.com

IMPORTANT- Before submitting articles or initiating/ renewing membership first peruse the details from the website www.entosocindia.org or the OJMS website: indianentomology.org. Article submissions are mandatorily to be online at the OJMS website: indianentomology.org (it is the online peer review platform). Acceptance of submission/ priority for publication is subject to fulfilling the requirements of article processing charges and membership requirements of the Society. It is essential for authors to peruse the website/ their email continuously, after submission to get to know the progress/ attend to details that will arise in the publication of their articles. Communications related to these may be addressed to: The Chief Editor, Entomological Society of India, Division of Entomology, IARI, Pusa, New Delhi-110 012 and at Email- entosocindia@gmail.com

For overseas transactions

SWIFT SBININBB550, State Bank of India, Ajmal Khan Road, Karol Bagh, New Delhi- 110005, India. A/C name: Entomological Society of India Current Account No. 11084230887 at State Bank of India, NSC Bheej Bhavan, Pusa campus, New Delhi110012 (IFSC Code SBIN0005389, if required).

For domestic transactions

For Online/ NEFT payments the details are as follows: State Bank of India, NSC Bheej Bhavan, Pusa campus, New Delhi-110012, A/C name: Entomological society of India, Current Account No. 11084230887. IFSC code: SBIN 0005389. For one stop/click payment nodes, now a link is available with ICICI payment gateway (PAY NOW) See under Tab-Membership in the website of the Society. Authors are encouraged to use this for convenience. This payment link is available under Membership/ Fellow Heading. NEFT/ SWIFT transactions are to be followed up with communication of the transaction/ other details in Email entosocindia@gmail.com

THE ENTOMOLOGICAL SOCIETY OF INDIA

www.entosocindia.org

Founded 1938

Official Publication: Indian Journal of Entomology

(website: www.indianentomology.org)

Subscription Details

			Online (only pdf)	Online + Print
Indian (Individual)- Member (Ordinary)	:	Rs. 1000 + Admission Fee Rs. 100/-**	Rs. 1000**	Rs. 2500**
Life Member	:	Rs. 15000 (Rs 5000/- for first five years + Rs. 10000/- fee for life member)		
Foreign (Individual)- Member (Ordinary)	:	US $ 100***	US $ 100/- ***	US $ 300***
Life Member*	:	US $ 1000***		
Institutional/Libraries- Indian	:		Rs. 6000**	Rs. 6500**
Foreign	:		US $ 600***	US $ 700***

Payments can be made by bank draft/ multicity cheque in favour of Entomological Society of India. Payable at New Delhi

* Life Membership will be declared after completion of five years of ordinary membership. (This condition is relaxed at present for a specific period as per Executive Committee decision).

** For online payment within India- State Bank of India, NSC Beej Bhavan, Pusa Campus, New Delhi- 110012. Pay Now (ICICI payment gateway) link is now available. See the website: www.entosocindia.org under Tab Membership/ Fellow.

Current A/c No. 11084230887, IFSC Code SBIN0005389. A/c Name–Entomological Society of India.

*** Overseas payment- State Bank of India, NSC Beej Bhavan, Pusa Campus, New Delhi- 110012, India, Current A/c No. 11084230887 IFSC Code SBIN0005389. A/c Name–Entomological Society of India, SWIFT- SBININBB550, State Bank of India, Ajmal Khan Road, New Delhi 110005, India

The Entomological Society of India
Division of Entomology, IARI, New Delhi-110012
Email: entosocindia@gmail.com

Membership Form*

(Membership fee/processing fee for manuscript)

To
The General Secretary
The Entomological Society of India, Division of Entomology
IARI, New Delhi-110012

Are you a new or Existing member?

□ New Membe □ Indian- Member (Ordinary) □ Foreign- Member (Ordinary)

□ Indian- Member (Life) □ Foreign- Member (Life)

□ Existing Member □ Indian- Member (Ordinary) □ Foreign- Member (Ordinary)

Dear Sir,

Please enroll/ renew me as Member (Ordinary)/ Life Member of the Entomological Society of India. I agree hereby to abide by the Rules and Regulations of the Society.

□ I remit Rupees/ US Dollar_____ by Cheque/NEFT/UPI/Cash as my Admission Fee (Rs./US $._____) and Subscription (only pdf) Rs._____ for the year _____

□ I remit Rs. 1000/- by Cheque/NEFT/UPI/Cash as processing fee for the manuscript. It is certified that the manuscript has been online submitted in www.indianjournals.com. The manuscript is also uploaded as attachments in the website www.entosocindia.org

□ The transactions details are being sent by email (entosocindia@gmail.com)

Name in Block letters Dr./Mr./Miss/Mrs._____

Date of Birth_____ Educational Qualifications_____

Profession or Designation_____

Address 1_____

Address 2_____

COUNTRY _____STATE _____PIN CODE_____

Phone (O):_____ (R):_____(Mobile) :_____

E-mail_____

Place_____ Date _____

Yours truly,

Note: Please Print, avoid handwriting *See website for recent changes and new directions

Signature

Registered with the Registrar of Newspaper for India under No. R.N. 17615/69

Indian Journal of Entomology

Vol. 84 **March 2022** **Part 1**

CONTENTS

Research Article

Research Communication

Published by the Entomological Society of India, Division of Entomology, Indian Agricultural Research Institute, New Delhi 110012 and Printed at New United Process, A-26, Naraina Indl. Area, Ph-II, New Delhi 110028; Ph.: 9811426024

Indian Journal of Entomology is now open access and its website is indianentomology.org which has all details required for a Journal's website. The journal is online at indianjournals.com. It is listed in Clarivate Analytics/ Web of Science Masterlist, and UGC and NAAS. The papers published in this journal are selectively abstracted/ indexed in Zoological Record; CAB Abstracts, CAB International, Wallingford, U.K; also CrossRef, Agricola, Google Scholar, CNKI Scholar, ICI, Indian Science, and Indian Citation Index. Also indexed in Electronic Magazine library, Max Planck Institute for Bildungsforschung, Berlin; and EBSCO*host* global library database, USA. It is UGC approved. Each paper bears a doi number to facilitate online identity and access. The journal articles are also subjected to JATS Conversion from 2019 onwards.

STATEMENT ABOUT OWNERSHIP AND OTHER PARTICULARS ABOUT INDIAN JOURNAL OF ENTOMOLOGY

FORM-IV

(See Rule 8)

1.	Place of Publication	New Delhi
2.	Periodicity of its Publication	Quarterly
3.	Printer's Name Nationality Address	Dr. V. V. Ramamurthy Indian Entomological Society of India Division of Entomology Indian Agricultural Research Institute New Delhi 110 012 email: entosocindia@gmail.com website: www.entosocindia.org indianentomology.org
4.	Publisher's Name Nationality Address	Dr. V. V. Ramamurthy Indian Entomological Society of India Division of Entomology Indian Agricultural Research Institute New Delhi 110 012 email: entosocindia@gmail.com website: www.entosocindia.org indianentomology.org
5.	Editor's Name Nationality Address	Dr. V. V. Ramamurthy Indian Entomological Society of India Division of Entomology Indian Agricultural Research Institute New Delhi 110 012 email: entosocindia@gmail.com website: www.entosocindia.org indianentomology.org
6.	Name and addresses of individuals who own the newspapers and partners or shareholders holding more than 1% of the total capital	The Entomological Society of India (Registration No. S 2434)

I, Dr. V. V. Ramamurthy, hereby declare that the particulars given above are true to the best of my knowledge and belief.

Sd/- V. V. Ramamurthy

Dated: 1st March 2022

Signature of the Publisher