FAUNISTIC STUDIES ON HAIRY CATERPILLARS (LEPIDOPTERA: NOCTUOIDEA) IN DIFFERENT CROPPING ECOSYSTEMS

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DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE, SHIVAMOGGA

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JUNE, 2016

Affectionately
Dedicated
To
My Beloved Parents
BASAVARAJ WARAD
And
BHAGYAMMA
&
ALL MY TEACHERS

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE, SHIVAMOGGA

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SHIVAMOGGA - 577204

CERTIFICATE

This is to certify that the thesis entitled **"Faunistic studies on hairy caterpillars (Lepidoptera : Noctuoidea) in different cropping ecosystems"** submitted in partial fulfilment of the requirement for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL ENTOMOLOGY,** to the University of Agricultural and Horticultural Sciences, Shivamogga, is a record of research work done by **Mr. MALLIKARJUN WARAD., ID.NO. MA1TAD049** during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Shivamogga

June, 2016

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3. **(K. S. SHESHAGIRI)**

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"Nature gives everything for your need but not for your greed"

- Dr. A. P. J. KALAM

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Shivamogga
June, 2016 ***(MALLIKARJUN WARAD)***

FAUNISTIC STUDIES ON HAIRY CATERPILLARS (LEPIDOPTERA: NOCTUOIDEA) IN DIFFERENT CROPPING ECOSYSTEMS

MALLIKARJUN WARAD

ABSTRACT

Investigations were made on faunistic studies on hairy caterpillars (Noctuoidea: Lepidoptera) in different cropping ecosystem. Among lymantrid hairy caterpillars reared, *Euproctis* was documented to feed on banana and paddy, *Lymantria* on castor and *Perina* on fig and one wingless species from *Mimosa pudica* which was not identified to species level. Among arctiids *Creatonotus* was documented from cocoa, *Utetheisa* from sunhemp, *Spilarctia* from castor and *Pericalia* from pigeonpea. *Estigmena*, *Argina, Amerila*, *Asura*, *Amata* were collected from light traps. Seven unidentified species were also recorded on different hosts. Biology of the Bihar hairy caterpillar, *Spilarctia obliqua* reared on field bean leaves revealed that the eggs were creamy white became pale yellow in colour. The number of eggs per mass varied from 148 to 232 in batches. Egg period, larval and pupal period varied from 5 to 6, 20 to 21 and 8 to 9 days, respectively. The average eggs laid by a female moth was 148 - 232. The length of male and female moth varied from 51 to 55 mm and 55 to 59 mm, respectively. The total life span of male and female ranged from 37 to 42 days and 39 to 44 days, respectively. Variation in morphological and genital characters of adults were studied in all the collected species of hairy caterpillars. Based on these variations, an illustrated key was prepared for families of super-family Noctuoidea, sub-families of Erebidae and to the genera of twelve species of hairy caterpillars. The developed illustrated identification key may be useful for identification of important adults of hairy caterpillars occurring in this region.

June, 2016
Dept. of Agril. Entomology
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Dr. Kalleshwaraswamy, C. M
(Major Advisor)

ವಿವಿಧ ಬೆಳೆ ಪರಿಸರದಲ್ಲಿ ಕಂಬಳಿ ಹುಳುಗಳ (ನಾಕ್ಟುಆಯ್‌ಡಿಯೇ : ಲೇಪಿಡೊಪ್ಟೆರಾ) ವೈವಿಧ್ಯತೆಯ ಅಧ್ಯಯನ

ಮಲ್ಲಿಕಾರ್ಜುನ ವಾರದ

ಸಾರಾಂಶ

ಕಂಬಳಿಹುಳುಗಳ (ಎರೆಬಿಡೆ : ಲೇಪಿಡೋಪ್ಟೆರಾ) ಅಧ್ಯಯನವನ್ನು ವಿವಿಧ ಬೆಳೆಗಳ ಪ್ರದೇಶಗಳಲಿ ನಡೆಸಲಾಯಿತು. ಈ ಕಂಬಳಿಹುಳುಗಳು ಆರ್ಕ್ಟಿನೇ ಮತ್ತು ಲೈಮ್ಯಾಂಟ್ರಿನೇ ಉಪವರ್ಗಗಳಿಗೆ ಸೇರಿವೆ. ಲೈಮ್ಯಾಂಟ್ರಿನೇ ಕಂಬಳಿ ಹುಳುಗಳ ಪೈಕಿ ಯುಪ್ರೋಕ್ಟಿಸ್ ವರ್ಗವನ್ನು ಬಾಳೆ ಮತ್ತು ಭತ್ತ, ಲೈಮ್ಯಾನ್ಟ್ರೀಯಾ ವರ್ಗವನ್ನು ಔಡಲ ಮತ್ತು ಪೆರಿನಾ ವರ್ಗವನ್ನು ಅಂಜೂರದ ಮೇಲೆ ದಾಖಲಿಸಲಾಗಿದೆ. ಆರ್ಕ್ಟಿನೆ ಉಪವರ್ಗದ ಪೈಕಿ ಕ್ರಿಯೊಟೊನೊಟಿಸ್ ವರ್ಗವನ್ನು ಕೊಕೋ, ಉಟೇತಿಸಾವನ್ನು ಸೆಣಬು, ಸ್ಪೈರ್ಲಾಕ್ಟಿಯಾವನ್ನು, ಔಡಲ ಮತ್ತು ಪೇರಿಕೆಲಿಯಾ ವರ್ಗವನ್ನು ತೊಗರಿಯಿಂದ ದಾಖಲಿಸಲಾಗಿದೆ. ಎಸ್ಟಿಗ್ಮೇನಾ, ಅರ್ಜಿನಾ, ಅಮೇರಿಲಾ, ಅಸುರ ಮತ್ತು ಅಮಟಾ ವರ್ಗಗಳನ್ನು ಬೆಳಕಿನ ಬಲೆಗಳಲ್ಲಿ ಸಂಗ್ರಹಿಸಲಾಗಿದೆ. ಸುಮಾರು ಏಳು ಪ್ರಭೇದಗಳನ್ನು ಬೇರೆ ಬೆಳೆಗಳ ಮೇಲೆ ದಾಖಲಿಸಲಾಗಿದೆ. ಬಿಹಾರ ಕಂಬಳಿಹುಳುವಿನ ಜೀವನ ಚಕ್ರವನ್ನು ಅವರೆ ಎಲೆಯ ಮೇಲೆ ಅಧ್ಯಯಿಸಲಾಯಿತು. ಮೊಟ್ಟೆಗಳು ಕೆನೆ ಬಿಳಿ ಬಣ್ಣದಿಂದ ಮುಸುಕಾದ ಹಳದಿ ಬಣ್ಣಕ್ಕೆ ಹಂತಹಂತವಾಗಿ ಬದಲಾದವು. ಮೊಟ್ಟೆಗಳ ಸಂಖ್ಯೆ ಪ್ರತಿ ಗುಂಪಿಗೆ 148 ರಿಂದ 232 ರವರೆಗೆ ಬದಲಾಗುತ್ತವೆ. ಮೊಟ್ಟೆ, ಮರಿಹುಳುಗಳು ಮತ್ತು ಕೊಶಗಳ ಅವಧಿಯಲ್ಲಿ ಕ್ರಮವಾಗಿ 5 ರಿಂದ 6, 20 ರಿಂದ 21 ಹಾಗೂ 8 ರಿಂದ 9 ದಿನಗಳವರೆಗೆ ಬದಲಾದವು. ಗಂಡು ಮತ್ತು ಹೆಣ್ಣು ಚಿಟ್ಟೆಗಳ ಉದ್ದ 51 ರಿಂದ 55 ಮಿ.ಮಿ. ಮತ್ತು 55 ರಿಂದ 59 ಮಿ.ಮಿ. ಕ್ರಮವಾಗಿ ಬದಲಾಗುತ್ತವೆ. ಗಂಡು ಮತ್ತು ಹೆಣ್ಣು ಚಿಟ್ಟೆಗಳ ಆಯುಷ್ಯ ಕ್ರಮವಾಗಿ 37 ರಿಂದ 42 ಮತ್ತು 39 ರಿಂದ 44 ದಿನಗಳು ಮುಟ್ಟಿತು. ಪತಂಗಗಳ ರೂಪವೈಜ್ಞಾನಿಕ ಮತ್ತು ಜನನಾಂಗಗಳ ಬದಲಾವಣೆಯ ಮೇಲೆ ಅಧ್ಯಯನ ನಡೆಸಲಾಯಿತು. ಈ ವ್ಯತ್ಯಾಸಗಳನ್ನು ಆಧರಿಸಿ ಸೂಪರ್ ಫ್ಯಾಮಿಲಿ ನಾಕ್ಟುಆಯಾಡಿಯೇ, ಎರೇಬಿಡೇ ವರ್ಗಕ್ಕೆ ಮತ್ತು 14 ಜಾತಿಯ ವಿವಿಧ ವರ್ಗಗಳ ಕಂಬಳಿಹುಳು ಪತಂಗಗಳಿಗೆ ಸಚಿತ್ರ ಕೀಲಿಯನ್ನು ಅಭಿವೃದ್ಧಿಪಡಿಸಲಾಗಿದ್ದು, ಈ ಕೀಲಿಯು ಕಂಬಳಿ ಹುಳು ಪತಂಗಗಳನ್ನು ಸುಲಭವಾಗಿ ಮತ್ತು ನಿಖರವಾಗಿ ಗುರುತಿಸಲು ಸಹಾಯವಾಗುತ್ತದೆ.

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(ಡಾ. ಸಿ.ಎಂ. ಕಲ್ಲೇಶ್ವರಸ್ವಾಮಿ)

ಜೂನ್, 2016

ಕೃಷಿ ಕೀಟಶಾಸ್ತ್ರ ವಿಭಾಗ,

ಕೃಷಿ ಮಹಾವಿದ್ಯಾಲಯ, ಶಿವಮೊಗ್ಗ.

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INTRODUCTION

I. INTRODUCTION

Herbivorous insects are a major fraction of all life on earth (Price, 2002). Their diversity and ecological roles have become a focus of many studies in the last decades. Lepidoptera (butterflies and moths) is one of the largest taxa among this group, with currently approximately 1,55,000 species described (Pogue, 2009). According to recent estimates, over 1,27,000 species of moths have been reported from all over the world (Alfred *et al.,* 1998), of which, over 12,000 species are from India (Chandra and Nema, 2007). Their immense diversity and ability to adapt to virtually any climate has made them some of the most successful creatures on earth.

Most lepidopteran larvae are plant feeders and nectar feeding as adults, and they are a prominent element of terrestrial ecosystems, functioning as herbivores, pollinators and prey, as well as being one of the most damaging groups of pests to agriculture (Regier *et al.,* 2009). Approximately 6000 Lepidoptera species noted to be of economic importance, about one-quarter of these belong to the Noctuoidea (Zhang, 1994). Although a large number of these can be assigned to what Mitchell *et al*. (2006) termed the 'pest clade', many more are distributed across the whole superfamily Noctuoidea in over 500 genera (Zhang, 1994). The larvae of many noctuoid genera have massive economic impact annually (Kitching, 1984). In addition, the adults of some genera damage fruit crops by piercing the skins to suck juices (Banziger, 1982). The economic damage caused by lepidopteran pests in field crops and on stored grain exacerbates the problem of food security and malnutrition in many developing countries. Therefore, the resolution of a stable, extrapolative higher-level classificatory structure for the major lineages of these moths is of importance for pest bionomic studies.

Superfamily Noctuoidea is one of the largest groups among the macrolepidopteran families in tropical and subtropical countries which includes dominating families like Noctuidae, Erebidae and Notodontidae *etc*. A robust phylogenetic framework for the superfamily Noctuoidea has recently been published (Zahiri *et al.,* 2011), which suggests that six strongly supported family group names: Oenosandridae, Notodontidae, Erebidae, Eutellidae, Nolidae and Noctuidae.

Zahiri *et al*. (2011) presented a new phylogeny for Erebidae consisting of 18 moderate to strongly supported subfamilies: Scoliopteryginae, Rivulinae, Anobinae, Hypeninae, Lymantriinae, Pangraptinae, Herminiinae, Aganainae, Arctiinae, Calpinae, Hypocalinae, Eulepidotinae, Toxocampinae, Tinoliinae, Scolecocampinae, Hypenodinae, Boletobiinae and Erebinae.

Arctiinae is currently considered as subfamily of Erebidae (Lafontaine and Schmidt 2010) and includes approximately 11,000 species worldwide (Scoble, 1992). These moths are divided into four tribes, and only Arctiini and Lithosiini occur in the Neotropics (Zahiri *et al.*, 2011). The Arctiidae family of small to medium-sized moths have antennae that are usually bipectinate or ciliate in the males, the pectination or ciliation being reduced or absent in the females. The proboscis is reduced and short, and the palpi are also generally short (Barlow, 1982). Arctiinae moths are used as bioindicators as they respond rapidly to environmental changes, are abundant and easy to sample (Kitching and Rawlins, 2000). Lithosiinae is the largest subfamily of Arctiidae in the oriental tropics and Bornean lithosiinae include 298 species in 70 genera. Records of host-plants for arctiids indicate that a large number of lithosiine larvae are lichen, algal, liverwort or moss browsers. The larvae tend to graze on these wherever they are abundant, such as moist walls, cliffs and rocks, the trunks and branches of trees and, in very humid biotopes, on leaves (Holloway, 2001). Most other arctiids tend towards polyphagy with some concentration on weedy herbaceous plant taxa (Barlow, 1982; Holloway, 1988; Holloway, 2001).

The subfamily Lymantriinae is distinguished by a strongly reduced proboscis, although such a reduction also occurs in other noctuoids (e.g. some Arctiinae). The larvae have characteristic dorsal glands at the centre of the sixth and seventh abdominal segments. Lymantriinae is represented by the five tribe *viz.*, belonging to Arctornithini, Lymantriini, Leucomini, Nygmiini and Orgyiini (Zahiri *et al.*, 2011). Lymantriinae include over 2900 described species in nearly 360 genera, distributed primarily in the Old World tropics. The larvae of many genera feed on arboreal hosts and are frequently polyphagous, but, unlike the arboreal Notodontidae (apart from Thaumetopoeinae), many lymantriines are major forest pests, defoliating large areas (Kitching and Rawlins, 1998).

India is gifted with rich moth fauna, about 4438 moths recorded by Cotes and Swinhoe (1887) in catalogue of moths of India and 5277 moths recorded by Hampson (1896) in Fauna of British India. The taxonomic studies on Indian arctiinae were mainly initiated in nineteenth century. A total of 525 species under 140 genera from three tribes have been reported. This includes Arctiini (151 species and 42 genera), Lithosiini (308 species and 90 genera) and Syntomini (66 species and 08 genera) (Singh *et al.*, 2014).

Many species of hairy caterpillars are reported as pests of agricultural crops. Among them the red headed hairy caterpillar, *Amasacta albistriga* (Lepidoptera : Arctiidae) is one of the major pest causing damage to the crops in south India (Ghewande and Nandagopal, 1997). In Karnataka, *Amasacta albistriga* has been a major pest in red loamy soils in the districts of Raichur, Bellary, Gulbarga, Belgaum, Bijapur, Chitradurga, Chikkamagaluru and Kolar (Puttarudraih, 1956; Thontadharya *et al.,* 1976). In endemic areas, crops like groundnut, sesamum, cowpea, greengram, sunflower etc. suffer heavy defoliation from large population of RHC leading to resowing of crops by the farmers. However many species of hairy caterpillars are polyphagous and assumed severe pest status in some parts of India (Sharma and Bisen, 2013).

Even though the hairy caterpillars are well studied group of insects, there is lack of information about their fauna, host range and reproductive biology. Similarly, there is a considerable problem involved in identifying the larvae of many species because of difficulty in handling them. Many hairy caterpillar species undergo diapause and need to be cultured till adult emergence for their identification and associate them with larvae. In this context, the present investigations on "Faunistic studies on hairy caterpillars (Lepidoptera : Noctuoidea) in different cropping ecosystems" has been undertaken with the following objectives:

1. To collect and document hairy caterpillars in different cropping ecosystem along with their host range
2. To study the biology of the Bihar hairy caterpillar, *Spilarctia obliqua* on field bean leaves
3. To develop taxonomic key of hairy caterpillars based on morphological characters of adults and associate them to larvae

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The available literature on diversity of hairy catterpillars in respect of description and distribution, economic importance, taxonomy of super-family Noctuoidea, collection of Noctuoidea through survey, studies on morphological and genital characters of the adults and preparation of illustrated identification keys were compiled and presented in this chapter under the following headings.

2.1. Diversity of hairy caterpillars in different cropping ecosystem along with their host range

No documented work on the diversity of hairy caterpillars in different cropping ecosystem in this part of India. Hence this sort of work done elsewhere have been depicted here.

The silver- spotted tiger moth, *Halisidota argentata* Pack., is a potentially dangerous defoliator of Douglas fir in British Columbia. Natural control factors have always prevented populations from building up to destructive proportions (Silver, 1959).

Pandit (1985) reported that Bihar hairy caterpillar, *Spilarctia obliqua* (Lepidoptera: Arctiidae) considered as a sporadic and irregular pest in recent times attained the status of a regular and major pest causing significant damage to the jute crop.

The wooly-bear caterpillars of *Grammia (=Apantesis) blakei* (Grt.) are abundant on native range pastures in the short-grass region of Southern Alberta and Southwestern Saskatchewan and occasionally cause early season damage to adjacent cultivated crops (Byers, 1988).

Tiwary and Kashyap (1989) determined the potential host range of *Spilarctia dalbergiae* (Moore) by feeding damage to 67 plant species and varieties. This indicated that *Spilarctia dalbergiae* is polyphagous, and has both horticultural and agricultural pest potentialities.

Pareuchaetes aurata aurata (Butler) from *Chromolaena jujuensis* in Northern America was biological control candidate for the Composite *C. odorata*. The larvae feed voraciously and complete their development on *C. odorata* (Kluge and Caldwell, 1993).

Larvae of the arctiid, *Pareuchaetes insulata* from Florida fed on the leaves of *Chromolaena odorata,* a serious Composite, alien weed in Natal, South Africa. In starvation test trials using 48 plant species, *P. pseudoinsulata* completed its development on *C. odorata* and *Ageratum houstonianum* (Kluge and Cardwell, 1993).

Worth **(**1994**)** reported that fall webworm, *Hyphantria cunea* (Drury), (Lepidoptera: Arctiidae), probably has the widest host range for any insect. The larvae feed on an estimated 636 species of plants worldwide.

Baranchikov *et al*. (1995) reported that the pink or rosy gypsy moth, *Lymantria mathura* Moore, is a major defoliator of deciduous trees in the Palearctic, primarily in Eastern Asia from India to the Russian Far East.

The Rattlebox moth, *Utetheisa ornatrix* (L., 1758) (Lepidoptera: Arctiidae), is considered to be the most important pest of *Crotalaria* spp. pest in Brazil (Signoretti *et al.*, 2008). The larvae feed on the green pods and on the developing seeds, and they may reduce the crop yields when the infestation is high (Ferro, 2001).

Euproctis scintillans is an important polyphagous pest. It causes up to 40% damage to the foliage of *Robinia pseudoacacia* in some areas of Himachal Pradesh, India. Heavy infestation during monsoons results in large defoliation of the trees (Kalia and Pandey, 2004).

Ramadan *et al*. (2011) evaluated *Secusio extensa* (Lepidoptera: Arctiidae) as a potential biological control agent for Madagascar fireweed, *Senecio madagascariensis* (Asteraceae), which has invaded over 400,000 acres of rangeland in the Hawaiian islands and is toxic to cattle and horses**.**

Ferro *et al.* (2012) showed that the tiger-moth assemblage collected in the grassland was more diverse than the assemblages from the Araucaria forest and the transition zone. The assemblages in the forest and forest edge resembled each other, whereas the grassland assemblage was distinct.

Zanuncio *et al*. (2013) identified *Eupseudosoma involuta* (Arctiidae) as a major defoliator among 40 secondary pests of *Eucalyptus* causing great damage to plantations in Brazil, making it necessary to study these important insect pests.

Sharma and Bisen (2013) recorded *Spilarctia obliqua* Wal. is a major polyphagous pest, particularly Sesamam, linseed and minor pest of cabbage, sweet potato, but is a major pest of sunhemp, maize and jowar and *Utetheisa pulchella* as a major pest of sunhemp.

Gupta and Tara (2014) studied seasonal variation, percent infestation and effect of abiotic factors *viz*. rainfall, relative humidity and temperature on the population dynamics of yellow tailed tussock moth *Euproctis scintillans* Walker (*Somena scintillans* Walker) in J&K State of India for the first time.

Braga *et al.* (2014) reported that the caterpillars of *Idalus lineosus* Walker (Arctiinae) are external folivores that are specialized in eating mature leaves of *Roupala montana* Aubl. (Proteaceae) in the cerrado (Brazilian savannah).

Thakur *et al*. (2015) reported that Indian Gypsy Moth (IGM) *Lymantria obfuscata* Walker, is a serious pest of about 200 broad-leaved tree species, throughout India, namely oak (*Quercus* spp.), willow (*Salix* spp.), popular (*Populas* spp.), walnut (J*ugulans* spp.), apple (*Malus* spp.), apricot (*Prunus* spp.), cherry (*Prunus cerasus*) and almond (*Prunus amygdalis*). It was reported as the major pest of ban oak and apple trees at Kotgarh, Shimla (H.P.)

Favetti *et al*. (2015) reported that *Spodoptera eridania* (Walker) (Lepidoptera : Noctuidae) as a polyphagous defoliator that feeds on apple, cotton, soybean, beans, maize, sorghum, salad greens and fruit and weeds like morning glory and pig weed.

Tea is a perennial cash crop which is grown at a large scale in Northern parts of West Bengal, India with a great susceptibility to attack of variety of insect pests throughout the year. The study revealed fourteen adult moth species of the family Erebidae of which two species *Arctornis submarginata* Walker and *Somena scintillans* (Walker) have been found pests (Biswas *et al*., 2015).

2.2. The biology of the Bihar hairy caterpillar, *Spilarctia obliqua* on field bean leaves

As such there was no biological and morphological studies of *Spilarctia oblique* were available. Confirmation was drawn from other related hairy caterpillars, which was presented here under.

Larvae of *Ecpantheria icasia* (Cramer) sometimes become pests of bananas in Central America by feeding on the banana fingers. It lays upto 2885 eggs in 3–4 masses. The eggs hatch in 5–6 days. In the insectary larvae passed through 7–9 instars in 35–57 days. The pupal stage lasted 13–18 days for specimens reared in the insectary. Adults lived up to 26 days in the insectary (Harrison and Stephens, 1969).

Roonwal (1979) studied life-history of Sal defoliator, *Lymantria mathura* (Lepidoptera : Lymantriidae), on Sal tree of sub Himalayan forests. Fecundity was 50 - 1,200 eggs /female and females are apterous. Ist instar has mean head-width 0.5 mm, II nd instar 0.7 mm, IIIrd instar 1.5 mm, IVth instar 2.5 mm, Vth instar 3.5 mm and VIth instar 5-6 mm. The data couldn't follow Dyar's law.

Head capsule widths of laboratory reared and mature field collected larvae of *Pyrrharctia isabella* were measured. The number of larval instars varied from 7 to 10, yet in all larvae studied, average size and increament in the successive instars, there was the same for instars 1 to 3. In the latter instars, there was an inverse relationship between size of increment and prospective number of instars. Insects which completed 10 instars were only little larger than those maturing after only 7 instars. These data fail to support Dyar's law (Goettel and Philogene, 1979).

The Lymantriid, *Euproctis virguncula* Wlk. remained active throughout the year, with a peak in August-October. In summer, there were five larval instars and larval development (on maize silks) took 23-31 days. In winter there were 11 instars and development (on rice leaves from sprouted stubble) took 103-108 days. The pupal stage lasted 5-7 days in September and 14-15 days in February-March. The generations were distinct, and six generations a year were reared (Sandhu *et al.*, 1979).

Laboratory studies with *Euproctis subnotata*, reared on sorghum ears, showed that the average incubation period was 6.7 days, larval period 23.57 days, pupal period 11 days, total life cycle 42.77 days and adult longevity 8.5 days. Females laid an average of 113 eggs and the larvae underwent 6 instars (Patil and Kulkarni, 1990).

Studies conducted on the biology of the pest *Dasychira mendosa* on the new host show that the pest takes 57.80 ± 2.94 days to complete its life cycle. The female moth lays 211.43 ± 41.70 eggs. The incubation period is 8 days and hatchability is 16%. The larval period is 41.80 ± 3.19 days, with 6-8 instar stages and the pupation period is 7.82±0.27 days. The adult longevity is 7.63 ± 0.60 days and the difference between the male and female longevity is not significant. The female had a pre-oviposition period of 4.67 ± 0.17 days, an oviposition period of 3.00±0.46 days and post-oviposition period of a maximum of 2 days (Das, 1990).

Biology of castor hairy caterpillar, *Euproctis lunata* Walk. Was studied in Bangladesh. It had six larval instars that averaged 3·3 ± 0·07, 3·5 ± 0·08, 3·7 ± 0·11, 4·7 ± 0·12 and 5·0 ± 0·15 days respectively; 204 ± 6·5 eggs were laid per female; 97·2 ± 0·37 eggs hatched. Male and female moths lived 4·00 ± 0·16 and 4·45 ± 0·13 days, respectively (Islam *et al*., 2003).

The artificial diet containing the bean and yeast extract led to an adequate development of the immature and adult *Utetheisa ornatrix* stages. The duration and viability of the egg, larval, and pupal stages were 4.5 and 84.2, 26.5 and 85.3, and 10.3 days and 91.4%, respectively, for a total duration of 42 days and a 65.6% viability of the biological cycle from egg to adult (Signoretti *et al*., 2008).

Sarasu (2009) studied the biology of *Asura conferta* (Arctiidae : Lepidoptera). Adult of *A. conferta* are brightly colored. Eggs are laid in large clusters after mating. Fecundity is 250-300. The eggs are small and are about 35-50 µ in diameter. About 7 instars were found in the larval life of the insect. All the instars were completed within about 28 days. The pupal life lasted for about 7-8 days. Pupa shelter is made by its own hairs.

Gotyal *et al*. (2013) studied the comparative biology of Bihar hairy caterpillar, *Spilarctia obliqua* on wild and cultivated species of jute. They found that larval growth rate in terms of weekly weight gain was significantly impaired on the wild species particularly *Corchorus tridens* and *C. aestuans* but later it was reversed.

Thakur *et al*. (2015) studied the detailed larval biology of Indian Gypsy moth *Lymantria obfuscata* Walker on *Quercus leucotrichophora* Roxb. in Himachal Pradesh (India). First instar larval stage lasted for 12.75±1.50 days, second instar larva lasted for 10.75±1.71 days, third instar larval stage lasted for 13.75±1.26 days, fourth instar larval stage lasted 16.50±1.91 days, fifth instar larva almost same as that of fourth instar larva and sixth instar larvae were the largest lasted for 11.25±0.96 days.

Favetti *et al*. (2015) studied the biology and reproductive capacity of *Spodoptera eridania* (Walker) (Lepidoptera : Noctuidae) on different soybean cultivars in laboratory conditions found that *Spodoptera eridania* has 6 larval instars and there was no difference in incubation period and larval period on different cultivars except BRS cultivar.

2.3. To develop taxonomic key of hairy caterpillars based on morphological characters of adults and associate them to larvae

Strand (1919-1922) catalogued the Arctiidae and reported 413 species distributed over 85 genera from India in five subfamilies, viz., Nolinae, Arctiinae, Lithosiinae, Callimorphinae and Nyctenlerinae. Of these, 285 species distributed over 65 genera occur mainly in the areas of Assam and Sikkim.

Arctiinae is distributed worldwide, with around 11,000 described species, of which 6,000 inhabit the Neotropics (Watson and Goodger, 1986). Jacobson and Weller (2002) classified the subfamily into 3 tribes: Lithosiini, Syntomini, and Arctiini.

Koda (1987) classified the genera of the subfamily Arctiinae of the Palaearctic and Oriental regions based on male and female genitalia (Lepidoptera, Arctiidae). The Palaearctic and Oriental genera of the subfamily Arctiinae are revised and the genera are diagnosed based on the male and female genitalia. The generic grouping is discussed and six genus groups, *i,e., Ameria, Utetheisa, Callimorpha, Arctia, Rhymparoides* and

Spilaratia groups are proposed, and one new genus, *Aglaomorpha*, of the *Callimorpha* genus group is erected.

Taxonomy is not a static field but a field where new morphological and biological information continually becomes available and it is necessary to modify the classification to reflect this new information. Several checklists (Munroe *et al.*, 1995; Shaffer, 1996) from major geographic areas are published in the last ten years with many new combinations and synonymies.

Hauser and Boppre (1997) revised the Afrotropical species of the genus *Amerila*, based on adult morphology. Examinations of type material for various described taxa has resulted in numerous taxonomic changes. From a total of 47 previously described African taxa, 35 species including five newly described species and two new subspecies are recognized. A brief diagnosis based on external character and genitalia is given with illustrations.

Fibiger and Lafontaine (2005) reviewed higher classification of the Noctuoidea (Lepidoptera) with special reference to the Holarctic fauna. Several taxa are reinstated, described as new, synonymised, or redescribed. Some characters that have been inadequately described, poorly understood, or misinterpreted, are redescribed and discussed. One family, two subfamilies, four tribes, and three subtribes are proposed as new to science.

Dubatolov and Kishida (2007) reviewed the all known species of the genus *Argyarctia* Koda. The genus is divided into two subgenera *A. fuscabasalis* Matsumura (the type species) and *A. reykoae* Kishida.

Wang *et al*. (2010) identified a new species of Lymantriidae belonging to genus *Oravasca* from Hainan. The new species clearly differs from its allied species by difference in wing pattern, and genitalia such as deeply bifid valve, broad dorsal arm, ventral arm triangle shaped. Aedegus straight, concave near the apex, vesica expanded with numerous spinules.

An annotated check list of the North American species of Noctuoidea (Lepidoptera) is presented, consisting of 3693 species. One-hundred and sixty-six

taxonomic changes are proposed, consisting of 13 species group taxa accorded species status, 2 revalidated genus-group taxa, and 2 family-group taxa raised to subfamily. Sixty-nine species-group taxa are downgraded to junior synonyms or subspecies, and 6 genera relegated to synonymy. Sixty-seven new or revised generic combinations are proposed (Lafontaine and Schmidt, 2010).

India includes a diverse environment and vegetation, which comprises of different ecosystems. India is gifted with rich moth fauna, about 4438 moths in catalogue of moths of India and 5277 moths recorded by Hampson G.F. (1896) in Fauna of British India (Gurule *et al*., 2011)**.**

Idris and Abang (2011) conducted survey on macro-moth diversity in Perlis State Park (N6°41’51.7" E100°11’29.3") by setting four modified-Pennsylvanian light-traps. Out of 95 species and 310 individuals collected, six female specimens of *Cyclosiella spiralis* (Arctiidae: Lithosiinae), were collected.

Dombroskie (2011) provided matrix based key for an easy and reliable way to identify the more difficult groups of adult Lepidoptera using a standard dissecting microscope. The key allows identification to the level of subfamily or tribe for most Canadian Lepidoptera, includes 222 taxa, and uses 73 characters with 266 character states.

Kirti and Joshi (2012) conducted taxonomic studies on type species of genus *Tarika* Moore (Lepidoptera: Erebidae: Arctiinae) from India and described taxonomic feature of type species, *Tarika varana* (Moore). Genus *Tarika* Moore has been recharacterised by incorporating female genitalic features of the type species. The female genitalia of the type species have been illustrated for the first time.

A new species, *Lymantria* (*Nyctria*) *furvinis* is described from Guangdong Nanling National Nature Reserve, South China. The new species can be distinguished from all previously described species by the basal area on the forewing yellow with black spots, valve with a transverse sclerite connecting a long digitate process medially. Illustrations of the adults, wing venation and genitalia are provided (Wang *et al*., 2012).

Becker (2013) made taxonomic changes in the Neotropical *Pericopina* and *Ctenuchina* moths (Erebidae, Arctiinae, Arctiini), with description of new taxa. One genus and 53 species names are given new synonyms, six revised synonyms, and six new and three revised species are established; 11 lectotypes are designated.

Singh and Singh (2013) revised the Indian Arctiidae. More than 300 species of Indian Arctiidae were studied, out of which one genus *Pareuchaetes* Grote and four species *Pareuchaetes pseudoinsulata* (Rego Barros), *Olepa duboisi* (Orhant), *Macotasa orientalis* (Hampson) and *Poliosia binotata* (Hampson) have been reported for the first time from India.

Arimoto and Iwaizumi (2014) studied the morphological characteristics of adult male and female moths of seven Japanese Lymantria species which consisted of four Asian gypsy moth (AGM) species [*L. dispar* (Motschulsky), *L. umbrosa* (Butler), *L. albescens* Hori and Umeno, and *L. postalba* Inoue] and three other species [*L. xylina* Swinhoe, *L. mathura* Moore, and *L. monacha* (Linnaeus)]. The result suggests that morphological characteristics of adult male and female moths are useful in identifying these seven Japanese Lymantria species.

Kirti *et al*. (2014) conducted taxonomic studies on three *Caeneressa* Species (Lepidoptera: Syntominae) from India with special reference to their external genitalia. With genitalia studies, they showed that, genus *Caeneressa* was represented by five species from India, *C. diaphana* (Kollar), *C. diaphana muirheadi* (Felder), *C. brithyris* (Druce), *C. melaena* (Hampson) and *C. swinhoei* (Leech).

Genus *Stictane* Hampson of Arctiinae in Cambodia was reviewed, which included seven species. Of them, *S. cambodiensis* Bae and Bayarsaikan, *S. khmerensis* Bae and Bayarsaikan, and *S. bokorensis* Bayarsaikan and Bae were described as new to science (Bayarsaikan and Bae, 2015).

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The present investigations deal with the "Faunistic studies of hairy caterpillars (Lepidoptera : Noctuoidea) in different cropping ecosystem". The detailed material and methods adopted during the course of the study are presented below.

3.1 Collection and documentation of hairy caterpillars in different cropping ecosystem along with their host range

3.1.1. Field collection

Intensive collections of hairy caterpillars infesting many agricultural and horticultural crops were made by undertaking survey in different localities in and around Shivamogga and Mudigere. The collection was carried out with frequent field visits to different cropping ecosystems.

3.1.2. Collection techniques

The hairy caterpillar larvae of most of the species feed on living plants externally as defoliators. Since, the present study was mainly focused on recording host ranges of caterpillars and associating them to larvae, the larval life stage of hairy caterpillars were photographed in their habitat on the host surface. The eggs and larvae were collected along with host plant and brought to the laboratory for further studies in the Department of Agricultural Entomology, College of Agriculture, Shivamogga.

Collections were also made by setting a mercury vapour light trap during cropping season by using 160 Watt mercury vapour lamp. A white nylon cloth was placed in such a way that the moths attracted to light source rest on that. The light trap was employed from dusk period onwards and collections were made for 2 – 3 hours.

3.1.3. Rearing of immature stages of hairy caterpillars

The immature stages of hairy caterpillars collected from field were reared in the laboratory by adopting the methodology proposed by Doerksen and Neunzig (1976), Tashiro (1976), Genc *et al.* (2003) and Rosario *et al.* (2007) with slight modification wherever required.

The specimens collected were transferred to rearing cages along with its host. The culture was monitored carefully and fresh food was provided to the larvae until they

reached pupal stage. Later, pupae were collected and kept for adult emergence in cages. The rearing cages were disinfected with absolute alcohol at regular interval to maintain the hygiene.

3.2. Studies on the biology of the Bihar hairy caterpillar, *Spilarctia obliqua* on field bean

Immature stages of hairy caterpillars were collected from the field and reared to adults. The freshly emerged adult moths were collected. Later on a pair of adult moths were released in a cage for egg laying. During this period the adults were fed with 10 per cent honey solution. This rearing was carried out at Department of Agricultural Entomology, College of Agriculture, Shivamogga at room temperature.

The observations were recorded daily on pre-oviposition period, oviposition and post oviposition period, egg period, larval period, pre-pupal period, pupal period, total life cycle and fecundity. The freshly hatched larvae were placed on its host with the help of hair brush and kept in a petri plate whose cap is made perforated in order to facilitate aeration and were observed twice a day for the larval moulting. For the last instar larvae the soil was be provided to facilitate pupation. After pupation the pupal period was also recorded.

3.3. To develop taxonomic key of hairy caterpillars based on morphological characters of adults and associate them to larvae

3.3.1. Mounting and labeling

The adults after emergence were killed using ethyl acetate and pinned using stainless anticorrosive insect pins (No. 4). The insects were mounted on mounting board, the antenna and wings were stretched properly on which identification is based. Each specimen was labeled with the information pertaining to date of collection, locality, name of collector and host on which it was reared. The specimens were dried properly and preserved in insect cabinet boxes at department of Entomology, UAHS, Shivamogga.

3.3.2. Preparation of genitalia

Genitalia of adults (male and female) were dissected using the technique described by Clark (1941) and Kirti and Gill (2005) with little modification wherever

required. Dried and preserved specimens were used for the study of genitalia. Before dissection of genitalia, adults were photographed. Then the abdomen was detached from thorax with the help of a fine needle. The abdomen was then transferred to a test tube containing a few milliliters of 10 per cent caustic potash (KOH). This was heated slowly in a water bath till the convection currents were observed in the solution and then it was kept for cooling. After cooling, the abdomen was transferred to a glass cavity dish containing 10% alcohol and the macerated soft tissues were pressed out with the help of a pair of bent needles mounted on plastic handles. After repeated washings in water, the genitalia is detached by cutting out intersegmental membrane. The genitalia which was dissected is then dehydrated in absolute alcohol for proper visualance of all the parts of genitalia. The vesica eversion of aedegus is done with 10% alcohol using micro syringe. And observation was made under a stereoscopic microscope. Later the dehydrated genitalia was mounted on a glass slide using coverslip with Euparol mountant. These permanent slides were kept in hot air oven for drying. After the study, the dissected genitalia were preserved in slide boxes.

3.3.3. Mounting of wings

The preparations of wing slides of collected specimens were made by adopting procedures given by Robinson (1976) and Thomas (2007) with a slight modification. The right side wings *i.e.* both fore and hind wings were detached and dipped in 70 per cent alcohol for wetting. Then the wings were transferred to Sodium hypo chloride solution for bleaching. After bleaching, the wings were washed 3-4 times in distilled water. Later, wings were stained using fuchsin. After staining, wings were transferred to 90 per cent alcohol to rinse off excess stain and then transferred to absolute alcohol for complete dehydration. Later, the wings were placed on the slide, centered and properly oriented (preferably with the base of the wings to the left) in a required direction with the help of needles. A cover slip was placed on the slide gently. The mounted slides were photographed and line diagram was drawn using camera lucida using Leica M205C with auto montage. Comstock and Needham system was followed for studying the wing venation.

3.3.4. Illustrations and Photographs

The parts of the genitalia were illustrated using a compound microscope fitted with a mirror type Camera Lucida. Before photography, only female genitalia were stained with chlorajal black. The parts of male genitalia were held in the desired position in a cavity slide by means of a small quantity of wax. All the species studied were photographed using Leica M205C with auto montage.

3.3.5. Identification

The specimens collected were identified to subfamily and generic level, if possible to species level based on the keys developed by Hampson (1986) in the Moths volumes of the Fauna of India and adjacent countries series and also using other available literature. Those species which did not agree with descriptions and figures of already known species were considered as new species.

The keys have been prepared from referring different sources like other published keys, descriptions, and an examination of specimens of the groups concerned. Some are taken largely from previously published keys based on study of different authors like, Dombroskie (2011), Clark (1986), Hampson (1896) *etc*., generally with some changes in wording or organization and adding some more morphological and genitalial characters.

3.3.6. Description

Descriptions of subfamily, genera and available species were provided. In case of known species, descriptions of additional characters or variations observed, if any, were given in addition to brief description. In addition, information on larval description, materials examined and remarks regarding the specimens were mentioned.

3.3.7. Terminology

The definitions / terminologies have been drawn from a number of sources, including Triplehorn and Johnson (2005); Torre-Bueno (1937) and Klots (1970). Scoble (1992) described the parts of the genitalia of Lepidoptera and their arrangement and terminology for external features can be found. Some definitions used in the thesis are described here.

Aedeagus: Tube-like organ of the male genitalia lying between the valves and functioning as a penis, often adorned with spines and useful in determining the species. It houses the vesica (sometimes referred to as the endophallus)

Ampulla: In males, a process arising from the sacculus, usually thin and tubular and on the costal side.

Anal angle: In ventral view, the anterior extremity of the cucullus (in the male).

Anellus: In male, the membranous covering of the aedeagus.

Antrum: In the female, a chamber or cavity formed from part of the ostium in some species

Apophyses anteriores: In the female, the pair of elongate processes arising from the eighth sternite.

Apophyses posteriors: In the female, the pair of elongate processes arising from the ovipositor.

Appendix bursae: In the female, a secondary swelling attached to the bursa copulatrix (which is then called the corpus bursae).

Basal, basally, basad: Closest to the body; towards the body or point of attachment.

Bursa copulatrix: In the female, part of the bag-like structure connected to the ductus bursae, which is used to store sperm. If an appendix bursae is also present, this together with the bursa copulatrix constitute the corpus bursae. It is often adorned with spines, which may be distinguishing identification features.

Cilium (pl. cilia): Scale or scales resembling hairs, a row of which usually border the wings, or adorn the antennae or other organs.

Clasper(s): The valves in the male genitalia or parts of the armature thereof (usually on the median section or towards the base). It is also synonymous, in both meanings, with harpe.

Coecum: In the male, a blind sac (part of the aedeagus).

Colliculum: In the female, a small dorsal plate or narrow ring-like sclerite of the ductus bursae.

Cornutus (pl. cornuti): In the male, a spine arising from the aedeagus.

Corona: In the male, a row of spines along the outer margin of the cucullus, extending across its inner face.

Corpus bursae: In the female, the bag-like structure connected to the ductus bursae, used to store sperm. Comprises the bursae copulatrix and appendix bursae (which may be absent). It is often adorned with spines, which may be distinguishing features.

Costa, costal: In male genitalia, referring to the uppermost (i.e. posterior) margin of the valva in ventral view. On the wing of a moth, the leading edge.

Cucullus: In male genitalia, the tip of the valva, often necked, rounded and bearing spines.

Dentate: Toothed or strongly serrated.

Distal, distally, distad: Away from the body or point of attachment.

Diverticulum: A blind side passage, forming a sac or swelling, e.g. in the vesica (as seen when everted) or bursa copulatrix.

Ductus bursae: In the female, the tube extending from the ostium to the bursa copulatrix.

Ductus ejaculatorius: In the male, the single duct or tube through which the seminal fluid is ejected into the ostium of the female.

Ductus seminalis: In the female, the tube connecting the bursa copulatrix with the oviductus communis (the median outlet of the female genital system).

Fasciculate: Clustered or tufted.

Gnathos: In male genitalia, a hardened part of the vinculum near the uncus, which supports the anal tube.

Harpe: In male genitalia, the hardened clasping organ on the inner face of the valva (see also clasper and valvae).

Juxta: In male genitalia, a hardened plate-like structure between the valvae which supports the aedeagus.

Lamella ante-vaginalis: In the female, a hardened plate partially surrounding the ostium placed anteriorly.

Lamella post-vaginalis: In the female, a hardened plate partially surrounding the ostium placed posteriorly.

Medial, medially, median: Middle; the central area (medio-distal = away, more distant from, the middle).

Ostial plate: In the female, a hardened plate surrounding the ostium.

Ostium: In female genitalia, the external opening.

Ostium bursae: A chamber or cavity formed from part of the ostium (see also antrum).

Ovipositor: In the female, the tubular or valved structure used to deposit the eggs, sometimes extendable beyond the apex of the abdomen.

Papillae anales: In the female, a paired process at the apex of the ovipositor.

Pollex: In the male, a process on the valva, usually on the cucullus as an extension of the anal angle. Also sometimes used to describe a process arising from the median section of the valva.

Sacculus: In male genitalia, dominant part of the base of the valva, often adorned with spines.

Saccus: In male genitalia, the lowest part of the vinculum.

Seta (pl. setae): Stiff hair or bristle.

Signum (pl. signa): In the female, sclerotised spines and plates on the bursa copulatrix.

Socius: In the male, a paired extension of the vinculum.

Sub-basal: Near the base of.

Sub-genital plate: The plate beneath the genitalia (eighth tergite).

Taxon (pl. taxa): A group of organisms adjudged to be a unit.

Tegumen: The dorsal half of the large central transverse ring-like part of the male genitalia.

Termen: The outer edge of the wing of a moth, adorned with cilia.

Truncate: With a squared-off ending.

Uncus: In the male, the top part of the vinculum, sometimes forming a large hooked or curved structure.

Valva (plural valvae, or informally 'valves'): The large pair of laterally extending clasping organs of the male genitalia (see also clasper and harpe), articulating with the vinculum.

Vesica: In the male, the inner sac of the aedeagus, also known as the endophallus.

Vinculum: In the male, the ventral half of the large central transverse ring-like part of the male genitalia.

Illustrations of immature and adults were made to associate them as there is no literature available on this aspect. Along with this, light traps were also set during rainy season, to capture adults of hairy caterpillars. An illustrated identification key was provided for easy and accurate identification of adult of hairy caterpillars based on their morphological characters. The study throw a light on the existence of sexual dimorphism, polyphagous nature and diapause are the major hindrance in taxonomic identification. Hence, attempts were made to address these issues in the study. After description of all known adults, an effort was made to associate them to larvae, to support the preparation of field guide, if any, in future.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The present investigation on 'Faunistic studies of hairy caterpillars (Lepidoptera : Noctuoidea) in different cropping ecosystem' was carried out at the Department of Agricultural Entomology, College of Agriculture, Shivamogga. The results on diversity, biology of *Spilarctia obliqua*, studies on morphological and genital characters of the adults, preparation of illustrated identification keys are presented below.

4.1. Collection and documentation of hairy caterpillars in cropping ecosystem along with their host range

Survey was carried out to collect hairy caterpillars occurring on crops like paddy, castor, pigeonpea, sunhemp, field bean, fig, cocoa, banana and other plants from different regions of Shivamogga and Mudigere.

During the survey, a total of twelve genera of hairy caterpillars were collected. The species belonged to two sub-families *viz*., Arctiinae and Lymantriinae. Arctiinae is represented by genus *Creatonotus, Utetheisa, Estigmena, Spilarctia , Pericalia, Argina, Amerila, Asura* and *Amata*. Genus *Creatonotus* is represented by two species *Creatonotus gangis and Creatonotus transiens* and genus *Pericalia* represented by *Pericalia ricini and Pericalia obliquiformis.* Lymantriinae is represented by genus *Perina, Euproctis* and *Lymantria* (Table 1).

Results revealed that among lymantrid hairy caterpillars reared, *Euproctis* sp. was documented to feed on banana, *Lymantria* sp. on castor and *Perina* sp. on fig and one wingless species from *Mimosa pudica* which was unable to be identified. Among arctiids *Creatonotus* is documented from cocoa, *Utetheisa* from sunhemp, *Spilarctia* from castor, *Pericalia* from pigeonpea. *Estigmena, Argina, Amerila, Asura, Amata* are collected from light traps.

4.2. Studies on the biology of the Bihar hairy caterpillar, *Spilarctia obliqua* on field bean leaves

The growth parameters such as egg, larvae, pupae and adult developmental periods recorded was presented in table 3 (Plate 1).

Table 1. Hairy caterpillars larvae recorded in different cropping ecosystems

Sl. No.	Species	Host range
	Subfamily : Arctiinae	
1.	*Creatonotus gangis* (plate 1)	Cocoa,*Theobroma cacao*
2.	*Utetheisa pulchelloides* (plate 2)	Sunhemp, *Crotalaria juncea*
3.	*Spilarctia oblique* (plate 3)	Sunflower, *Helianthus annus*; Fieldbean, *Vicia faba*
4.	*Pericalia ricini* (plate 4)	Pigeonpea, *Cajanus cajan*
	Subfamily : Lymantriinae	
5.	*Perina nuda* (plate 5)	Fig, *Ficus carica*
6.	*Euproctis* sp. (plate 6)	Banana, *Musa* sp.; Paddy, *Oryza sativa*
7.	*Lymantria* sp. (plate 7)	Castor, *Ricinus communis*
	Unknown *	
	Sp. 1 (plate 14)	Sunflower, *Helianthus annus*
	Sp. 2 (plate 14)	Marigold, *Tagetes* sp.
	Sp. 3 (plate 14)	Gliricidia, *Gliricidia sepium*
	Sp. 4 (plate 14)	Croton, *Codiaeum variegatum*
	Sp. 5 (plate 14)	Sorghum, *Sorghum bicolor*
	Sp. 6 (plate 14)	*Mimosa pudica*
	Sp. 7 (plate 14)	Lime, *Citrus aurantifolia*

*larvae did not reached to adult stage

Egg mass

First instar (1X)

Second instar (0.8 X)

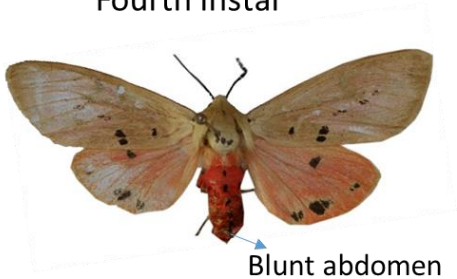
Third instar (0.8 X)

Fourth instar

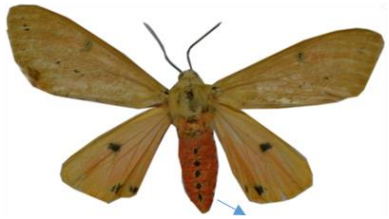
Fifth instar

Sixth instar

Pupa



Female



Male

Plate 1 : Life stages of *Spilarctia obliqua* on field bean leaves

4.2.1 Egg

The freshly laid eggs were creamy white and turned pale yellow and are slightly flattened at one side. The egg measured about 0.25 ± 0.021 mm in diameter. The number of eggs per mass varies considerably but was often 148 to 232 in batches and covered with hairy scales of the tip of the abdomen of the female moth. When the eggs were about to hatch, turned blackish which was the developing head of the larvae (Table 3).

One day prior to hatching, the dark head of the young larva was observed inside the egg shell. Incubation period ranged from 5 – 6 days with an average of 5.75 days.

4.2.2 Larva

During its larval developmental period, the caterpillar moulted five times and had six larval instars. The total larval period ranged from 20 – 21days with an average of 20.55 days.

4.2.3 First instar

The newly hatched larvae were sluggish in nature which became active after some time. Young larvae were translucent light yellow with dark head. The head is prominently big and was bigger than any part of the body. The larval body was covered with number of long hairs arising from dark coloured tubercles. The width of the first instar larval head capsule ranged from 0.06 – 0.07mm with an average of 0.07 mm (Table 2).

The first instar took 3 to 4 days with an average of 3.3 days to enter into next instar (Table 3).

4.2.4 Second instar

As the larva advances to second instar, the body grows faster and as a result, the body turns wider than the head. The larva was translucent light yellow in colour with prominent setae and tubercles.

During the second instar, the width of the head capsule was 0.09 – 0.12 mm with an average of 0.10 mm (Table 2). The second instar varied from 2 to 3 days with an average of 2.25 days to enter into next instar (Table 3)

Table 2. Head capsule width of *Spilarctia obliqua* during different moults on field bean leaves

Stage of insect	Head capsule width (mm)	
	Range	**Mean**
First moult	0.06 - 0.07	0.07 ± 0.002
Second moult	0.09 - 0.12	0.10 ± 0.01
Third moult	0.17 ± 0.19	0.18 ± 0.007
Fourth moult	0.21 ± 0.28	0.25 ± 0.01
Fifth moult	0.40 ± 0.54	0.47 ± 0.03
Sixth moult	0.45 ± 0.70	0.61 ± 0.06

N = 20

Table 3. Duration of different life stages of *Spilarctia obliqua* on field bean leaves and fecundity of adults

Sl. No.	Life stages		Range (days)	Mean (days)
1.	**Incubation period**		5.00 – 6.00	5.75 ± 0.44
2.	**Larval period**	I instar	3.00 – 4.00	3.30 ± 0.47
		II instar	2.00 – 3.00	2.25 ± 0.44
		III instar	5.00 – 6.00	5.60 ± 0.50
		IV instar	3.00 – 4.00	3.80 ± 0.41
		V instar	3.00 – 4.00	3.70 ± 0.47
		VI instar	5.00 – 6.00	5.35 ± 0.48
		Total	20.00 – 21.00	20.55 ± 0.51
3.	**Pupal period**		8.00 – 9.00	8.60 ± 0.50
4.	**Pre-oviposition period ***		1.00 – 1.50	1.33 ± 0.25
5.	**Oviposition period ***		3.00 – 4.00	3.66 ± 0.51
6.	**Post-oviposition period ***		1.00– 1. 50	1.10 ± 0.22
7.	**Fecundity/female ***		148 - 232	194.6 ± 36.08
8.	**Male adult longevity ***		4.00 – 5.00	4.40 ± 0.54
9.	**Female adult longevity ***		6.00 – 7.00	6.20 ± 0.44
10.	**Total life cycle**	**Male**	37.00 – 42.00	39.80 ± 1.92
		Female	39.00 - 44.00	41.60 ± 2.07

Mean of 20 observations

* Data of six adults

4.2.5 Third instar

The third instar larva was morphologically similar to that of second instar with prominent setae and tubercles. The larva was light yellowish in colour with black patches on the anterior and posterior region of the body. The spiracles were black in colour and are nine in number.

The head capsule width of third instar larva was 0.17 to 0.19 mm with an average of 0.18 mm (Table 2). The duration of third instar larvae was 5 to 6 days with an average of 5.60 days (Table 3).

4.2.6 Fourth instar

The larva was yellowish in colour with yellow longitudinal stripes. Head and prothoracic shield were dark brown. Black patches were present on the anterior and posterior region.

The width of fourth instar larva head capsule measured 0.21 to 0.28 mm with an average of 0.25 mm (Table 2). The duration of fourth instar larvae was 3 to 4 days with an average of 3.80 days (Table 3).

4.2.7 Fifth instar

Fifth instar larva was almost similar to fourth instar, except in its size. Black patches were present on the anterior and posterior region. The larvae had dense hairs on its body.

The head capsule width of fifth instar larva was 0.40 to 0.54 mm with an average of 0.47 mm (Table 2). The duration of fifth instar larvae was 3 to 4 days with an average of 3.70 days (Table 3).

4.2.8 Sixth instar

The fully grown larva was stout and cylindrical, brown in colour, the head of the larva was dark brown and conspicuous dark anterior and posterior patches of the larva. The larvae had dense hairs on its body.

The head capsule width of sixth instar larva was 0.45 to 0.70 mm with an average of 0.61 mm (Table 2). The duration of sixth instar larvae was 5 to 6 days with an average of 5.35 days (Table 3).

4.2.9 General habit and behaviour of the larva

Immediately after hatching the larva is gregarious at first, later spread over the leaves. Later instar larvae fed voraciously on field bean leaves. At the time of moulting, the larva became inactive.

4.2.10 Pupa

Pupation occured in the soil as sterilized soil was provided as medium. The pupa was elongated and oval in shape. The eyes and the antennal case were prominent. The freshly formed obtect pupa was yellowish and gradually reached to dark brown. The abdomen showed periodic movement. The covering of the wing was similarly prominent and was darker than the rest of the body. The abdomen has dark spiracles. Six of these spiracles were visible on either side. Female pupa was bigger than male pupa in size.

Pupa was obtect type with the anterior end broad, round and tapering posterior to a pointed tip. Their legs and appendages are not capable of free movement.

The sexes were differentiated at the pupal stage based on the position of the genital opening. In case of female, the genital opening was found on the eighth abdominal segment which was like a slit and was away from anal slit. Whereas in males the genital slit was found on the ninth segment which was smaller and closer to anal slit.

The total pupal duration ranged between 8 to 9 days with an average of 8.60 days (Table 3).

4.2.11 Adult

The adults are medium sized brown moths and had pink abdomen. Wings pinkish with numerous black spots. The head, thorax, and abdomen were distinct. The antennae and legs were light brown. Two long segmented filiform antennae were located dorsally on the head and close to the compound eyes.

The male moth was almost similar to the female but it was smaller than female in size. The abdomen was sharply tapered compared to female. The average longevity of the adult male was 4.00 to 5.00 days with an average of 4.40 days (Table 3).

The female was bigger than the male. The abdomen of female was blunt while the abdomen of male was narrower and pointed. The average longevity of the adult female was 6 to 7 days with an average of 6.20 days (Table 3).

4.2.12 Total life span

Total life span of male and female ranged from 37 to 42 days with an average 39.80 days and 39 to 44 days with an average of 41.60 days, respectively (Table 3).

4.2.13 Oviposition

The mated female moths laid their eggs during night hours. The oviposition site was first located by the female. After the site was identified, the insect cleaned the leaf surface area by wiping using the tip of the abdomen. Oviposition takes place immediately after. The eggs were deposited in 2 to 3 batches.

The pre-oviposition period varied from 1.00 to 1.50 days with an average of 1.33 days, ovipositional period was 3.00 to 4.00 days with an average of 3.66 days and post-oviposition period was 1.00 to 1.50 days with an average of 1.10 days. The fecundity data of 6 females studied individually revealed that the egg laying capacity varied from 148 to 232 eggs with an average of 195 eggs per female (Table 3).

4.3. To develop taxonomic key of hairy caterpillars based on morphological characters of adults and associate them to larvae

The results on morphological and genital characters of the adult hairy caterpillars collected in different cropping ecosystems revealed that the variation with respect to characters, *viz*., antenna, maxillary palps, and wing venation. Similarly, genital characters like uncus, saccus, valvae and phallus, were recorded. The above results clearly indicated that there were variations with respect to both morphological as well as genital characters. These variations were utilized for classifying the collected specimens into different families, sub-families, genus and species. These variations were also used to

prepare an illustrated key for easy and accurate identification of hairy caterpillars collected during survey.

The variations with respect to morphological as well as genital characters recorded for super-family, families, sub-families, genus and species along with their illustrated identification keys are given under the following headings.

Super family Noctuoidea

Diagnosis: Noctuoidea are ditrysian moths. The fundamental features that define the Noctuoidea are, presence of tibial spurs, well developed tympanum on metasternite.

Key to the families of the Superfamily Noctuoidea

1. Tarsal claw with blunt tooth at base (Plate 3)……..……..…**Notodontidae**

-Tarsal claw without blunt tooth at base (Plate 3)……..……..….….. **2**

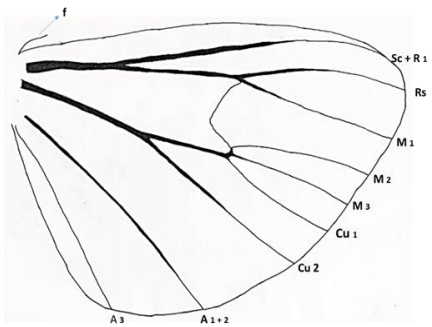
2. Sc in hindwing fused with Rs only a short distance at the base of discal cell, trifid wing venation (where vein M2 reduced so that the cubital vein appears three branched) (Plate 3)……..……..……..…..…..**Noctuidae**

-M 3 and Cu 1 in hindwing usually stalked, quadrified wing venation (where cubital vein appears three-branched) (Plate 3)……..…..…..**Erebidae**

Family Erebidae (Plate 3)

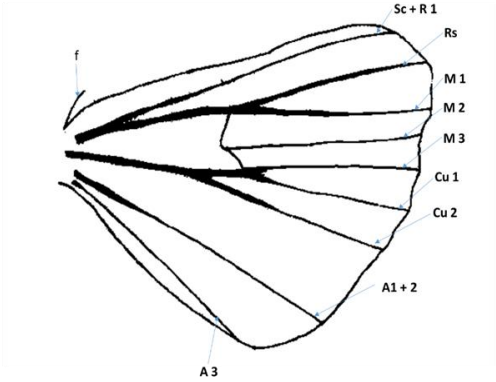
Diagnosis : Among the superfamily Noctuoidea, Erebid moths may be identified by the wing characteristics of the adults. They typically have their forewing vein 5 arising closer to the origin of vein 4 than vein 6, in the lower part of the discal cell, so that the veins 2-5 arising from the lower parts of the cell appears to be four-branched (quadrifid) and similar type of splitting of vein is also seen in hind wing hence termed as quadrifine hind wing. Scales on the ventral half of the frons deciduous, quickly falling off to leave the area bare in most specimens. Presence of tymbal organ is also characteristic of Erebidae

A) Erebidae



a. M 3 and Cu 1 in hindwing usually stalked,

B) Noctuidae



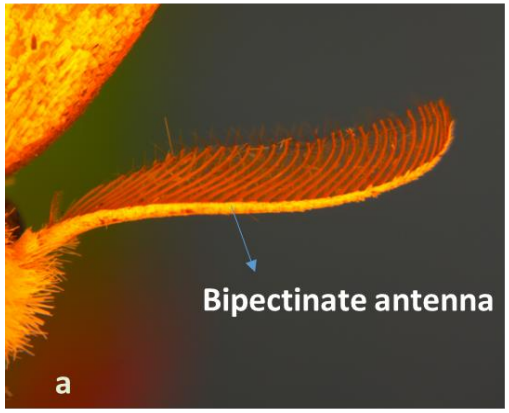
b. Sc in hindwing fused with Rs only a short distance at the base of discal cell

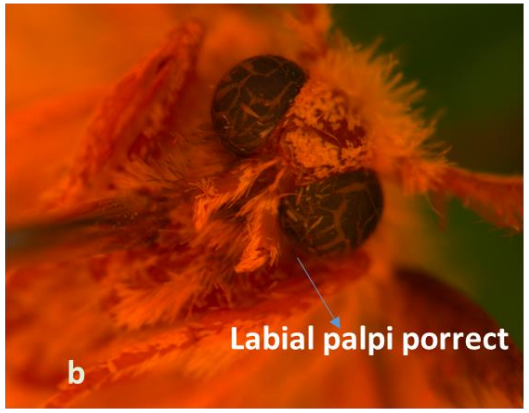
C) Notodontidae

c. Tarsal claw with blunt tooth at base

Plate 2: Diagnostic characteristic features of families of Noctuoidea

Subfamily - Lymantriinae





Subfamily - Arctiinae

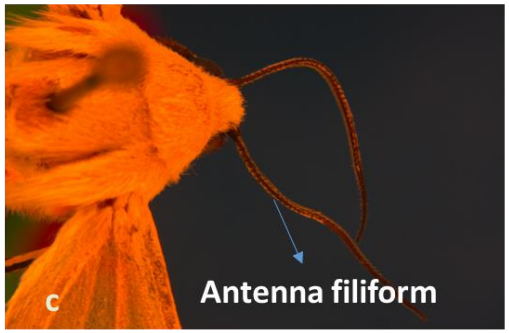
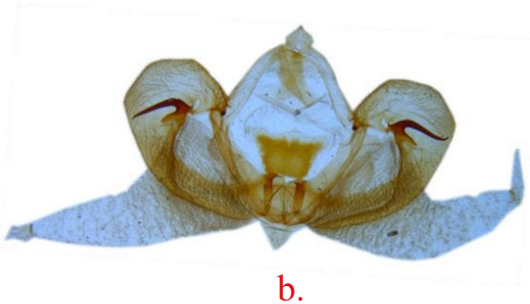


Plate 3: Diagnostic characteristic features of subfamilies of Erebidae

Genus - *Amerila*

a.



b.

c.

Genus - *Nyctemera*

d.

Plate 4: a) Adult *Amerila astreus* b) *A. astreus* genitalia

c) A. astreus aedegus vesica d) Adult *Nyctemera* sp.

Genus - *Amata*

a.

b.

c.

Genus - *Asura*

d.

e.

f.

Plate 5: a) Adult *Amata* sp. b) *Amata* sp. genitalia *c) Amata* sp. aedegus vesica

d) Adult *Asura* sp. e) *Asura* sp. genitalia f) *Asura* sp.. aedegus vesica

Genus - *Pericalia*

a.

b.

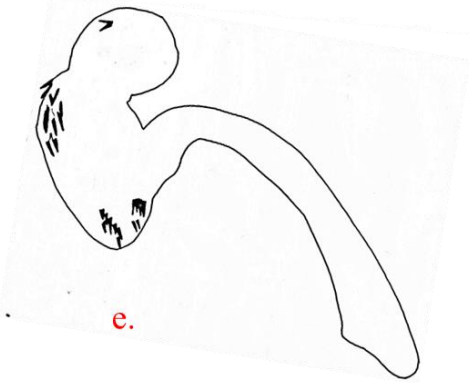
c.

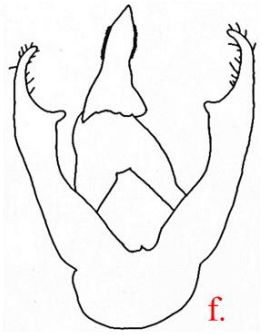
d.

Plate 6: a) Caterpillar of *Pericalia obliquiformis* b) Adult *P. obliquiformis*

c) P. obliquiformis genitalia *d) P. obliquiformis* aedegus vesica

Genus - *Creatonotus*





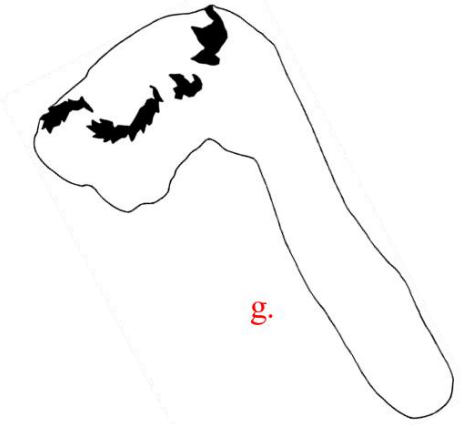


Plate 7: a) Caterpillar of *Creatonotus* b) Adult *Creatonotus gangis* *c)* Adult *Creatonotus transiens* *d) C. gangis* genitalia *e) C. gangis* aedegus vesica *f) C. transiens* genitalia *g) C. transiens* aedegus vesica

Genus - *Estigmena*

a.

b.

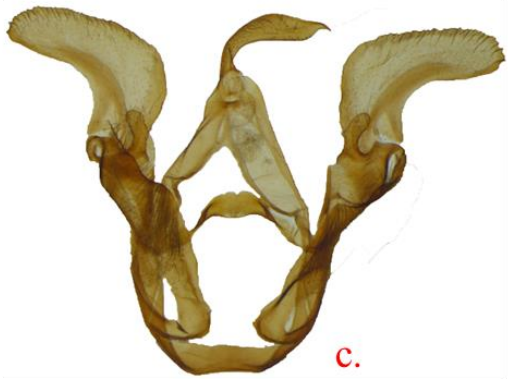
c.

Plate 8: a) Adult *Estigmena* sp. b) *Estigmena* sp. genitalia *c) Estigmena* sp. aedegus vesica

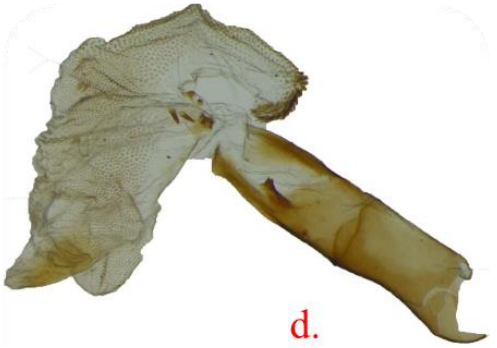
Genus - *Utetheisa*

a.

b.



c.



d.

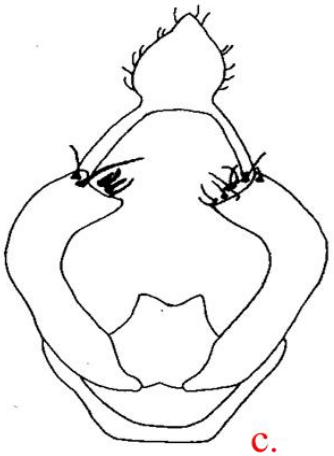
Plate 9: a) Caterpillar of *Utetheisa pulchelloides* b) Adult *U. pulchelloides*

c) U. pulchelloides genitalia *d) U. pulchelloides* aedegus vesica

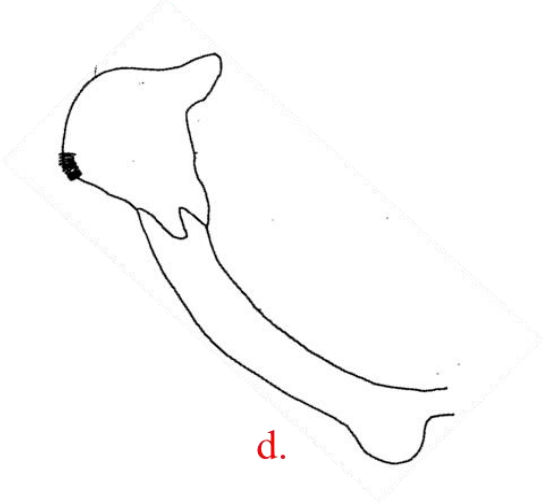
Genus - *Spilarctia*

a.

b.



c.



d.

Plate 10: a) Caterpillar of *Spilarctia obliqua* b) Adult *Spilarctia obliqua*

c) Spilarctia obliqua genitalia *d) Spilarctia obliqua* aedegus vesica

among Noctuoidea. Erebidae have a heavily sclerotised scaphium, and often also a less sclerotised subscapium.

Key to subfamilies of family Erebidae:

1. Presence of bipectinate antenna, porrected labial palpi, ocelli absent (Plate 3) ……..**Lymantriinae**

- Antenna variable , labial palpi not porrected, ocelli present (Plate 3)…...**Arctiinae**

Sub family Arctiinae (Plate 3)

Diagnosis: Antennae bipectinate, unipectinate, serrate or simple. Proboscis usually well developed, rarely aborted labial palpi short or long, porrect or upturned. Tibial spurs short or long, rarely medial spurs absent. Fore- and hind wings without vein CU 2 ; vein M2 from lower angle of cell, sometimes slightly about it, or coincident with the vein M in fore- or hind wings, or both wings. Hind wing with vein Sc not free at base but coincident with Rs nearly up to middle of cell, or rarely beyond it. In males, frenulum present, retinaculum bar shaped.

Key to genus of Sub family Arctiinae

1. Hind wings are reduced compare to forewings……..……**2**

- Hind wings are well developed ……..…..……..…...….**3**

2**.** Antenna more than 80 segmented, hind tibia having one pair spurs, rounded vulva having centralhook interiorly and protrusible corema externally, vesica has two large cornuti (Plate 4) ……..…….***Amerila***

- Antenna less than 80 segmented, hind tibia having two pair of spurs, asymmetrical vulva, vesica has rows of cornuti (Plate 5)……..…….……..……..….***Amata***

3. Presence of bipectinate antenna, hind tibia having two pair of spurs……..……...**4**

- Antenna variable (filiform), hind tibia having variable number of spurs ……..……..…**5**

4. Female abdomen with tuft of hairs at its tip (Plate 4)……..……..... ***Nyctemera***

- Female abdomen without tuft of hairs, male genitalia with bilobed vulva and cornuti arranged in groups (Plate 6)…….....***Pericalia***

5. Hind tibia having one pair spurs and have coremata on eigthth abdominal segment……..…….…….**6**

- Hind tibia having two pair of spurs and without coremata……..….**7**

6. Vulva long, slender and tapering with acute lateral process (Plate 7)……...***Creatonotus***

- Vulva not slender and shorter in length and not tapering (Plate 8)…… ***Estigmena***

7. Bulbous vulva with interior spine and cornuti absent (Plate 5) …..……..... ***Asura***

- Vulva not bulbous and cornuti present……...……..... **8**

8. Inverted V-shaped vulva having ornamented vesical (Plate 9)……..…….… ***Utetheisa***

- Bilobed vulva, aedegus with group of small cornuti (Plate 10)……..…….. ***Spilarctia***

Genus *Amerila* Walker (Plate 4)

Amerila astreus

Diagnosis: Adults of *Amerila* is characterized as follows: medium to large sized (wingspan 17-32 mm) and quite robust; proboscis particularly well developed; antenna filiform in both sexes, black, dark brown or red; The antennae have more than 80 segments. Forewings elongated, comparatively narrow. Often fully or partially transparent medially; hindwings much shorter than forewings, generally weakly scaled; ground colouration of head and thorax white, grey or various shades of brown, aposematic pattern of black dots; in most species, dorsally, one black spot medially on the occiput, two on the patagiae, one or two on the tegulae, three pairs on the thorax and two on the forewings on the base on the base of the subcoastal/radial vein; colouration of abdomen dorsally and of inner parts of femora, tibiae, and tarsi often red or yellow.

Male genitalia: The male has a broad, rather rounded valve with a central hook-like process interiorly and a massive corema exteriorly; the uncus is small; the juxta is divided into a dorsal plate and a ventral pocket; the aedeagus has a large, tubular vesica, with several distal diverticula, one of which is scobinate and bears two large cornuti.

Material examined: INDIA: Karnataka: Shivamogga, 2♂, 03.ix.2015, collected on light trap, Mallikarjun warad.

Remarks: Most *Amerila* species have been reported from Afrotropical region (Hauser and Boppre, 1997). The species *amerila astreus* is reported from India. There was a close resemblance in genitalia and abdominal colouration of the studied specimen to available literature.

Genus *Amata* Fabricius, 1807 (Plate 5)

Diagnosis: well developed proboscis, short, porrect labial palpus, downcurved or upturned; variable antenna with simple to bipectinate in males and simple to serrate in females; forewing with vein M2 from near the lower angle of cell, anal vein 2A forked at base R5 stalked with R3 + R4, hindwing small, Sc+R1 absent or rudimentary, rarely forming a fork with Rs; frenulum present; tibia with spurs short.Wing markings more elongate, with the black separating them narrower. The posterior distal transparent patch is divided by vein M3; sometimes the anterior patch also extends to beyond vein R5. Each abdominal segment is ringed finely and evenly with yellow. The male genitalia are distinctive.

Male genitalia: The genitalia is asymmetric. In the male the tegumen has prominent lateral lobes. The valves have strong, curved, asymmetric processes from the base of the costa and are themselves asymmetric. The aedeagus vesica contains a row (or rows if it has more than one lobe) of small cornuti, some of which can become very long. They have the valve apex produced into a setose process. These possess the aedeagus vesica ornamentation that characterises that genus.

Material examined: INDIA: Karnataka: Shivamogga, 4♂, 13.ix.2015, collected on light trap, Mallikarjun warad.

Remarks: This genus is best defined based on genitalic characters, also exhibits great variety in wing pattern and abdominal banding. The genitalia of the studied specimen do not match with the available literature. So we are not able to identify the studied specimen to species level due to lack of of literature.

Genus *Nyctemera* Hubner, 1820 (Plate 4)

Diagnosis: Head and thorax yellowish white. The abdomen white with black bands, the extremity yellow. Tegulae with three black spots. Fore wing white with the costa dark at base, an irregular medial band sending streaks along the veins to the marginal band which extends from costa through apex to vein 3 and has three white marginal spots and dentate inner margin. Hind wing white with black patch at lower angle of cell and five sub marginal spots.

Material examined: INDIA: Karnataka: Shivamogga, 1♀, 13.vii.2015, collected on light trap, Mallikarjun warad.

Remarks: Genus *Nyctemera* is known to be reported from Assam, India. The studied specimen was female and there were no specific genitalic characters for species identification. Due to lack of availability of literature we could not able to proceed further.

Genus *Pericalia* Fabricius (Plate 6)

Pericalia obliquiformis

Larval description: Larva are black with brown head having long brown hairs known as "Woolly Bear" (Plate 5).

Diagnosis : The species is characterised by the fore wing being darker throughout, marked with a series of black brown spots edged with white; hind wings are also sin1ilarly marked with maculate bands particularly in subbasal, medial, postmedial and terminal area but without pale edging. The antennae in the specimen presently studied, show that these are very minutely serrate on one side.

Male genitalia : Male genitalia with bilobed vulva and cornuti arranged in groups.

Material examined : INDIA: Karnataka: Shivamogga, 2♂, 29.vi.2015, collected on light trap, Shashank P. R.

Remarks : The species is of great economic importance, commonly known as "Woolly Bear". The studed specimen were identified to species level as *Pericalia obliquiformis* based on wing colourations. The literature on this genus is not available.

Genus *Utetheisa* Hampson (Plate 9)

Utetheisa pulchelloides

Larval description: The larva is bright lemon-yellow with black patterning. The ground colour forms a narrow dorsal stripe broken by black at the centre of each segment, the head is dark tan (Plate 8).

Diagnosis: There is a red patch between the more elongate pair of black marginal marks at the tornus and the subdorsal black spot of the submarginal region. *There is* reliable

difference in the forewing: there is a red patch between the more elongate pair of black marginal marks at the tornus.

Male genitalia : Valves have general configuration, the aedeagus vesica have ornamentation, the juxta like an inverted 'V', and the fusion of the transtillae into a single narrow band are features shared with *Utetheisa,* as are elliptical 'windows' (less sclerotised) lateral to the apodemes of the basal abdominal sternite.

Material examined : INDIA: Karnataka: Shivamogga, 4♂, 02.vii.2015, reared on sunhemp, Mallikarjun warad

Remarks : *Utetheisa pulchelloides* is known to be reported from India. The most frequently recorded host-plant is sunhemp. This genus was well described using male genitalia. The studied specimen was idenfied as *Utetheisa pulchelloides* based on the literature available.

Genus *Creatonotos* Hubner, 1819 (Plate 7)

Keys to the species of Genus *Creatonotos*

1. Forewing having black fascia, aedegus vesica with long cornuti (Plate 6)…...…….….. ***gangis***

- Forewing having three black discal dots, aedegus vesica with short cornuti (Plate 6)…….……..... ***transiens***

***Creatonotos transiens* Walker, 1855 (Plate 7)**

Larval description: The skin is very dark brown, with a dorsal stripe. The setae on the verrucae are a paler, more rufous brown (Plate 6).

Diagnosis: Head and thorax dark, chestnut-brown. Abdomen golden yellow, with a series of dorsal black spots. Fore wing dark chestnut, the costa and cell of fore wing suffused with white. Three orbicular and reniform spots outlined in grey on discocellulars. Hind wing with a broad irregular black margin and with a black spot on discocellulars.

Male genitalia : In the male genitalia, the valve is long, slender, tapering, with an acute lateral process. In *transiens,* there are usually two or more fields of short, broad spines fused at their bases so each field appears as a single block of sclerotisation.

Material examined : INDIA: Karnataka: Shivamogga, 2♂, 23.x.2015, collected on light trap, Mallikarjun warad.

***Creatonotos gangis* Linnaeus, 1763 (Plate 7)**

Diagnosis: Head, thorax and fore wing pale pinkish brown, palpi and legs smoky black, the femora yellow, a broad dorsal band on thorax. Species in this genus tend to have rather narrow forewings, somewhat lenticular in shape, typically with longitudinal blackish streaks on a pale ground. Hind wing pale, some specimens with a sub marginal series of black spots.

Male genitalia : In the male genitalia the valve is long, slender, tapering, with an acute lateral process. The juxta extends as a sclerotised band into the anellar tube. The aedeagus vesica has three fields of numerous moderate, long spines.

Material examined : INDIA: Karnataka: Shivamogga, 3♂, 23.x.2015, reared on cocoa, Mallikarjun Warad.

Remarks : Strand (1919) recorded two species, *gangis* and *transiens* under this genus from India. These species are identified based on aedegus vesical character.

Genus *Asura* Walker (Plate 5)

Diagnosis: Moderate-sized species with forewings boldly banded in black and yellow.

Male genitalia : The male has reduced to vestigial abdominal coremata, and a valve apex simply divided into a lobe of the lamina without a distinct costal projection, and a tapering saccular process. The saccus is often acute. The aedeagus vesica is distinguished by clusters of moderate but slender spines on several lobes.

Material examined : INDIA: Karnataka: Shivamogga, 2♂, 29.vi.2015, collected on light trap, Shashank P. R.

Remarks : Information is not available with respect to species of *Asura,* hence could not be identified to species level.

Genus *Spilarctia* Butler, 1875 (Plate 10)

Spilarctia obliqua

Larval description: Larva orange coloured with broad transverse band with tufts of yellow hairs that are dark at both ends (Plate 9).

Diagnosis: The species, popularly known as the 'Bihar hairy caterpillar', is characterised by porrected Labial palpi. Antennae bipectinate in males, ciliated in females. The forewings of the male are red rather than creamy colour, and the hindwings are immaculate. Both wings grade distinctively yellowish at the margin. The oblique series of black spots on fore wing starts from apex; hind wing being of the same colour as of forewing. Hind tibia with two pairs of spurs.

Male genitalia : Uncus moderately long, broad at base and gradually narrowing towards tip; acrotergite well developed; fenestrula absent; saccus present; valvae simple with costa narrow and linear, sometimes produced at proximal end; sacculus present, valvula and cucullus not clearly differentiated; juxta trapejoid; aedeagus moderately long and broad; vesica membranous with irroration of small spines.

Material examined : INDIA: Karnataka: Shivamogga, 5♂, 20.ix.2015, reared on field bean, Mallikarjun warad.

Remarks : The species is very common throughout India and is economically important, being a pest of a variety of hosts, including vegetables, grains, spices, soybeans, tobacco, sunflower, oil seeds, lablab and lantana. The studied specimens were identified to species level as *Spilarctia obliqua* based on the available literatute on Indian species of the genus *Spilarctia* Butler (Kirti and Gill, 2010).

Genus *Estigmena* Walker (Plate 8)

Diagnosis: Forewings are white with brown streaks all along the coastal margin of wing. Hindwing has few to many black spots; antenna filiform; hind tibia with one pair of spur.

Male genitalia : Adults have coremata on 8th abdominal segment; Vulva simple and broader, shorter in length and not tapering, vinculum V-shaped. Uncus is triangular; aedegus vesica has numerous short cornuti distributed in patches.

Material examined : INDIA: Karnataka: Shivamogga, 2♂, 23.x.2015, collected on light trap, C. M. Kalleshwaraswamy.

Remarks : During study we are able to collect only one species of *Estigmena*. Due to lack of availability of literature we are unable to proceed further.

Key to genus of Sub family Lymantriinae :

1. Presence of 2 pairs of tibial spur……... **2**

- . Presence of 1 pair of tibial spur (Plate 11).……..……*Perina*

2. Hindwing with veins 3 and 4 stalked for a long distance (Plate 12).....…*Euproctis*

- Hindwing with veins 3 and 4 are stalked near the discal cell (Plate 13).....*Lymantria*

Subfamily Lymantriinae (Plate 3)

Diagnosis: Small to medium sized moths, antennae of both sexes strongly bipectinated, the pectinations longer in male, a thoracic tympanum as well as a prespiracular counter-tympanal hood present as found in the Arctiinae, fore wing areole can be present or absent, often with long, hair-like scales on thorax and abdomen.

Genus *Perina* Walker (Plate 11)

Perina nuda

Larval description: The larva has a grey head and flanks, with the dorsum broadly black. Within this black band, there is a narrow wedge over the thoracic segments that tapers towards the head and then expands as a 'T' along the anterior margin of the prothorax. The black over the abdominal segments is circular on each and is bisected over the central three by a double pale yellow band. The setae are white, arising from red verrucae (Plate 10).

Genus - *Perina*

a.

b.

c.

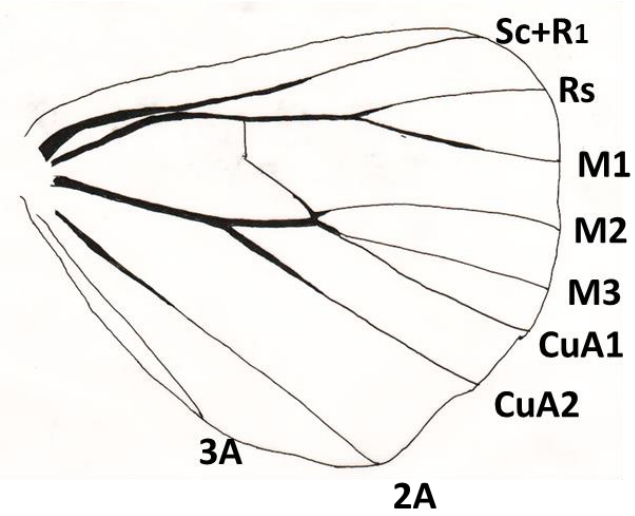
d.

Plate 11: a) Caterpillar of *Perina nuda* b) Male *P. nuda* *c)* Female *P. nuda* d) Hind tibia with one pair of spurs

Genus - *Euproctis*

a.

b.



c.

Plate 12: a) Caterpillar of *Euproctis* sp. b) Adult *Euproctis* sp. c) Hindwing veins 3 and 4 stalked for a long distance

Genus - *Lymantria*

a.

b.

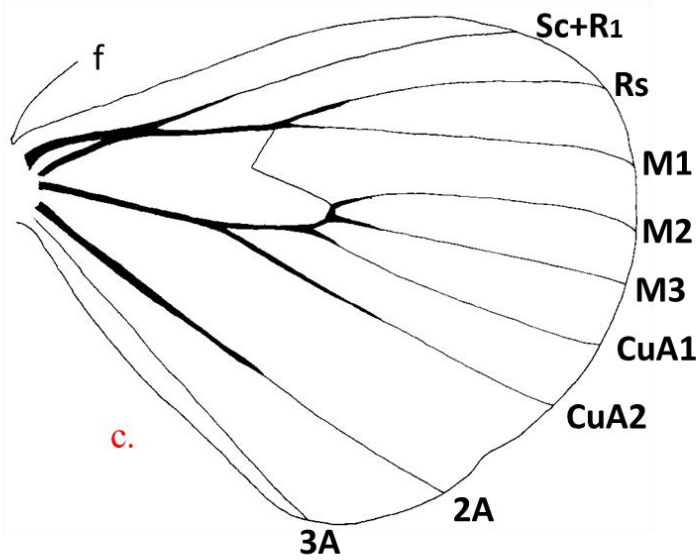


Plate 13: a) Caterpillar of *Lymantria* sp. b) Adult *Lymantria* sp.
c) Hindwing veins 3 and 4 stalked for a short distance near discal cell

Sp. 1

Sp. 2

Sp. 3

Sp. 4

Sp. 5

Sp. 6

Sp. 7

Plate 14: Caterpillars did not reach to adult stage

Diagnosis: M2 and M3 are connate in the forewing and strongly stalked in the male hindwing (connate in the female); the male hindwing is also modified to a rather squarish shape and M1 is lost. The scaling is black in most species but can be brown or white, the type species showing some variation in this.

Male genitalia: The male genitalia show a sort of asymmetry valva fused and narrow. Aedeagus long and pointed with swollen base. Vinculum narrow and long.

Material examined: INDIA: Karnataka: Shivamogga, 2♂, 15.i.2016, reared on fig leaves, Mallikarjun warad.

Remarks: This genus shows striking sexual dimorphism, the males with extensive transparent areas across the forewing and at the costal angle of the hindwing, the females resembling members of the other Lymantriid females. The studied specimen was identified as *Perina nuda* based on the literature available on moths of Borneo.

Genus *Euproctis* Hübner, 1816 (Plate 12)

Larval description: Larva is reddish brown hairy caterpillar, having tuft of hairs emerging from a single point like a shoe polish on the dorsum of the abdomen (Plate 11).

Diagnosis: proboscis absent or rudimentary; vertex and thorax covered with moderately long hairs; frons rounded with short hairs; abdomen longer than hind wings, covered dorsally with short hairs and ventrally longer hairs; mid tibiae with one pair and hind tibiae with two pair of spurs. Fore wing long and hind wing triangular. Abdomen in female with tuft of hairs.

Male genitalia: Vinculum U- shaped; saccus very much elongated, curved and U-shaped; Valvae with the tip depressed; uncus beak like; aedegus with well developed cornuti.

Wing venation: Fore wings with veins 7, 8, 9, and 10 stalked, vein 10 given off towards apex;

Material examined: INDIA: Karnataka: Shivamogga, 2♂, 08.vii.2015, reared on paddy, Mallikarjun warad.

Remarks: Genus *Euproctis* is known to be reported from India. From the general appearance and other characters *Euproctis* differs from other lymantriids in having black

spots at the end of the cell and Hindwing with veins 3 and 4 stalked. Our study specimen did not matched to the available literature so we are not able to identify to species level.

Genus *Lymantria* Stephens (Plate 13)

Larval description: Yellow coloured hairy caterpillar, having tuft of hairs emerging from a single point like a shoe polish on the dorsum of the abdomen (Plate 12).

Diagnosis: Proboscis absent; palpi porrect and covered with short hairs; reduced compound eyes; Antenna bipectinate; hind tibiae with two pairs of spurs; abdomen with anal tuft of hairs.

Wing venation: forewing with veins 7, 8, 9 and 10 stalked, vein 7 and 10 given off from more or less same point; hind wing with veins 3 and 4 originating from same point of cell and not stalked , vein 6 and 7 stalked.

Material examined: INDIA: Karnataka: Shivamogga, 2♂, 12.x.2015, reared on sunflower, Mallikarjun warad.

Remarks: This genus is certainly allied to *Euproctis*, from which it has most probably separated.

DISCUSSION

V. DISCUSSION

In this chapter, a detailed experimental results of 'Faunistic studies on hairy caterpillars in different cropping ecosystems' obtained from the collection of hairy caterpillars through survey, biology of *Spilarctia obliqua* and morphological and genital characteristic studies of adults were discussed in the light of literature available on Noctuoidea and related Lepidoptera. Most of the discussions relating to individual taxa have already been covered under "Remarks" for each taxon in the previous chapter.

5.1. To collect and document hairy caterpillars (Erebidae) in different cropping ecosystem along with their host range

Intensive collections of hairy caterpillars (Erebidae) occurring on different crops were made by undertaking survey. During the survey, total of fourteen species in which five were identified upto species level. Five hairy caterpillars were recorded collected through light trap. These belonged to two subfamilies *viz.,* Arctiinae and Lymantriinae. The sub- family Arctiinae was documented with nine genus *viz., Amerila, Amata, Nyctemera, Pericalia, Creatonotus, Estigmena, Asura, Utetheisa* and *Spilarctia* respectively. While the subfamily Lymantriinae was recorded with three genera *viz., Perina, Euproctis and Lymantria.* Of the thirteen genera, the genus *Creatonotus* was represented with two species namely; *Creatonotus gangis* and *Creatonotus transiens* respectively. The remaining genera represented with single species each.

Among the arctiids *Pericalia ricini* was found to feed on pigeonpea leaves. Sunhemp was recorded as host plant of *Utetheisa pulchelloides.* Similarly Miyata (1983) recorded host-plant of *Utetheisa pulchelloides* as *Messerschmidia, Bothriospermum, Heliotropium*. *Creatonotus gangis* were found to feed on cocoa leaves during rainy season. Pholboon (1965), Browne (1968) and Miyata (1983) recorded the wide range of host-plants of *C. gangis* including *Beta*, *Dioscorea*, *Paspalum, Zea Pithecelbobium, Vigna, Musa, Salix, Cayratia* and *Cissus.* The host plant of *Spilarctia obliqua* recorded were field bean, sunflower and castor. Similarly Singh and Singh (1992) reported extensive damage to crops such as oilseeds, pulses, vegetables, fodder, fiber crops, fruit trees by *S. obliqua*. This may be due to the polyphagous and sporadic nature of the pest.

Among the Lymantriid hairy caterpillars collected during the study, *Perina nuda* is found to feed voraciously on fig leaves. This genus shows striking sexual dimorphism, where the males with extensive transparent areas across the forewing and at the costal angle of the hindwing, the females resembling members of other lymantriid adults. Sevastopulo (1938, 1940), Toxopeus (1948), Pholboon (1965) and Browne (1968) recorded *Ficus religiosa* (the banyan), other *Ficus* and *Artocarpus* (Moraceae) as host plants of *Perina nuda*. *Euproctis* sp. is recorded from paddy and banana. Gupta and Tara (2014) reported *Euproctis scintillans* causing considerable damage to apple plantations (*Malus domestica* Borkh.). *Lymantria* sp. is recorded from castor where it was found to feed on leaves and capsules of the castor. It was found that the females of this genus were wingless.

During the study four species of adults were recorded on light trap. The light trap collection of hairy caterpillars, other than the host based ones indicate still there are other species of hairy caterpillars apart from our collection exists in this region. If studied intensively the document of hairy caterpillars is strengthened. Chandra and Nema (2007) collected twenty six species of Erebidae moths using light trap. Of which 6 genera belong to Arctiinae and 4 genera to sub-family Lymantriinae from Arunachal Pradesh. In another study, Gurule *et al.* (2011) while investigating macro moth fauna of North Maharashtra, collected 180 moth species of superfamily Noctuoidea. A total 372 species are collected from various families, 173 species of moths identified from superfamily Noctuoidea, which represent the most diverse group includes family Noctuidae and Notodontidae and Erebidae.

Similar results were also reported by various authors like Zaspel *et al.* (2012), Gupta and Tara (2014), Weseloh (2003), Ferro and Romanowski (2012), Tiwari and Kashyap (1989), Sharma and Bisen (2013), Ramadan *et al*. (2011).

5.2. Studies on the biology of the Bihar hairy caterpillar, *Spilarctia obliqua* on field bean leaves

The present studies indicated that the eggs are pearly white become pale yellow in colour slightly flattened on one side. The number of eggs per mass varies considerably

but is often 148 to 232 in batches and covered hairy scales from the tip of the abdomen of the female moth. In absence of the literature pertaining to the biology of *S. obliqua* on field bean, reviews on other crops were considered. There is no relevant literature is available on this aspect to support the present study. Gotyal *et al.* (2013) studied the comparative biology of *Spilarctia obliqua* on jute. They reported effect of cultivated and wild species of jute on the larval survivability, larval weight, pupal weight and adult emergence of *Spilarctia obliqua* at different days after feeding.

5.3. To develop taxonomic key of hairy caterpillars based on morphological characters of adults and associate them to larvae

The morphological characters of adults of different species were highly variable, for example, frons, antenna, labial palps, wing venation, structure of tympanum *etc*. And also modifications in male genitalia like uncus, saccus, valvae and phallus and in female, corpus bursa, ductus bursa and signum *etc*., were also variable. In the current study, the variation with respect to morphological characters like frons, labial and maxillary palps, wing venation, structure of tympanum and tibia of hairy caterpillars fauna of different cropping ecosystems were studied and recorded. Similarly, Arora (1982) documented variations with respect to morphological characters like color pattern and shape of the wing, body and palpi of the North-East Indian arctiids. Arimoto and Iwaizumi (2014) also studied and recorded various morphological variations like color pattern of the wing, wing venation and shape of the body of lymantriid adults.

The male genitalia of two different species will not be same in their structure. Studies on genital characters play a very important role in resolving the species complexity among pest species attacking the economically important crops where the species were externally homologous or with slight morphological variations. Such variations with respect to genital characters like uncus, saccus, valvae and phallus were studied and recorded during the current study. Similarly, Saldaitis *et al.* (2012) described two new species of *Eospilarctia* based on differences in wing pattern and genitalia.

In the current study, all the above discussed variations were used for classifying the surveyed specimens into different families, sub-families, genus and species. These variations were also used to prepare illustrated keys for easy identification. Similarly,

Fibiger and Lafontaine (2005) prepared a key for identification of moths of family Erebidae based on genital characters. In another study, Arimoto and Iwaizumi1 (2014) provided illustrated key to the Japanese Lymantria Species.

Family Erebidae

The results on the morphological and genital characteristics of adults indicated that the sub-families Arctiinae and Lymantriinae are different. These sub-families are closely associated with each other, but they can be easily separated / differentiated using certain peculiar characters as indicated in key.

Generic keys

The nine genera of the sub family Arctiinae was studied viz., *Amerila*, *Amata*, *Nyctemera*, *Pericalia*, *Creatonotus*, *Estigmena*, *Asura*, *Utetheisa* and *Spilarctia* respectively. These genera were easily differentiated by morphological and genital characters.

The genus *Amerila*, can be easily recognised by the antenna filiform in both sexes, black, dark brown or red. The male has a broad, rather rounded valve with a central hook-like process interiorly and a massive corema exteriorly. Genus *Estigmena* characterized by forewings are white with brown streaks all along the coastal margin of wing. adults have coremata on 8^{th} abdominal segment.

The genus *Amata* differs from all the other genera by the presence of asymmetric male genitalia. Aedeagus vesica ornamentation that characterises this genus from others. Genus *Nyctemera* differs from rest by fore wing white with the costa dark at base, an irregular medial band sending streaks along the veins to the marginal band which extends from costa through apex to vein 3 and has three white marginal spots and dentate inner margin.

Genus *Pericalia* differs by the fore wing being darker throughout, marked with a series of black brown spots edged with white and male genitalia with bilobed vulva. Genus *Utetheisa* There is reliable difference in the forewing: there is a red patch between the more elongate pair of black marginal marks at the tornus.

Genus *Asura* characterized by moderate-sized with forewings banded in black and yellow. The aedeagus vesica is distinguished by clusters of moderate but slender spines on several lobes. Genus *Spilarctia* characterised by antennae bipectinate in males, ciliated in females. valvula and cucullus not clearly differentiated.

The three genera of the sub family Lymantriinae were studied. The genus *perina* is easily differentiated by the other genus were it has one pair of tibial spur. Genus *Euproctis* being hindwing veins 3 and 4 stalked for a long distance beyond discal cell. Genus *Lymantria being* hindwing veins 3 and 4 are stalked near the discal cell.

Keys to species of the Genus *Creatonotos* Hubner, 1819

The genus *Creatonotos* is represented by two species. They look very similar externally but can be recognized by the differences in their fore wing patters and genitalia, aedegus vesica is being long cornuti in *C. gangis and* aedegus vesica with short cornuti in *C. transiens*.

Knowledge about the immature stages of lepidoptera is important because it aggregates information on the biology and ecology of these organisms and it is also useful for their taxonomy and systematics (Bizarro *et al*., 2003). In this region there is a huge menace of hairy caterpillars especially in rainy season in different cropping ecosystems including domestic areas as well. The larva of many hairy caterpillars looks alike and there is lack of information regarding the association of larvae to their adults. The correct identification of pest is of primary importance in the management. It is difficult to identify the hairy caterpillars during larval stage. Nascimento *et al.* (2014) studied morphological variation between instars, and presented varied color patterns in the last larval instar. In this study the immatures were reared to adults so that associations were made to their adults. Study on larval characters of identified species helps in development of a field guide.

SALIENT FINDINGS OF THE INVESTIGATION

- Hairy caterpillars are highly diverse in their habitat infesting agricultural, horticultural and also weed plants
- Total 13 genera of hairy caterpillars were recorded in this region
- The studies on the biology of Bihar hairy caterpillar, *Spilarctia obliqua* revealed the presence of seven instars with the fecundity of 194 ± 36.08
- Studies on morphological and genital characters of adult moths of hairy caterpillars facilitated classification and preparation of illustrated identification keys, which helps easy and accurate identification of pest species.
- Also the association of adults with their larvae helps as a guide to field workers

FUTURE LINE OF WORK

- Hairy caterpillars are highly diverse and polyphagous occurring in different cropping ecosystems. Intensive collection should be made for longer period to know their diversity in different cropping ecosystems
- Larval taxonomy is in need as work on larval taxonomy on hairy caterpillar is meager
- Colour morphs have also been reported in larval stage and also among instars. A robust illustrated identification guide is needed to help field workers and pest managers
- DNA bar coding is the emerging field to resolve confusions for species status. The hairy caterpillars fauna collected in the current study can be utilized for DNA bar coding. Hence, there is need to bar code all the hairy caterpillars of India, thereby helping the researchers and practitioners in the field of Erebid taxonomy and their management
- Understanding the distribution of hairy caterpillars and their mapping is one of the prerequisite to know the existence of such species in different agro-ecosystem
- There is a need to prepare the checklist for all the hairy caterpillars of India, as it provides a synopsis of the species occurring in different cropping ecosystem

SUMMARY

VI. SUMMARY

The results of the investigations made on faunistic studies on hairy caterpillars (Lepidoptera : Noctuoidea) in different cropping ecosystem are summarized in this chapter.

A total of fourteen genera of hairy caterpillars were documented from the study. The species belonged to two sub-families *viz.,* Arctiinae and Lymantriinae. Arctiinae is represented by genus *Creatonotus*, *Utetheisa*, *Estigmena*, *Spilarctia* , *Pericalia*, *Argina*, *Amerila*, *Asura*, and *Amata*. Genus *Creatonotus* is represented two species *Creatonotus gangis and Creatonotus transiens* and genus *Pericalia* represented by *Pericalia ricini and Pericalia obliquiformis.* Lymantriinae is represented by genus *Perina*, *Euproctis* and *Lymantria*.

Among lymantrid hairy caterpillars reared, *Euproctis* is documented to feed on banana and paddy, *Lymantria* on castor and *Perina* on fig and one wingless species from *Mimosa pudica* which was unable to be identified. Among arctiids *Creatonotus* is documented from cocoa, *Utetheisa* from sunhemp, *Spilarctia* from castor, *Pericalia* from pigeonpea. *Estigmena*, *Argina*, *Amerila*, *Asura*, *Amata* are collected from light traps. About seven unidentified species were recorded on different hosts too.

Biology of the Bihar hairy caterpillar, *Spilarctia obliqua* reared on field bean leaves revealed that the eggs were creamy white became pale yellow in colour. The number of eggs per mass varied from 148 to 232 in batches. Egg period, larval and pupal period varied from 5 to 6, 20 to 21 and 8 to 9 days, respectively. The average eggs laid by female moth were 148 - 232. The length of male and female moth varied from 51 to 55 mm and 55 to 59 mm, respectively. The total life span of male and female ranged from 37 to 42 days and 39 to 44 days, respectively.

Studies on development of taxonomic keys for adult hairy caterpillars based on morphological characters of adults revealed that morphological and genital characters of adults of different species exhibited variations. Based on these variations, an illustrated key was prepared for families of super-family Noctuoidea, sub-families of Erebidae and to the genera of twelve species of hairy caterpillars.

Three genera of the sub-family of lymantriinae were studied. The genus *Perina* was documented with only one species. This genus shows striking sexual dimorphism, the males with extensive transparent areas across the forewing and at the costal angle of the hindwing, the females resembling members of the Nygmiini. The genus *Euproctis* Hübner From the general appearance and other characters *Euproctis* differs from other lymantriids in having black spots at the end of the cell and Hindwing with veins 3 and 4 stalked. Our study specimen did not match to the available literature so we are not able to identify to species level. The genus *Lymantria* Stephens with veins 3 and 4 stalked for a short distance near discal cell. There is no literature is available on this genus so we are unable to go further level.

Three genera of the sub-family of Arctiinae were studied. The nine genera of the sub family Arctiinae was studied viz., *Amerila*, *Amata*, *Nyctemera*, *Pericalia*, *Creatonotus*, *Estigmena*, *Asura, Utetheisa* and *Spilarctia* respectively. These genera were easily differentiated by morphological and genital characters.

The genus *Amerila*, can be easily recognised as the male has a broad, rather rounded valve with a central hook-like process interiorly and a massive corema exteriorly. Genus *Estigmena* characterized by forewings are white with brown streaks all along the coastal margin of wing. adults have coremata on 8^{th} abdominal segment.

The genus *Amata* differs from all the other genera by the presence of asymmetric male genitalia. Aedeagus vesica ornamentation that characterises this genus from others. Genus *Nyctemera* differs from rest by white forewing with the costa dark at base, an irregular medial band sending streaks along the veins to the marginal band which extends from costa through apex to vein 3 and has three white marginal spots and dentate inner margin.

Genus *Pericalia* is characterised by the forewing being darker throughout, marked with a series of black brown spots edged with white and male genitalia with bilobed vulva. Genus *Utetheisa* there is reliable difference in the forewing: there is a red patch between the more elongate pair of black marginal marks at the tornus.

Genus *Asura* is characterized by moderate-sized with forewings boldly banded in black and yellow. The aedeagus vesica is distinguished by clusters of moderate but slender spines on several lobes. Genus *Spilarctia* characterised by antennae bipectinate in males, ciliated in females. valvula and cucullus not clearly differentiated.

The developed illustrated identification key may be useful for identification of important adults of hairy caterpillars occurring in this region.

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