STUDIES ON LAC INSECT, *Kerria lacca* (Kerr.) (TACHARDIIDAE: HEMIPTERA) IN ODISHA WITH SPECIAL REFERENCE TO ITS NATURAL ENEMIES COMPLEX

A

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IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE IN AGRICULTURE
(ENTOMOLOGY)

By

SUBODH KUMAR ROUT

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THESIS ADVISOR **DR. C. R. SATAPATHY**

DEPARTMENT OF ENTOMOLOGY
COLLEGE OF AGRICULTURE
ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR- 751003, ODISHA

Dr. C.R.SATAPATHY
Professor & Principal Investigator,AICRP on Honey Bees & Pollinators
Department of Entomology
College of Agriculture
O.U.A.T., Bhubaneswar -751 003

CERTIFICATE-I

This is to certify that the thesis entitled "***STUDIES ON LAC INSECT, Kerria lacca (Kerr.) (TACHARDIIDAE: HEMIPTERA) IN ODISHA WITH SPECIAL REFERENCE TO ITS NATURAL ENEMIES COMPLEX***" submitted in partial fulfillment of degree of ***Master of Science in Agriculture (Entomology)*** to the ***Orissa University of Agriculture and Technology, Bhubaneswar*** is a faithful record of *bona fide* research work carried out by ***SRI SUBODH KUMAR ROUT*** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma or published in any other form.

The help and information availed during the investigation have been duly acknowledged by him.

Satapathy 01/08/12

Bhubaneswar
Date: 01.08.12

(Dr. C.R.SATAPATHY)
Chairman
Advisory Committee

CERTIFICATE-II

This is to certify that the thesis entitled ***"STUDIES ON LAC INSECT, Kerria lacca (Kerr.) (TACHARDIIDAE: HEMIPTERA) IN ODISHA WITH SPECIAL REFERENCE TO ITS NATURAL ENEMIES COMPLEX"*** submitted in partial fulfillment of degree of ***MASTER OF SCIENCE IN AGRICULTURE IN*** **DEPARTMENT OF ENTOMOLOGY** of Orissa University of Agriculture and Technology, Bhubaneswar by **SRI SUBODH KUMAR ROUT** has been approved by the student's advisory committee after an oral examination on the same in collaboration with the external examiner.

Approved by Advisory Committee

CHAIRMAN : **Dr. C. R. Satapathy**
Professor& Principal Investigator,
AICRP on Honey Bees & Pollinators
Department of Entomology
College of Agriculture
O.U.A.T., Bhubaneswar-751003 ----------

MEMBER : **Dr. B. C. JENA**
Professor and Head
Department of Entomology
College of Agriculture
O.U.A.T., Bhubaneswar-751003 ----------

MEMBER : **Dr. S.N. Mahapatra**
Professor
Department of Nematology
College of agriculture
O.U.A.T., Bhubaneswar-751003 ----------

EXTERNAL EXAMINER : ----------

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Subodh Kumar Rout

Bhubaneswar **(Subodh Kumar Rout)**

1st August, 2012



Dedicated to

my

Beloved Parents

Name of the student	:	**Sri Subodh Kumar Rout**
Admission Number	:	11Ent /10
Title of Thesis	:	STUDIES ON LAC INSECT, Kerria lacca (Kerr.) (TACHARDIIDAE: HEMIPTERA) IN ODISHA WITH SPECIAL REFERENCE TO ITS NATURAL ENEMIES COMPLEX.
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Name of the Department	:	Department of Entomology, College of Agriculture, OUAT, Bhubaneswar-751 003
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Name of the Advisor	:	Dr.C.R.Satapathy Professor & Principal Investigator, AICRP on Honey bees and Pollinators, Department of Entomology,OUAT, Bhubaneswar-751 003

ABSTRACT

Studies on the lac insect, *Kerria lacca* (Kerr.) (Tachardiidae: Hemiptera) in Odisha with special reference to its natural enemies complex was undertaken during 2011-12 in the Department of Entomology, College of Agriculture, OUAT, Bhubaneswar along with survey of Nabarangpur , Mayurbhanj and Boudh districts of Odisha to know the growth and development of lac insect on *Flemingia semialata* under Bhubaneswar agro- climatic conditions, occurrence and relative abundance of different natural enemies in Bhubaneswar as well as lac ecosystems of three selected tribal lac growing districts of Odisha and analyze the lac ecosystem with special reference to diversity of natural enemies complex in Odisha. The winter aghani crop of Kusumi strain on *Flemingia semialata* Roxb. under Bhubaneswar conditions within a temperature regime of 18.1 to 35.1 ^{0}C took a period of 158-163 (Av.159.5$\pm$ 2.26) days from inoculation to the emergence of nymphs for succeeding crop . The pinkish red first instar nymph of aghani crop settled completely on the host plant within a week with density of 158 – 212 (Av.173.4 $\pm$52.1) nymphs/cm^{2}.Two encyrtid parasitoids viz., *Tachardiaephagus tachardiae* (Howard) and *Parechthrodryinus clavicornis* (Cameron) and an eupelmid *Eupelmus tachardiae* (Howard) attacked the lac insect under Bhubaneswar conditions, the former being most abundant. Out of ten natural enemies, three inimical parasitoids viz., *Tachardiaephagus tachardiae* (Howard, *Parechthrodryinus clavicornis* (Cameron) and *Eupelmus tachardiae* (Howard); four beneficial parasitoids viz.,*Apanteles tachardiae* Cam., *Apanteles fakhrulhajiae* Mahd. *Bracon greeni* Ashm and *Pristomerus sulci* Mahd and Kolub and three predators viz., *Eublemma amabilis* Moore, *Pseudohypatopa (=Holcocera) pulverea* Meyr.and *Chrysopa* sp. were recorded from lac ecosystem of Odisha. *T. tachardiae* , *P, clavicornis* , *E.tachardiae* , *A. tachardiae* among the parasioids and *E. amabilis* and *P.pulverea* among the predators were found in all the three districts and relatively in large number indicating their vital role in regulating natural balance in the lac ecosystem. Analysis of lac eco system of Odisha with special reference to diversity of natural enemies complex indicated that ten species of natural enemies represented six families viz Encyrtidae(2), Braconidae (4) ,Eupelmidae, Ichneumonidae, Noctuidae, Blastobasidae and Chrysopidae (1 Each) and three orders viz Hymenoptera(7) , Lepidoptera(2) and Neuroptera(1).The inimical parasitoids i.e. *T. tachardiae and E.tachardiae* assumed the dominance status while *P, clavicorns*, *E. amabilis* and *P.pulverea* assumed sub dominant status in the lac ecosystem as a whole. Further, the natural enemies complex comprised 92.19 per cent detrimental (67.96% Parasitic + 24.23% Predatory) and 7.81 per cent beneficial fauna to lac cultivation .Thus, adoption of appropriate natural enemies management practices would be inevitable for higher lac production in the state.

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Chapter – 1

INTRODUCTION

Chapter - 1

Introduction

LAC insect *Kerria lacca* (Kerr) (Tachardiidae: Hemiptra), the crowning glory of India's rich insect fauna representing 21.8 per cent diversity of the known lac insect species is exploited for the products of commerce, viz. resin, dye and wax. Lac is a resinous compound secreted by lac insect while feeding on phloem sap of certain plants called lac hosts. Our country is the largest producer of lac in the world, accounting for about 50–60 per cent of the total world lac production. At present, production of raw lac in India is approximately 20,000 metric tonnes per annum. The major lac-producing states are Jharkhand (57% of the country's production), Chhattisgarh (23%) and West Bengal (12%) contributing to over 90 per cent, while Odisha, Gujarat, Maharashtra, Uttar Pradesh, Andhra Pradesh and Assam are the minor producers.

This scale insect is the, only insect known from time immemorial to produce resin having animal origin and seems to have attracted the attention of the naturalists. Since Vedic period, it has been in use in India. Its earliest reference is found in the Atharva Veda where it is termed as *Laksha* and its habits and behaviours are fairly accurately described. It is mentioned in the Mahabharata that Kauravas built the highly inflammable *lakhagriha* or *Jatugriha* (Lac house) with a motive of physically eliminating Pandavas by setting the lac palace on fire. The Ain-i-Akbari of 16th Century records the use of pigmented lac varnishes for painting screens. The use of lac was known to ancient Greek and

Romans also. However the first scientific account of the lac insect was given by J. Kerr in 1782. Increasing demand of lac products after World War-II has received attention in the present century. In order to increase the production of lac by scientific methods, an association named ***Indian Lac Association (I.L.A)*** was constituted in 1921, and the ***Lac Research Institute (L.R.I)*** was established at Namkum, Ranchi in 1924, with greater participation of the Government. In 1930, the ***Indian Lac Cess Committee (I.L.C.C.)*** was formed and the committee took over the Indian Lac Research Institute (ILRI) in 1957. Then the need for a Lac Extension wing was felt imperative and thereafter a Lac Extension Wing (**L.E.W.**) under the Indian Lac Cess Committee (I.L.C.C.) was created. ILRI in its new dimension as **Indian Institute of Natural Resins and Gums (IINRG)** presently engaged in lac production, lac processing, and transfer of improved technologies on lac and other natural resins and gums.

Over three million tribals of India are engaged in lac cultivation. Lac insects and their host plants play an important role in economics of lac growers. About 20–38 per cent of the total agricultural income of the tribal growers of Jharkhand is contributed by lac. Nearly one million man days per annum are generated by the industries engaged in post-harvest processing of lac. Besides, India fetches approximately Rupees 120–130 crores of foreign exchange through export of lac every year. Lac resin being natural, biodegradable and non-toxic finds applications in food, textiles and pharmaceutical industries in addition to surface-coating, electrical and other fields and provides immense employment opportunities.

Lac insect, *Kerria lacca* (Kerr.) is a pest on a number of plants both wild as well as cultivated. The tiny red-coloured larvae of lac insect settle on the young succulent shoots of the host plants in myriads and secrete a thick resinous fluid which covers their bodies. The secretions from the insects form a hard continuous encrustation over the twigs. The encrusted twigs are harvested and scraped off, dried and processed to yield the lac of commerce which is regarded as Non Wood Forest Product (NWFP) of great economic importance to India. Lac is an assured source of income for the majority of tribal's and in the states of Jharkhand, Chhattisgarh, West Bengal, Madhya Pradesh, Maharashtra, and Odisha etc. It is a good source of livelihood resource for poor farmers. Cultivated mainly by the economically backward communities especially tribal. Lac is the only natural resin of insect origin. Assured source of income during drought years. It requires meagre inputs (like water, pesticides etc.). Most suitably grown on marginal and degraded land. No competition with other horticultural, agricultural crops for land and farm operation. Do not harm host tree health neither other flora and fauna Avoids migration of rural population to urban areas. Increases opportunities for women for better occupation and returns.

The lac insect ecosystem is a complex multitrophic web of flora and fauna. It represents a rich biodiversity, which includes beside lac insects, lac host plants, several predators of lac insect, beneficial parasites, harmful parasites, microbes and a variety of pests of host plants. The lac host plants constitute the first tropic level, pests of host plants and lac insects make the second, and

predators along with primary parasites the third and parasitoids of lac predators constitute the fourth trophic level.

In Odisha only tribal districts are producing the lac. These districts are Mayurbhanj, Keonjhar, Sundargarh, Nabarangpur and Koraput having termed as the major lac producing districts of Odisha.Other districts like Balasore, Sambalpur are of minor importance in context of lac production.

Lac production is adversely affected by three categories of enemies' i.e. human enemies, insect enemies and non-insect enemies. The most serious enemies of lac are being the insect enemies which destroy 30-40 per cent of the shell.

According to Sharma *et al* (2006) the short bodied lac insects produce a resinous secretion, which protect them from adverse environment. In spite of this protective covering, the insect due to their sedentary habit they act as a sitting prey to predators and parasites. Twenty two lac insect predators, thirty primary parasites, forty five secondary parasites and several other associated insects visiting lac insect for honey dew represent a rich biodiversity of this ecosystem.

Odisha, by default was a traditional lac producing state but now it has been ranked down to a very low level. Though scientific studies on lac insect have been initiated in the state but the information generated on the associated fauna of lac ecosystem in general and natural enemies in particular is very scanty. Keeping this in view the present study has been under taken with the following objectives:

OBJECTIVES :

1. To study the growth and development of lac insect on *Flemingia semialata* under Bhubaneswar agro-climatic condition.
2. To study the occurrence and relative abundance of different natural enemies in Bhubaneswar agro-climatic condition.
3. To survey for the occurrence of different of natural enemies of lac ecosystem in different lac growing districts of Odisha.
4. To make an ecosystem analysis with special reference to faunal diversity in Odisha.

****

Chapter – 2

REVIEW OF LITERATURE

Chapter -2

Review of Literature

Information gained from previous research helps to establish a basic frame work for any proposed study. Therefore published literature pertaining to studies on lac insect, *Kerria lacca* (Kerr.) (Tachardiidae: Hemiptera) with special reference to its natural enemies complex has been vividly reviewed in this chapter. The reviews have been classified into the following sub-headings for drawing explicit information.

2.1 About lac insect

2.2 Host plants of lac

2.3 Biology of lac

2.4 Natural enemies of lac

2.1 ABOUT LAC INSECT

Lac, a Nature's gift to mankind, is a product of commerce derived from a specialized group of plant bugs commonly known as lac insect, *Kerria lacca* (Kerr.), (Tachardiidae: Hemiptera), which thrives on specific trees called as lac hosts. Lac is a resinous exudation from the body of female scale insect and it is the only natural resin of animal origin. It is a source of three basic materials viz., resin (68%), dye (1%) and Wax (6%) and the rest (25%) being the miscellaneous waste materials. The distribution of this lac insect is restricted mainly to the

tropical and sub tropical regions, 40° North and South of Equator (www.icar.org.in/ilri).

The history of lac can be traced back to Vedic period (1500-500B.C.) and Vedic people knew that the lac is obtained from numerous insects. They must know about the, biological and commercial aspects of lac industry, as *lakshgriha* in that period would need a lot of lac which could only come from a flourishing lac industry. Since ancient times, Greeks and Romans were also familiar with the use of lac. The cultivation of lac insect has a long history in Asia, with some suggestions Lac is cultivated in India since time immemorial (Singh, 2007).

The first scientific account of the lac insect was given by J. Kerr in 1782, which was published in Philosophical Transaction of Royal Society of London (vol. 71, pp.374-382). The first scientific name given to it was *Tachardia lacca* following the name of French Missionary Father 'Tachardia'. The systematic accounts of Indian common lac insect revealed that the generic name *Laccifer* Oken is invalid and rejected. Kerria appears to be the oldest and the valid name for this genus and this change has been approved by the **International Commission on Zoological Nomenclature**. The names of the family and other supra-generic taxa have also been changed according to article-36 of the International Code of Zoological Nomenclature (Ghorai, 1995).

Thus, the systematic position currently on use is as follows

Phylum – Arthropoda

Class - Insecta

Order - Hemiptera

Suborder - Homoptera

Super family - Coccoidea

Familv - Tachardiidae

Sub familv - Tachardinae

Tribe - Tachardinii

Sub tribe - Tachardii

Genus - *Kerria*

Species - *lacca*

This is the commonest and most widely occurring species of lac insect in India which produces the bulk of commercial lac. According to Singh (2007), around 300,000 insects of *Laccifer lacca* (Kerr) lose their life to produce1 kg of lac resin.

Sharma et. al.,(2006) documented that 87 species of lac insects falling under nine genera are recorded from the world out of which only 19 species belonging to two genera, namely *Kerria* and *Paratachardina* are found in India.

There are approximately 41 species in this genus *Kerria* of which Indian lac insect, *Kerria lacca* Kerr. is the most important one. This insect is widely exploited for lac cultivation and can be further distinguished into two strains rangeeni and kusumi on the basis of differences in life cycle, host preference and quality of lac produced. Besides, *K. chinensis* in northeastern states and *K.sharada* in coastal region of Orissa and West Bengal are also cultivated to certain extent. Lac insects under genus *Kerria* are generally bi-voltine but *K. lacca mysorensis* on *Shorea talura* and *K.sharada* on *Schleichera oleosa* and *Albizia saman* are tri-voltine.

Scientific lac cultivation necessitates certain tools for host plant management. According to Roonwal (1962) Secateur, Tree pruner, Pruning saw and pruning knife should be used for proper pruning of the host plants.

Branches in between 1.25- 2.5 cm in diameter should be cut leaving 1-1.5 ft. length from the point of origin. In case of *Acacia auriculiformis* branches < 7 cm diameter should be cut (ILRI, 2003).

Infection of host trees with lac insects may either be natural (self)i.e., without the help of man or may be artificial i.e., through human interventions. In self or natural inoculation the insect may be carried by natural agencies like falling leaves, strong wind, birds etc, but extent of infection by such means cannot be large enough. But where systematic large scale cultivation is the main aim, artificial infection is chiefly adopted (Ghorai, 1995).

In the *Rangeeni* strain, the insect of two crops *Katki* and *Baisakhi* are of unequal duration and mature in 3-4 months and 8 -9 months respectively. (Ghorai , 1995).

Brood lac bundles should be kept on the tree for the minimum period required for complete infection. The brood lac should not be kept on the tree for more than two or three weeks. If kept longer, there is the danger of emergence of large no. of enemy insects from the phunki lac sticks and starting heavy infestation in the field (Krishnaswami and Singh, 1962),

The selected brood lac sticks of about 6 to 12 inches in length should be first tied into bundles of 2-3 sticks and then such bundles are tied on to the branches of the host trees at such places that twigs above (with 15-20 times the length of brood lac sticks used in the bundles) gets full infection (Krishnaswami and Singh, 1962).

Lac is produced mainly in India, Thailand, Indonesia, Myanmar and China. *Butea monosperma* (Palas), *Zizyphus mauritiana* (Ber) and *Schleichera oleosa* (Kusum) are the major commercial lac host trees in India. Mostly it is the tribals in Jharkhand, Chhattisgarh, W.B, Maharashtra, M.P. Odisha, Gujarat and Assam that under take the production. Approximately three million people are engaged in production of lac in India. On an average India produces eighteen thousand tons of lac per year. It is an export oriented product. Some 80 per cent of the country's total product is exported that earns approximately U.S. $ 16-22 million as foreign exchange annually. It does not require any skill, requires less time

than other agricultural operations. The pruning of the host tree, bundling of the brood lac twigs, tying of brood lac on trees for infestation, removal of used brood lac stick (Phunki), from trees harvesting of crops and lac scrapping are the basic operation in lac production. These operation, are carried out manually with help of locally available traditional tools, (Niranjan et al, 2004).

Our country is the largest producer of lac in the world, accounting for about 50-60 per cent of the total world lac production. At present, production of raw lac in India is approximately 20,000 metric tonnes per year. The major lac producing states are Jharkhand (57% of the country's production), Chhattisgarh (23%), West Bengal (12%), while Orissa, Gujarat, Maharashtra, Uttar Pradesh, Andhra Pradesh and Assam are the minor producers. Over three million tribals inhabiting these states are engaged in lac cultivation. Lac insects and their host plants play an important role in economics of lac growers. Besides, India fetches approximately .120-130 crores of foreign exchange through export of lac every year. Lac resin being natural, biodegradable and non-toxic, finds applications in food, textiles and pharmaceutical industries in addition to surface-coating, electrical and other fields and provides immense employment opportunities (Sharma et al., 2006)

The lac production areas of India and Odisha as per Atlas of Indian lac (Anon. 1958) is presented in Fig-1 and Fig-2.

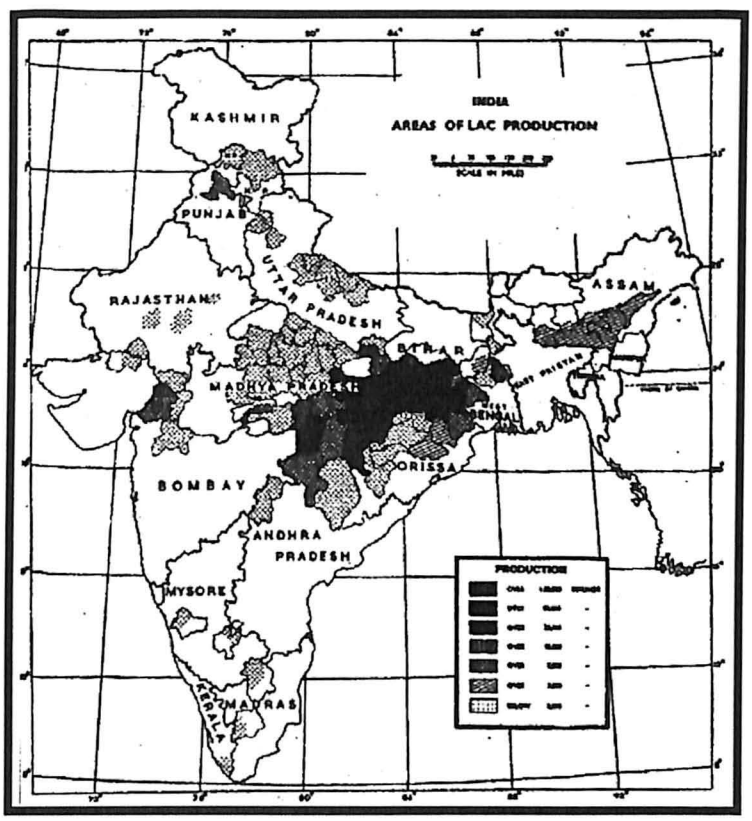


Fig 1 Lac growing areas of India (Anon. 1958)

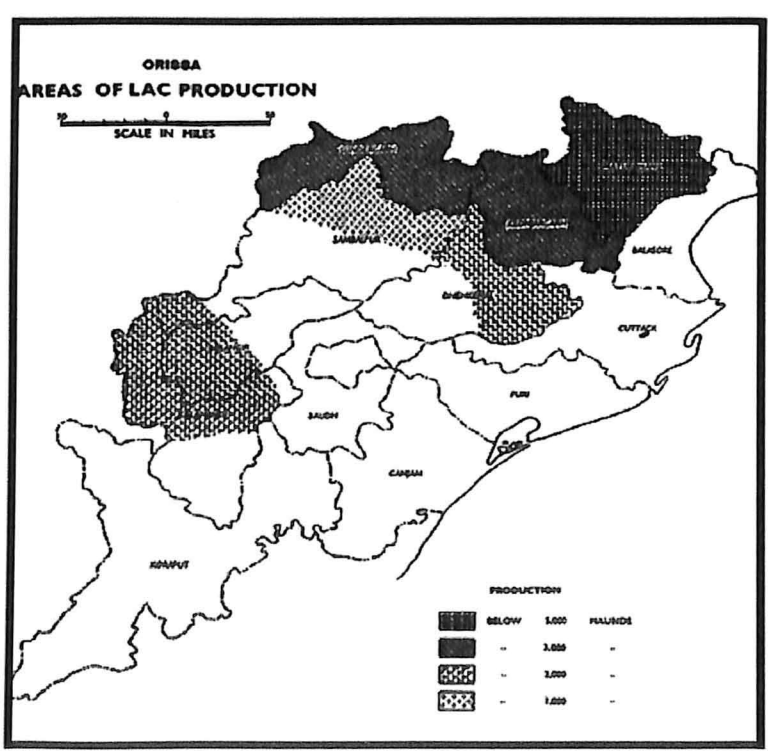


Fig 2 Lac growing areas of Odisha (Undivided Districts)

India produces more than 20000 tons of lac annually. Lac industry in the country provides livelihood to over one million cultivators. Over 150 processing units are there in the country engaging about 5000 workers (www.icar.org.in/ ilri).

Since the lac insects thrive and feed on certain species of the tropical trees, it is found distributed South-East Asian countries. It is currently produced in India, Myanmar, Thailand, Malaya, Lao and Yuan province of China. India and Thailand are main areas in the world, while India has prime position in relation to lac production. Lac cultivation is introduced into Thailand from India. Over 90 per cent of Indian lac produced comes from the states of Bihar, Jharkhand, West Bengal, Madhya Pradesh, Chhattisgarh, Eastern Maharashtra and northern Orissa. Some pockets of lac cultivation also exist in Andhra Pradesh, Punjab, Rajasthan, Mysore, Gujarat, and Mirzapur and Sonebhadra districts of Uttar Pradesh. (Singh, 2007)

The first authentic record of occurrence of lac insect in Gujarat was made by Varshney, 2000.According to the author the Lac insect *Kerria lacca* is widely distributed in India and its neighboring countries. In Western India its occurrence is however very rare. But *Kerria comunis* has been reported from Maharashtra, Goa, Karnataka and Kerala .

Mishra and Sushil (2000) reported that *Kerria sharada* spp. is a new trivoltine lac insect species infesting *Schleichera oleosa* from Eastern Ghat region of Orissa. It is very close to the species *Kerria albizzae*.

The Indian lac Research Institute (ILRI) established in 1924 at Namkum, Ranchi recently named as **Indian Institute of Natural Resins and Gums**, is the pioneer Institute contributed immensely in the field of lac research, transfer of technology on lac cultivation and product development related to lac in the country. So far as the lac research is concerned, the institute has made marvelous achievements in the management of important host plant for lac cultivation, lac pest management technologies, identification and development of promising lac insect lines and study of biology, taxonomy, morphology, genetics and cytogenetic of lac insect. (www.icar, org. in / ilri).

2.2 HOST PLANTS OF LAC

The Lac insects thrives on specific trees called as lac hosts. Various lac hosts are exploited for lac cultivation in different lac growing region of the country. Accordingly to Roonwal et al. (1958) there are 113 species of host plants belonging to 53 genera which are categorized into common or major hosts (7 genera, 14 species), occasional hosts (6 genera, 14 species) and rare hosts (40 genera, 85 species). The major three species of host plants of all India importance are Palas (*Butea monosperma*), Kusum (*Schleichera oleosa*) and Ber (*Zizyphus mauritiana*).

According to Sharma *et al.* (2006) out of more than 400 plants on which lac insects have been observed, only about two dozen are utilized for lac production. Commercial lac cultivation on other plants is economically not

viable. Moreover, lac host plants exploited for commercial production of lac vary from region to region.

Yang-chengyuan *et al* , 1998 studied on the root secretion of host tree and the quality of the lac produced were used as indices on the inter - adaptability between the lac insects and its host tree in China. A decrease in amount but increase in variety of amino acids on the root secretions were observed in the lac insect inoculated host trees. Significant differences in the composition of lac were observed from lac insects from different host trees.

The major host plant of *Kerria lacca* recorded in India are *Butea monosperma, Schleichera oleosa* and *Zizyphus rnauritiana.* Besides the other multipurpose trees recorded as host plant for the insect are ,*Albizia lucida, Grewia cerulata, Leea crispa, Ougeinia oojeinensis, Shorea talura* and *Z. xylophora* (Bahuguna and Shiva 2002).

Pigeon pea crop grown for fuel production, soil conservation and as a food source etc. is alternately used for mass rearing of lac Insect, in China

(Zhou Chao Hong et al, 2001). Li zhenghong et. al.,(2001) also reported pigeon pea as an excellent host for lac cultivation in China and is being used for major research studies.

Subarayudu(1997) recorded 53 species of host plants of *Kerria lacca* belonging to 32 genera in Bihar.

Shi lei(1999) recorded *Kerria lacca* on ten different host on growth *Schleichera oleosa, Litchi chinensis, Koelreuteria paniculata, Flemingia macr*udinal *Cajanus cajan, Albizia bracteata, A. lucidior(A. lucida), Acacia montana, Zizyp*the *mauritiana and Ficus racemosa.*

Ramadevi *et al,* (1997) recorded *Acacia auriculaeformis,* a multipurpose tree raised in Chitradurga as a natural host of *Kerria lacca.* Ramadevi *et al,* 1998 also recorded *Santalum album* L. as a host of *Laccifer lacca.*

Sharma (1997) recorded *Thevetia peruviana* as a new, food plant of *Kerria lacca* at Hisar,Haryana,lndia. Sabharayuba (1999) reported occurrence of lac insect on *Peltophorum pierocarpa.*Similarly Madras thorn *Pithecellobium dulce* was reported as a new host of *Kerria lacca* (Kerr) from Ludhiana.

(Jalaluddin *et al,* 1999). *Amherstia nobilis* a new host plant observed to be infected by lac insect in Kerala (Sudheendrakumar and Varma,1999).

Mishra *et al,* 1998 studied the performance of different lac insect (Kerria slip) stocks collected from different locality in Bihar, Odisha, W.B and M.P. and host plant species are compared with respect to density to settlement and percent initial mortality of nymphs on *Flemingia macrophylla* a promising busy host of lac insect. The mean density of settlement varied between 57 and 175 nymphs per cm^2 of the shoot surface where as mortality from 12. 94 to 42.8 per cent .

Chen you Qing *et al,* (2003) made very interesting observation on growth of the host plant of lac insects. According to their observation the longitudinal growth of branches was 5 times faster than the transverse growth. Further the host trees of lac insect grow slowly in the beginning of the insect life history, but grew faster after the insect matures. Younger branches grow faster than than older ones. Lac insect has higher mortality during the larval stage and the total mortality was 90 per cent.

Sharma *et al.,* 1999 reported different species of *Kerria* from India and their important host plants are listed are more than 400 plants which has tremendous scope for utilizing them in apiculture as copious amounts of honeydew are available almost throughout the year.

A study on performance of Kusumi strain on *Flemingia macroplylla* in the winter season indicated that the insect could successfully survive on *Flemingia macrophylla*. The plants were pruned 6 inch above to the ground level in Jan-Feb and inoculated on new shoot in July (Srivastava et al, 7998).

Flemingia semialata Roxb. (Leguminosae : Papilionaceae) is a short duration , bushy perennial, erect, fast growing input responsive lac host identified for intensive lac cultivation during winter season lac crop of kusumi strain(Aghani).It grows up to a height of about 3m , fix atmospheric nitrogen and thus enrich soil fertility. It is propagated through seed (more preferred) and stem cutting. Yield of lac, crop grown on this host plant increases (>50%) from second year onwards. (Yadav *et al,* 2005). This plant is well demonstrated as a suitable host of *K. lacca* at IINRG. (Fig-3)





Fig . 3 *Flemingia semialata* Roxb. an ideal host plant for lac cultivation.

2.3 BIOLOGY OF LAC

In India, Lac insect is known to have two distinct strains: Kusumi and Rangeeni. The Kusumi strain is grown on Kusum or on other host plants using Kusumi brood. The rangeeni strain thrives on host plants other than Kusum. The life cycle of lac insects take about six months, hence, two crops a year can be obtained.

The life cycle of a lac insect (*Laccifer lacca*) takes about six months and consists of four stages: egg, larva, pupa and adult. The brood lac containing the female lac insect is tied onto fresh new twigs of trees (lac host trees) where they thrive and complete their life cycle under a protective covering which prevent from attack by predators. This secretion forms hard resinous layers which completely cover their bodies leaving small anal and breathing openings. (Singh,2007)

Enumerating the life cycle of the lac insect Singh (2007) highlighted that the female insect is larger than male, measures 4-5 mm in length and has a pyriform body. The head, thorax and abdomen are not visible distinctly. The antennae and legs are in degenerated form, and wings are absent. The Life cycle of lac insect takes about six months and consists of stages: egg, nymph instars, pupa and adult. The lac insects have an ovoviviparous mode of reproduction. Female lays 200-500 ready to hatch eggs, i.e. the embryos are already fully developed in eggs when these are laid. Eggs hatch within a few hours of laying, and a crimson-red first instar nymph called crawlers come out. The crawler

measures 0.6 x.25 mm in size. The emergence of nymph is called swarming, and it may continue for 5 weeks. The nymphs crawl about on branches. On reaching soft succulent twigs, the nymphs settle down close together at rate of 200-300 insects per square inch. At this stage, both male and female nymphs live on the sap of the trees. They insert their proboscis into plant tissue and suck the sap. After a day or so of settling, the nymphs start secreting resin from the glands distributed under the cuticle throughout the body, except mouth parts, breathing spiracles and anus. The resin secreted is semi-solid which hardens on exposure to air into a protective covering. The nymphs molt thrice inside the cells before reaching maturity. The duration of each instar is dependent on several factors, viz. temperature, humidity and host plant. The female brood cell is larger and globular in shape and remains fixed to the twig. The female retain, her mouth parts but fails to develop any wings, eyes or appendages. While developing, it really becomes an immobile organism with little resemblance to an insect. The female increases in size to accommodate her growing number of eggs. Lac resin is secreted at a faster rate and a continuous layer coalesces or grows into one body. After fourteen weeks, the female shrinks in size allowing light to pass into the cell and the space for the eggs. About this time, two yellow spots appear at the rear end of the cell. The spots enlarge and become orange coloured. When this happens, the female oviposits a large number of eggs in the space called 'Ovisac'. The ovisac appears, orange due to crimson fluid called lac dye. It indicates that the eggs will hatch in a week time. When the eggs hatch, larvae emerge and the whole process begins all over again

Nagvi et al., 1998 studied the insect host relationship of the lac insect. For Rangeeni strain lac insects were collected from Bhalia *Flemingia macrophyll, Butea monosperma* and *Zizyphus xylapyra* and for Kusumi strain from *F. macrophylla, Schleichera oleosa* and Ber *Zizyphus xylopyra.* A total number of 15 amino acids were present in insects, 8 being common to both strains of insects. Methionine was specific to Rangeeni strain whereas Glutamic acid, proline and hydroxyproline were exclusive to the Kusumi strain. Some differences were also observed in amino acids content of insects feeding on summer crop and between different stages of development.

Jaiswal(2007) studied the life cycle of Lac insect in detail at IINRG,Ranchi.The life cycle commenced with the first instar larvae called crawlers which are soft, oval shaped body tapering on posterior side of the abdomen. The crawlers measured 0.6mm long from head to abdomen and 0.25mm broad at thorax, There was no pronounced demarcation between head, thorax and abdomen. The head carried a pair of antennae and the last abdominal segment carried a pair of greatly elongated setae. The female insect completed its life cycle in 44 and 69 days after inoculation as Jethwi and aghani crop and survived for another 150 and 90 days respectively recording a total life span of 194 and 159 days respectively.

Bhagat (2007) reported that the living lac insects secret wax filaments throughout the life to check the blockage of pores. Initially the secretion is very fast but at the time nearer to maturity, it slows down. This is also an indication from which one can forecast probable time of emergence.

Ghorai (1995) mentioned that the adult female is generally pyriform in shape but sometimes globular or elongate depending upon its positioning on twigs. The insects measure 4.02 - 6.00 mm in length and the width between 2.5 - 3.5 mm.

Chamberlin (1923) considers brachia or brachial process as the organ fundamentally associated with the aboral end spiracles and their function is to secret filamentous waxy threads that keep the spiracular openings of the lac cells from being closed by the secretion that covers the body and thus ensure smooth breathing. According to Mukhopadhyay and Muthana (1962) long waxy filaments are the striking features of a healthy encrustation of lac insect and these filaments protrude out of the anal and brachial pores of the female lac cells.

The duration of life cycle of lac insect depends upon several factors but primarily on the strain and the season of development. In Rangeeni strain insects of the two crops Katki and Baisakhi are of unequal duration and mature in 3-4 months and 8-9 months respectively, where as in Kusumi strain both Aghani & Jethwi crops are almost of equal in duration (Ghorai, 1995, Mukhopadhyay & Muthana, 1962). According to above authors the Baisakhi crops normally commence from the month of October-November and harvested in June-July, while the Jethwi crops is inoculated in January -February and harvested in June-July. According to Mukhopadhyay & Muthana (1962) duration of a generation of lac insect seems to depend very much on the prevailing temperature either at the time of maturation or during the development of a particular generation.

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A study carried out by Chen youQing et al, (2004) on characteristics of lac foraging behaviour of *Kerria lacca* and its preference to host branch indicated that *K. lacca* hardly hosted on branches over two years old and the distribution of lac insect on branches had no relation with orientation. The diameter of hosted branches range from 0.47 - 1.60 cm. on erect branches *K. lacca* was distributed round the branch but on most decline branches *K. lacca* only settle on the shaded parts.

The biology of the strain of the lac insect introduced from Nepal to Yuanjaing of Yunnan province of China was studied by He Ju *et al*,(2003). The insect completed its life cycle successfully twice in a year and based on the other habits this strain could be identified as Rangeeni of *Kerria lacca*. Individual of this strain could produce 19 mg/lac and 600-1000 eggs. The colour of lac was light yellow and it's quality was better than the lac produced by lac insect species. of China. *Kerria chinensis* . *Butea monosperma* was recorded as the best host followed by *Acacia glauca*.

Mishra *et al*, (1999) reported that the growth and development of lac insect is affected by the physiological state of the plant.

Behera (2009) made an explorative study on the lac insect, *Laccifer lacca* (Kerr.) in Orissa during 2008-09 in Bhubaneswar, Orissa and recorded the following salient observation from his investigations. Lac is cultivated in six district of Orissa viz., Keonjhar, Koraput, Mayurbhanj, Nabarangapur, Sundargarh and Balasore. Lac cultivation previously practiced in undivided

Kalahandi and Sambalpur district is no more in voyage. In Nabaranpur district it is being practiced in four blocks viz. Chandahandi, Raighar, Jharigaon and Umerkote. Concerted effort of the Tribal Co operative Marketing Development Federation of India Ltd. (TRIFED) had enabled the tribals to adopt improved lac cultivation

Practices in Sundargarh thereby harvesting about 100-120 kg of lac sticks/ tree/ season compared to 8.0-20.0 and 10-25 Kg of lac/ tree/ season harvested by the lac grower of Keonjhar and Mayurbhanj district respectively practicing traditional method. Four host plants viz., Kusum (*Schleichera oleosa*) , Palas (*Butea monosperma*) and Ber (*Zizyphus mauritiana*) and Dimbiri (*Ficus hispida*) are utilized for lac cultivation, the Kusum (*Schleichera oleosa*) being predominant species. *Ficus hispida* as a host plant of lac in Orissa was the first record. *Flemingia semialata* Roxb. a quick growing plant suitable host for commercial cultivation of Kusumi lac can very well be utilized for lac cultivation in Orissa. The ideal period for collection of brood lac for raising aghani and jethwi crop in our state is the month of July month of February respectively. The lac insect *Laccifer lacca*(*Kerria lacca*) completed its life cycle successfully at Bhubaneswar on *Flemingia semialata* and Ber (*Zizyphus mauritiana*) and issued swarm in 145 and 158 days after inoculation respectively while failed on arhar(*Cajanus cajan*).The first instar nymph are pinkish red in colour and oval in shape measured about 1.06 mm in length leaving aside the antennae and caudal setae and of 0.43 mm in width. The female cells are reddish in colour spherical in shape and measured 0.33cm in diameter weighing about 10.7 mg.

2.4 NATURAL ENEMIES OF LAC

An array of natural enemies attacking lac insects and predators of lac insects has been reported by various workers (Mukhopadhyay and Muthana, 1962 and Ghorai, 1995) explaining some details about the natural enemies. However Varshney (1976) reported 72 species of insects parasite associated with lac insect and their predators(Annexure I & II) in his check list indicating synonyms, region of occurrence and detail source of records etc.

Among the insect enemies the attack from parasite is not quite serious excepting certain favorable season. On an average parasitization may be up to 5-10 per cent of the total number of cells in a lac crop but the predators viz. *Eublemma amabilis* and *Holcocera pulverea* is quite serious and on an average 30 per cent cells are damaged. At times entire crop may be wiped out by these predators particularly in wet season. The *Chrysopa sp.* also assumed serious proportion sometimes and inflict considerable damage (Mukhopadhyay and Muthana, 1962).

Narayanan, (1962) reported large number of insect predators and parasitoids to cause severe damage to lac crop. Among the neuropteran, *Chrysopa lacciparda* and *C. madestes* are known as sporadic pest of lac insect.

Malhotra and Katiyar (1975) reported that culture of lac insect *Kerria lacca* (Kerr.) is subjected to attack by many species of insect predator and parasite. The major lac insect predator are two lepidopteron i.e. *Eublemma amabilis* (Moore) and *Pseudohypatopa pulverea* Meyr. and neuropteran predator *Chrysopa* sp.

Chrysopidae. The former two normally cause on an average 30-35 per cent damage.

Srivastava and Chauhan (1984) has shown that average parasitism for lac crop on the basis of female parasitize worked out to be 20-37 per cent.

Susil *et al.* (2002) in his study on predatory response of *Chrysoperla carnea* (Stephens) against the lac insect *Kerria lacca* (Kerr.). Informed that the predator could complete its lifecycle on early instar nymph of *Kerria lacca.* Thus caution the use of *C. carnia* in lac growing areas.

According to Mishra *et al.,* (1995) *Eublemma amabilis* Moore. (Lepidoptera: Noctuidae) is a monophagous predator of lac insect known to cause severe damage to lac crop in various countries of the world. At times, it may results total loss of lac culture. The larva of *E. amabilis* after hatching of the eggs on the surface of lac colony lead cryptic mode of life by borrowing and tunneling within the lac encrustation. Larvae feed exclusively on lac insect and mould ten times before pupation (Mishra *et al.* 1938).

Bhattacharya *et al.* (1998) documented that the larva of *Pseudohypotopa pulverea* (Meyr.) Lepidoptera: Blastobasidae predate on the life and fed on the lac insect *Kerria lacca* (Kerr.) causing considerable damage to lac crop during rainy and summer season.

Varshney(1976) recorded that the soft-bodied lac insects produce a resinous secretion, which protects them from adverse environment. In spite of this protective covering, the insects due to their sedentary habit are always a

sitting prey to predators and parasites. 22 lac insect predators, 30 primary parasites, 45 secondary parasites17,18 and several fungal pathogens of lac insects as well as lac hosts19,20, besides several other associated insects visiting lac insects for honey dew represent a rich biodiversity of this ecosystem. Moreover, natural lac insect complex maintains a variety of other tree flora, macro fauna and soil micro-organisms.

Shui-chen chiu *et al* (1982) during their extensive survey in Taiwan in 1981 recorded that two predators E. amabilis & Holcocera pulverea were reported to destroy 35 per cent of lac insect population of India. However because of these two species are lepidopterous insects which are generally plant feeders, the hazards of their importation into Taiwan should be given serious consideration. They also found that 5 species of parasitoids and predators that attack the lac insect.

Bhattacharya *et al,* 1996 during their extensive Survey in Bihar in the rainy season of 1995 recorded *Poecilomyces* sp. for the first time as an entomogenus fungi infecting larvae of *Eublemma amabilis* with recorded mortality of 5-10 per cent of the larvae.

Bhattacharya *et al,* 1997 reported that *E. amabilis* Moore plays havoc with not only the standing lac culture but with the stored lac.

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Bhattacharya *et al,* 1998 recorded 24.0 and 90.99 percent mortality of 1-3 day old eggs of *Eublemma amabilis* through exposure to U.V. light for a period of 5 and 25 minutes respectively.

Sharma and Ramani (1997) studied the life cycle of two strains of Indian lac insect *Kerria lacca* namely Rangeeni and Kusumi on fruits of pumpkin, *Cucurbita muschata.* Although the duration of life cycle and extent of resin secretion reduced than the normal but the strains could complete their life cycle satisfactory providing variable progeny without much effect on fertility.

Subbarayudu & Maheswar (1998) studied on the parasites of lac insects through collection of random samples from the field at weekly interval commencing from four week of inoculation.

Sushila *et al,* (1999) reported 5 hymenopterous egg parasitoid of *Pseudohypatopa pulverea* viz. *Tricogramma braziliensis, Trichogramma chilonis, T. pretiosum,Trichogrammatoidea bactrae* and *Telenomus remus*..

Sushil *et al,* 2000 reported five hymenopterous egg parasitoids namely *Trichogramma brasiliensis* Ashmead, *T. chilonis* Ishii, *T. pretiosum* Riley, *Trichogrammatoidia bactrae* on *Eublemma amabilis* among which *T. brasiliense* was the predominant one parasitizing 43.7 per cent of the *E. amabilis,* followed by *T. chilonis*(21.49%), *T. pretiosum*(20.88%) and *T. bactrae*(20.85%).

Sharma *et al,* 2001 reported that three new fungi are belonging to the family Eurotiaceae / Aspergilaceae viz. *Asperzilous awamori, A. terricola* and *Penicillium citrinum* infecting Indian lac *Kerria lacca.*

Studies on predatory activity of *C. carnia*, the most widely used beneficial predator in India indicated that the lac insect was not a preferred host for the predator as it failed to complete its life cycle on lac insect under laboratory conditions. (Sushil et al, 2002).

Sharma *et al.*,(2000) for the first time reported the occurrence of *Bracon bravicornis* as the larval parasite of *Eublemma amabilis* Moore, a major predator of lac insect *Kerria lacca*. Besides *Bracon greeni* Ashm and *B. hebetor* Say are also reported earlier reported earlier as the larval parasitoid of *E. amabilis* the former being the most abundant and occurring regularly in lac culture infested with predator.

Sharma & Ramani (2001) recorded 28.13 per cent and 32.18 per cent parasitisation of Kusumi and Rangeeni strains of female *K. lacca* in the rainy season. Parasitisation although had no effect on the size of lac cells but the quantity of resin production decline by 17.92 per cent and 17.44 per cent and fecundity decreased by 32.55 and 34.71 per cent in Kusumi and Ranginee strain respectively.

Satapathy *et. al,* (2011) reported that two important predators viz., the black moth, *Pseudohypatopa(Holcocera) pulverea* Meyr and the white Moth, *Eublemma amabilis* Moore in Orissa of which the former was more prevalent. Besides the larva of green lace wing bug feed on the first instar nymphs of lac insect. Five species of parasitoids, a beetle and the black ant ,feeding on honey dew were the other fauna associated with the lac insect were also reported.

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Chapter – 3

MATERIALS AND METHODS

3.1 Study location

The study was undertaken in the laboratories and field of the Department of Entomology, College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar during March, 2011-June 2012.In order to study the growth and development of the lac insect, the 18 months old *Flemingia semialata* Roxb. plants maintained in the Lac culture unit in the Department of Entomology was utilized .For this purpose brood lac sticks ready to issue swarm were collected from Chakiri brood lac farm located in Village Chakiri of block Jashipur of the tribal district Mayurbhanj of Odisha during first week of June, 2011 by observing initiation of movement of crawlers on such brood stick. The brood sticks of Jethwi crop on kusum plants were collected and tied on the next day towards middle portion of the host plant stem by help of the twine thread .Inoculation was done on six plants and the brood sticks were kept on the inoculated plants for three days till emergence of sufficient crawlers. Periodic observation was recorded at weekly interval starting from inoculation till issue of swarm from new lac crop. Soon after issue of swarm recorded on one host plant, observation was recorded daily on other host plants inoculated to mark the nymphal emergence. The density of the first instar nymph was recorded using the method adopted by Behera (2009).

3.2 Survey

In order to study the natural enemies complex of lac ecosystem, three traditionally lac growing tribal districts of Odisha, viz. Mayurbhanj, Nabarangpur and Boudh were selected. Browsing information through different sources, visited

Chapter -3

Materials and methods

Kerria lacca (Kerr.) (Tachardiidae: Hemiptera), is a typical scale insect of immense industrial importance. Its cultivation is done in traditional method as a conventional practice by the tribal dwellers without much scientific intervention. Lac cultivation is regarded as a simple income generating avocation for the tribal poor of the state and the country as well. As worked out elsewhere the lac ecosystem is very rich and diverse with regard to its faunal composition. But documented research information in this context on lac ecosystem of Odisha is not available. In order to generate some transferable research information present research work was undertaken during March, 2011-June 2012 with specific objectives to study the growth and development of lac insect on *Flemingia semialata* under Bhubaneswar agro- climatic conditions; occurrence and relative abundance of different natural enemies in Bhubaneswar and other lac growing districts of Odisha and to make an ecosystem analysis with special reference to faunal diversity of natural enemies of lac insect in Odisha. The materials utilized and the methods adopted are embodied in this chapter.

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physically to the **"Chakiri brood lac farm"** which is a Govt. of India undertaking brood lac farm established in the year 1956 in the Jashipur block of Mayurbhanj district in association with IINRG, Namkum, Ranchi for collection of brood lac sticks to initiate the studies on growth and development and subsequently to collect brood lac sticks after harvest of the crop for undertaking the study on natural enemies complex. Brood lac sticks of aghani crop were collected in January,2012 from Chakiri brood lac farm, Mayurbhanj personally during survey for study on natural enemies complex. The brood lac sticks were also collected from village Fatiki of Chandahandi block of Nabarangpur district through AAO, Chandahandi Block and village Amthapada of Boudh block of the district Boudh through the Programme Coordinator ,Krishi Vigyan Kendra ,OUAT for the purpose (Fig. 4).

3.3 Collection of Natural enemies.

The brood sticks collected for the study from different location were kept inside plastic jars separately with top covered with polythene bags and bottom portion covered with black cloth(Fig. 5) to facilitate the natural enemies emerged to move up to lighted portion(Fig. 6). Daily observation recorded twice i.e. during morning and evening hours. The parasites emerged from the samples were collected by a simple aspirator (Fig. 7) counted. Some of the samples were kept as dry specimens while some in 70 per cent alcohol. The bigger predators were collected by help of test tubes and their number is also counted daily. Some predators were dry preserved by pinning. The *Eublemma* adults collected were

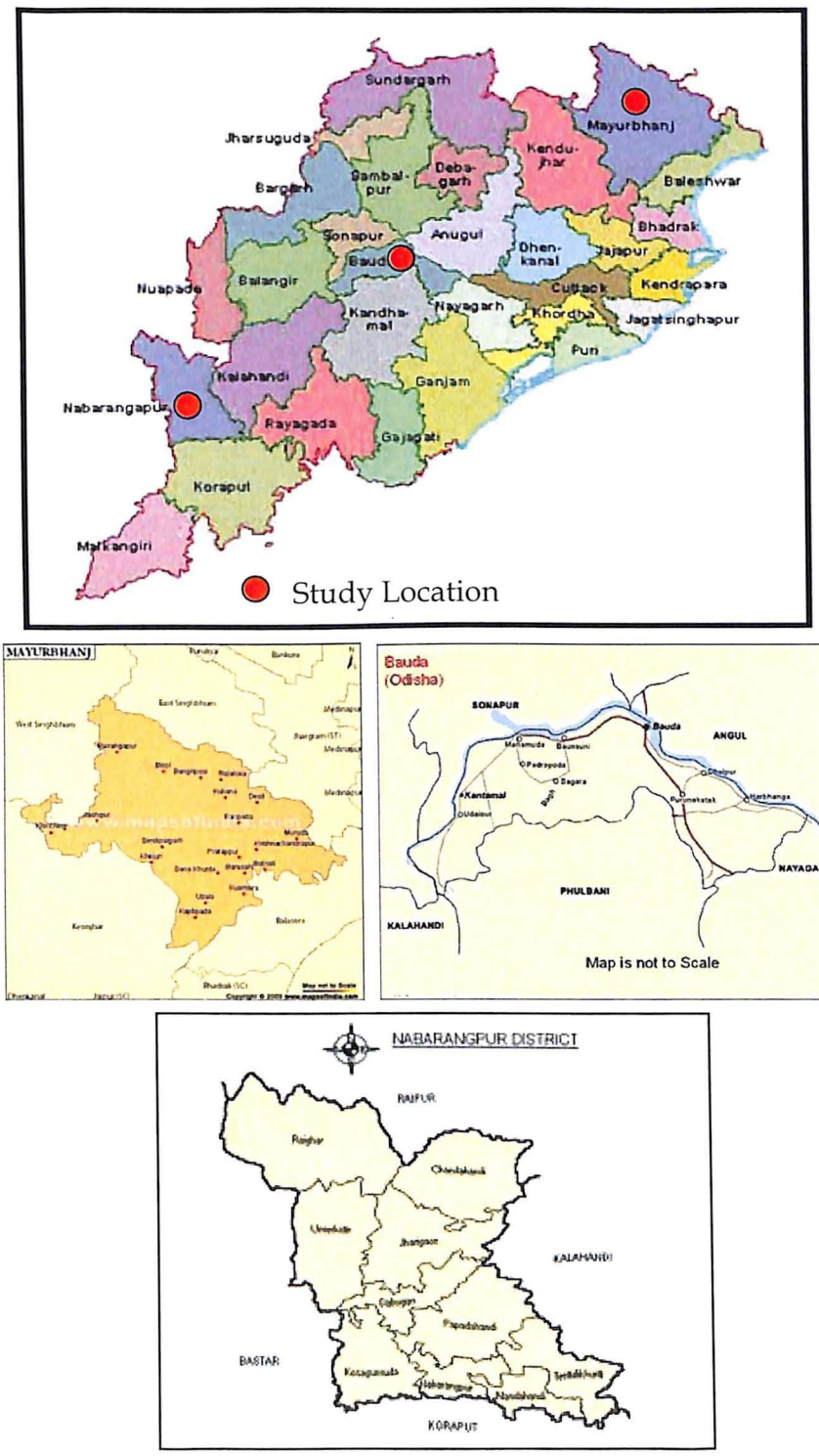


Fig 4 Districts covered under present investigation

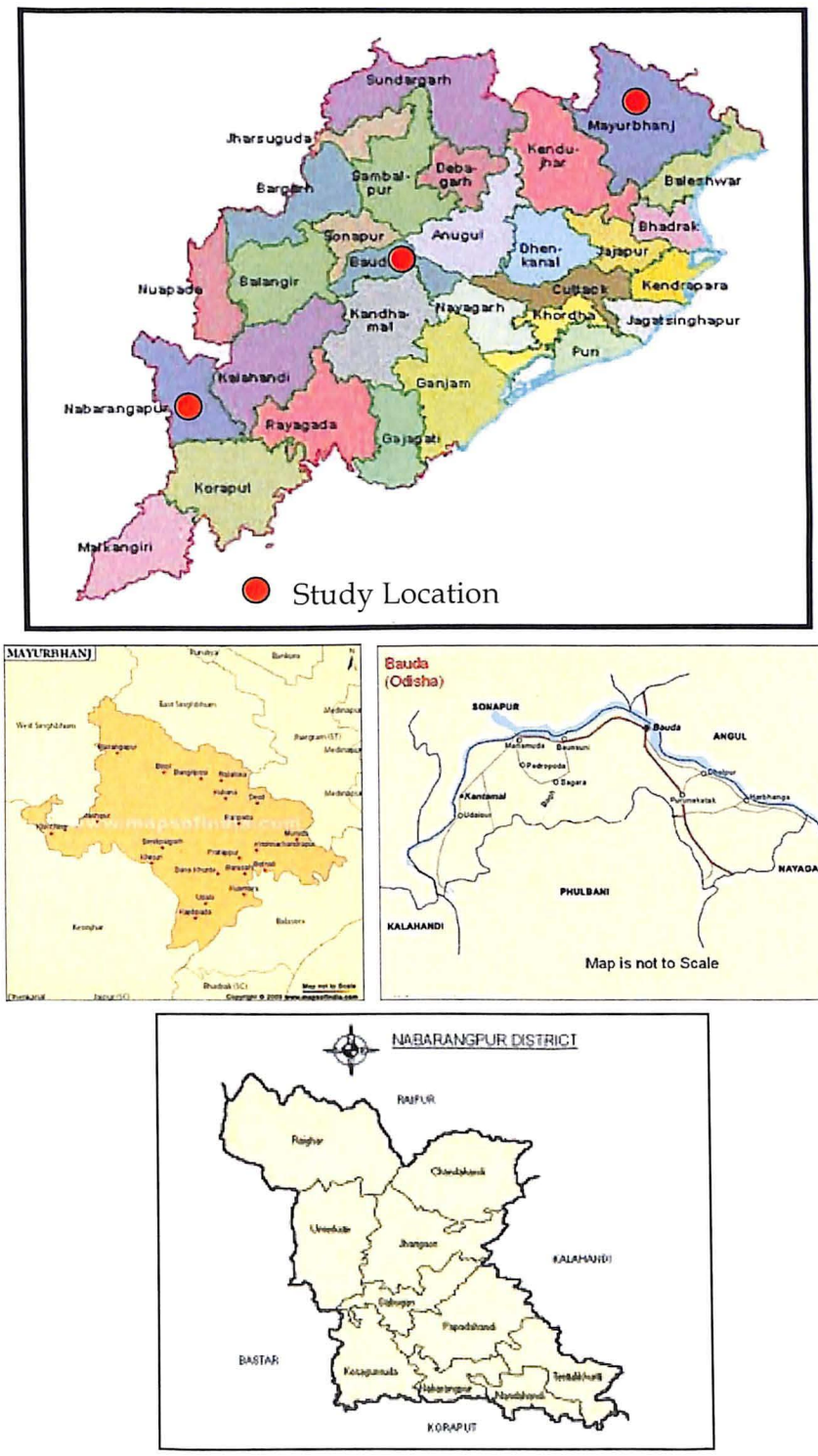


Fig 4 Districts covered under present investigation

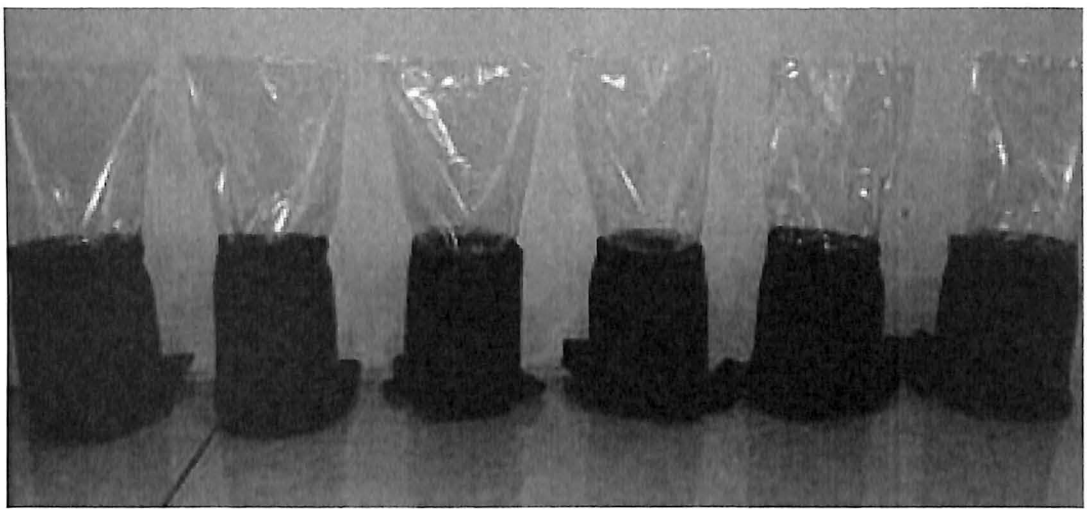


Fig. 5 Jars used for collection of natural enemies from brood lac sticks.

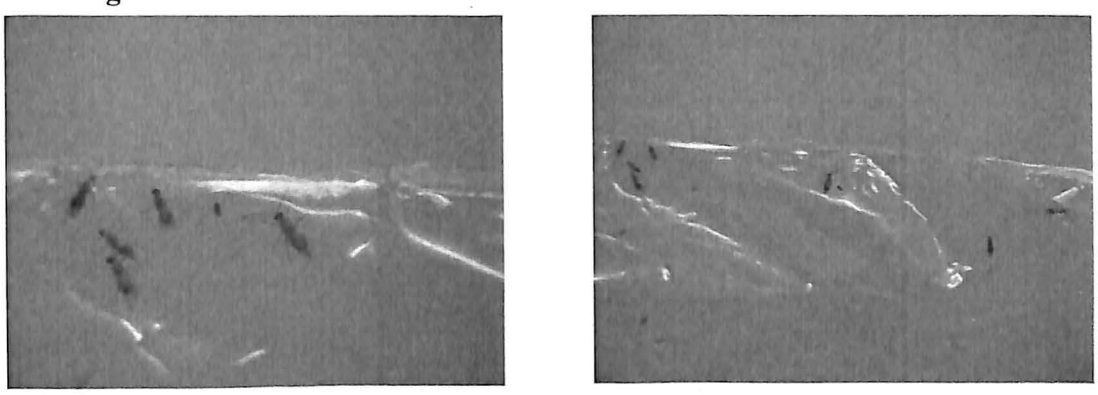


Fig. 6 Parasitoids emerged and captured in polythene bags.

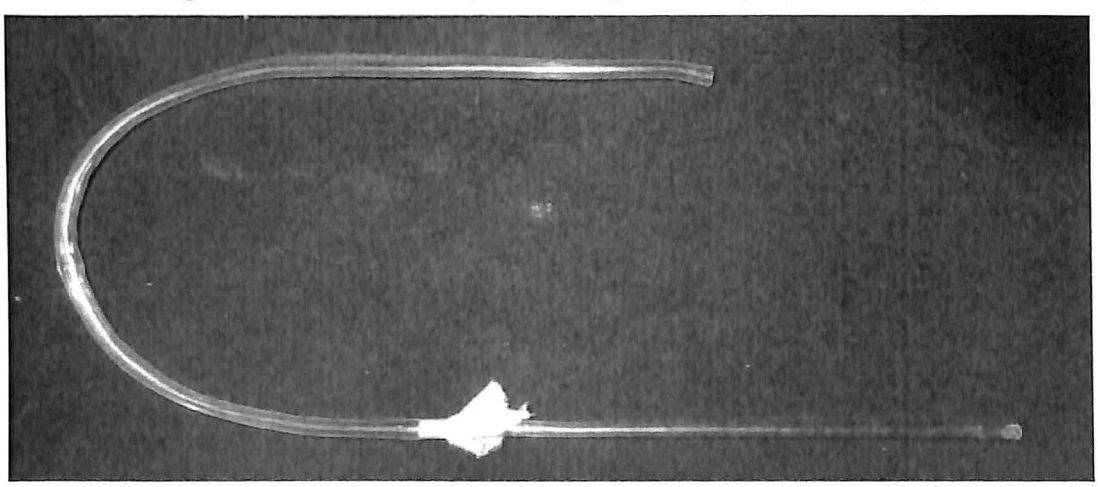


Fig .7 Plastic tube aspirator used for collection of natural enemies from polythene pack.

placed in glass jar covered with black cloth and provided with 10 per cent honey solution. A piece of corrugated paper is placed in the jar to facilitate egg lying.

The photographs of the natural enemies were taken by DSC H-20 Sony camera putting graph paper on background to ascertain their natural size. The micro photographs were taken by the help of Microscope Image Projection System (MIPS) using Magnus camera and computer aided accessories.

3.4 Identification of Natural enemies

In order to identify the unidentifiable parasitoids, wet preserved samples were send to National Bureau of Agricultural Important Insects(NBAII), (Formerly the PDBC ,Project Directorate Biological Control) Bangaluru, for identification during February,2012 through person. Due to non receipt of pertinent information in time a visit was made to the IINRG, Namkum, Ranchi between 08.072012 to 12.07.2012 with the specimens with prior appointment. The parasitoids were identified by Dr A.Mahanasundaram of Lac Production Division, IINRG with permission of the Director, IINRG.

3.5 Statistical analysis

The data collected from different sets of experiments were subjected to analysis adapting appropriate statistical tools like arithmetic mean, standard deviation. The data were analyzed following procedures as suggested by Gomez and Gomez (1976) and then they were utilized for deriving necessary inference.

3.6 Estimation of Relative Dominance and Diversity

The dominance status of various taxa were described on the basis of relative abundance which determine the percentage of specimens by a given species in the total number of insects collected and the index of dominance was described with the following classes of domination as suggested by Slawinska and Jauekiew (2005).

i) <1% = Subrecedent : 1-9% = Recedent

ii) 10-20% = Subdominant : 21-30% = Dominant

iii) 31-60% = Eudominant : > 60% = Superdominant

The diversity index to measure the species diversity in a community like Simpson's index of diversity and Simpson's Reciprocal Index were worked based on the Methods suggested by Simpson (1949). The Simpson's diversity Indices were calculated as per the following.

Simpson's Index (D): It means the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species) and the formula for calculating D as follows;

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

Where n = the total number of organisms of a particular species

N = the total number of organism of all species

Simpson's Index of Diversity: I-D

The value of this index ranges between 0 and almost 1, the greater the value, the greater the sample diversity. The Index represents the probability that two individuals randomly selected from a sample will belong to different species.

Simpson's Reciprocal Index: I/D

The value of this index starts with a 1 as the lowest possible figure. This figure would represent a community containing only one species. The higher the value, the greater is the diversity. The maximum value is the number of species in the sample. For example if there are five species in the sample, then the maximum value is 5.

Equitability or Evenness (E_D) was calculated by taking Simpson's Index (D) and expressing it as a proportion of the maximum value D. The equitability takes a value between 0, and 1 with 1 being considered as complete evenness.

The Simpson's Index (D) and expressing it as a proportion of the maximum value D. The equitability takes a value between 0 and 1 with 1 being considered as complete evenness.

Although, the biological diversity can be quantified in many different ways, but the diversity was measured by taking richness and evenness into account. Richness is a measure of the number of different kinds of organisms present in a particular area while, the evenness is a measure of the relative abundance of the different species making up the richness of an area.

The guild (community structure) was worked out by sorting the species family and order wise into guilds in addition to the feeding behaviour; and their impact on the ecosystem.

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Chapter – 4

RESULT AND DISCUSSION

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The results of the studies conducted to know the growth and development of lac insect on *Flemingia semialata* under Bhubaneswar agro-climatic condition occurrence & relative abundance of different natural enemies in Bhubaneswar as well as other lac ecosystems of some selected lac growing districts of Odisha and the lac ecosystem analysis thereof with special reference to faunal diversity in Odisha is embodied in this chapter along with pertinent literature citation to discuss the findings.

4.1 Growth and development of lac insect on *Flemingia semialata*

Flemingia semialata is a small annual leguminous herbaceous plant identified by the Indian Institute of Natural Resins and Gums (IINRG) Namkum, Ranchi as a very suitable host plant for cultivation of lac crop. This crop is maintained in the lac culture unit of the Department of Entomology. The growth and development of winter (Aghani) crop of Kusumi strain was studied on about 18 month old *Flemingia semialata* crop in field conditions and the observations made are presented in (Table 1 and Table 2).

Place of collection of Brood lac	:	Village - Chakiri (Fig.8)
Block	:	Jashipur
District	:	Mayurbhanj
Date of collection	:	6th June,2011
Strain of lac insect	:	Kusumi
Source of brood lac	:	Crop Jethwi
Host plant of brood lac	:	*Schleichera oleosa*
Host plant used for inoculation	:	*Flemingia semialata*
No of plants used for the study	:	6(Six)
Experimental site	:	Lac Culture Unit Dept.of Entomology
Mean Minimum Temp. ^{0}C	:	18.1 - 25.5 ^{0}C
Mean Maximum Temp. ^{0}C	:	31.4 - 35.1 ^{0}C

Table 1 : Growth and development aghani crop of Kusumi strain on *Flemingia semialata*

Date of observation	Days after inoculation	Observations
07.06.2011	0	Brood lac sticks ready to issue swarm are selected for inoculation. Two such brood sticks were tied between 8.00-9.00 am to each of the selected host plants of *Flemingia semialata* of about 18 month old maintained in the Lac Culture Unit of the Department of Entomology. Within an hour numerous nymphs moved on to the host crop and started searching a suitable site on host plants for settlement. Compared to soft green apical portion the freshly emerged nymphs preferred to settle on the lower half portion of the *Flemingia* bush.
14.06.2011	7	Crawlers settled firmly and started sucking the plant sap gregariously. Two brachial pores on lateral sides and one near the anal end of the insect were seen distinctly as whitish visible spots

21.06.2011	14	Nymphs were found slightly swollen dorso-ventrally and laterally as well and assumed dark pinkish colour (Fig. 9).
28.06.2011	21	Initiation of white waxy filament was marked. Many dead nymphal cells were found which were black in colour.
05.07.2011	28	Nymphs continued to remain uncovered, pinkish in colour with distinct whitish spot at anal end of the body. Small quickly moving small ants and the big black ants foraging over the crop were seen.
12.07.2011	35	Noticeable increase in waxy filamentous growth. Red and black ants found in close association with the lac insect most probably for feeding on honey dews. Many dead nymphal cells were found which were black in colour. Besides many cell showed holes indicating field parasitization of lac cells. (Fig. 10)
19.07.2011	42	Profuse whitish thread like filamentous growth presented cottony appearance covering the cells.
26.07.2011	49	
02.08.2011	56	
09.08.2011	63	Gradually increase in number and length of whitish thread like filaments was in progress.
16.08.2011	70	There was marked swelling of the cells under cottony filamentous mass.
23.08.2011	77	Pronounce growth of the lac cells and bigger in size with whitish thread like filaments.
30.08.2011	84	Increase in growth of the lac cells with decline in whitish filamentous mass.
06.09.2011	91	Gradual growth of lac cells observed with increase in size. Whitish filaments though continued to cover the lac cell but it was less.

13.09.2011	98	Cells were compact, started growing in size and coalescing with each other. Waxy secretion reduced. Female cell become distinct, globular in size showing distinct brachial and anal pores.
20.09.2011	105	Cells were compact and solidifying. Increasing in size. Whitish waxy filaments still noticed on the cells, but quantity was too less.
27.09.2011	112	Growths of the cells were pronounced. Developing individual cells started coalescing with adjacent cells forming brown coloured encrustation.
04.10.2011	119	Resin secretion continued with noticeable increase in encrustation formation.
11.10.2011	126	Growth of individual cell was not very uniform and enlarged cells showed hardening. No waxy filament remained but the respiratory pores showed coverage with whitish rudimentary wax filaments.
18.10.2011	133	
25.10.2011	140	
01.11.2011	147	Compact and solidified cells. Sporadic minute holes are seen on the lac cells.
08.11.2011	154	
11.11.2011	157	Emergence of few crawlers from the lac encrustation of one test plant (Plant - 4) was observed.
12.11.2011	158	Few crawlers started emerging from the lac encrustation of test plant 2 & 6
15.11.2011	161	Emergence of few crawlers from the lac encrustation of test plant - 5 was observed.
17.11.2011	163	Emergence of few crawlers from the lac encrustation of test plant - 6 was observed.

13.09.2011	98	Cells were compact, started growing in size and coalescing with each other. Waxy secretion reduced. Female cell become distinct, globular in size showing distinct brachial and anal pores.
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17.11.2011	163	Emergence of few crawlers from the lac encrustation of test plant - 6 was observed.

Table. 2 : Developmental period of Aghani crop of kusumi strain on *Flemingia semialata* at Bhubaneswar.

No of Test Plant	Date of inoculation	Dates of Issue of swarm	Total Developmental period(Days)
1	7.6.2011	14.11.2011	160
2	7.6.2011	12.11.2011	158
3	7.6.2011	17.11.2011	163
4	7.6.2011	11.11.2011	157
5	7.6.2011	15.11.2012	161
6	7.6.2011	12.11.2011	158
Range	-	-	158-163
Mean	-	-	159.5
S.D.±	-	-	2.26

The developmental period for complete cycle of Aghani crop of kusumi strain of the lac insect on *F.semialata* was found vary from 158 - 163 days with a mean of 159.5± 2.26 which was in between 5-6 month. Normally both aghani and jethwi crop of Kusumi strain takes 6 months (Ghorai, 1995).Nayak (2010) reported that *Rangeeni* strain of *Kerria lacca* could successfully completed its life cycle on *Cajanus cajan* and *Flemingia semialata* in 223 and 225 days respectively whereas the *Kusumi* strain could complete its life cycle in 154 days on *Flemingia semialata* under Bhubaneswar agro climatic conditions. The present finding also corroborates with the finding of the earlier workers.

During the course of investigation it was observed that the nymphs settle completely within 7 days of inoculation. The density i.e. congregation of nymphs per cm^2 was recorded. The density of nymphs on *Flemingia* stem was found to be 158 - 212 (Mean 173.4 ± 52.1) per cm^2 (Table - 3).

Table. 3 Density of first instar nymphs of lac insect on *Flemingia semialata* (Fig.9)

Date of observation – 10.06.2012

Host plant – *Flemingia semialata*

Strain – Kusumi

Crop - Aghani

(n = 12)

Sl. No.	No. of First instar nymphs per cm^2.
1	209
2	198
3	212
4	158
5	181
6	187
7	202
8	192
9	179
10	170
11	164
12	177
Range	**158 - 212**
Mean	**173.4**
S.D.±	**52.1**

n = Number of observations

As regards to the congregation density of first instar nymphs of lac insects, Mishra *et al*, 1998 reported mean density of settlement of different species of *Kerria* on *Flemingia macrophylla* which varied between 57 and 175 nymphs per cm^2. of the shoot surface. Nayak (2010) reported that the mean density of settlement of *Kerria* on *Flemingia macrophylla* ranged between 182 – 238(Mean 203.7 ± 16.9) nymphs per cm^2. The density of settlement of nymphs in



Fig. 8: Brood stick collected for studies



Fig. 9 First instar Nymphs settled on *F.semialata* host plant



Fig. 10 Lac cells showing field parasitization

the present study was 158 - 212 (Mean 173.4 ± 52.1) per cm^2 which was slightly less than the density reported by Nayak(2010).The reason of variation attributed to the difference in strain, host plant, season , rate of inoculums and period of exposure which has been well documented by various workers (A monograph on Lac, ILRI 1962) . The lower density in the present investigation may be due to the strain and short period of exposure made to study the growth and developments.

4.2 Occurrence of natural enemies on lac under Bhubaneswar conditions

During the course of investigation number of lac cells showed the emergence hole of parasitoids commencing from fifth weeks of inoculation. Due to insufficient experimental material, periodic collection of twigs with encrustation was not possible to record the status of parasites over the entire crop period. However, from the lac encrustation developed on *F.semialata* harvested and maintained in the laboratory only three parasitoides viz., *Tachardiaephagus tachardiae* (Howard), *Parechthrodryinus clavicornis* (Cameron) and *Eupelmus tachardiae* (Howard) (Table 4) could be collected within four weeks of harvest. All these parasitoids collected were inimical parasitizing the lac cells .All the three parasitoids belonging to Order Hymenoptera represented two families Encyrtidae and Eupelmidae. Encyrtidae constituted 63.3 per cent of the total parasitoids of which *Tachardiaephagus tachardiae* with 53.3 per cent accounted for the lion share of the natural enemies of the lac insect.

Under Odisha conditions natural enemies complex of lac ecosystem were reported by Behera (2009) and Nayak (2010), based on their study conducted in

different potential lac growing tracts of the state. Since this is the first work done under Bhubaneswar agro climatic conditions to record the natural enemies of lac insect the parasites may be regarded as new record of the area. Further, the work on lac insect in this department was initiated in the year 2008-09 and since then the lac cultivation on its host plant, *Flemingia semialata* has been introduced and the lac crop unit is maintained which is fairly in infancy. This, along with the short study period is the most possible reasons attributed to record of fewer parasitoids of the lac insect.

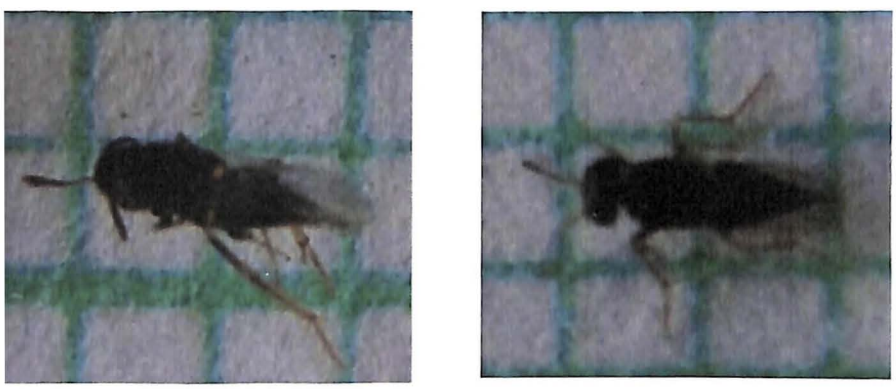
Table. 4 Occurrence of parasitoids of lac insect cultivated under Bhubaneswar agro climatic conditions (Fig. 11).

Sl. No	Name	Family	Order	No
1	*Tachardiaephagus tachardiae* (Howard)	Encyrtidae	Hymenoptera	16
2	*Parechthrodryinus clavicornis* (Cameron)	Encyrtidae	Hymenoptera	3
3	*Eupelmus tachardiae* (Howard)	Eupelmidae	Hymenoptera	11

In addition to the parasitoids mentioned above, three species of ants (one red and two black species) were found visiting frequently the lac insects for feeding on their honey dues excretion. Good number of pollinators including *Apis cerana indica* and *Trigona irridipenis* visited the host plant indicating the novel role of the plant in conservation of the pollinators.



Tachardiaephagus tachardiae



Parechthrodryinus clavicornis



Eupelmus tachardiae

Fig. 11 Parasitoid attacking lac insects at Bhubaneswar

4.3 Occurrence of natural enemies in lac ecosystem of Odisha

In order to record the occurrence of natural enemies complex of lac eco systems of Odisha, brood lac sticks of winter aghani crop of Kusumi stains from Fatiki village of Chandahandi block of Nabarangpur, Chakiri village of Jashipur block of Mayurbhanj and Amthapada village of Boudh block of Boudh districts were collected, maintained in the laboratory and regularly observed for recording the number and species of natural enemies emerged from the sample brood lac sticks every day. Lac cultivation is a traditional practice followed in succession from time immemorial in those selected tribal villages. Results revealed that, 10 different species of natural enemies (Table 5) were associated in lac ecosystems of Odisha irrespective of the districts. Out of these natural enemies three were detrimental parasitoids of order hymenoptera represented by two families i.e., Encyrtidae and Eupelmidae; four were beneficial parasitoids of order hymenoptera represented by two families i.e., Braconidae and Ichneumonidae; three were detrimental predators represented by two families i.e., Noctuidae and Blastobasidae of order Lepidoptera and a family Chrysopidae of Order Neuroptera. (Fig. 12, 13, 14)

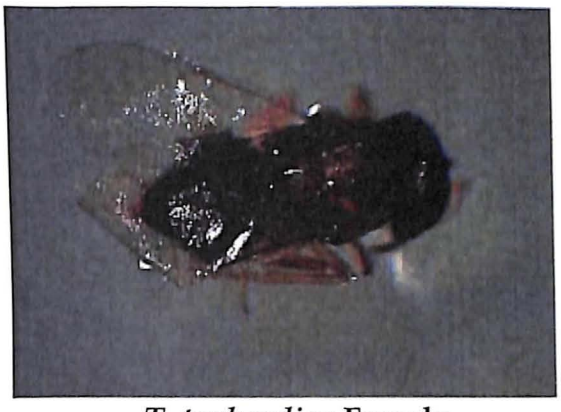
Besides, very few unidentified lepidopterous moths and one species of unidentified beetle in good number were encountered during the course of investigation. The lepidopterous moth appeared to be inimical while the beetles were most probably of scavenging by nature. (Fig.15)

Tachardiaephagus tachardiae (Howard), *Parechthrodryinus clavicornis* (Cameron) *Eupelmus tachardiae* (Howard) *Apanteles tachardiae* Cam among the parasitoids and *Eublemma amabilis* Moore and *Pseudohypatopa (=Holcocera) pulverea* Meyr among the predators found in relatively large number and must be playing a vital role in regulating natural balance in the lac ecosystem.

Sl.No	Name	Family	Order	Nature	Impact
1	*Tachardiaephagus tachardiae* (Howard)	Encyrtidae	Hymenoptera	Parasitoid	Detrimental
2	*Parechthrodryinus clavicornis* (Cameron)	Encyrtidae	Hymenoptera	Parasitoid	Detrimental
3	*Eupelmus tachardiae* (Howard)	Eupelmidae	Hymenoptera	Parasitoid	Detrimental
4	*Apanteles tachardiae* Cam.	Braconidae	Hymenoptera	Parasitoid	Beneficial
5	*Apanteles fakhrulhajiae* Mahd.	Braconidae	Hymenoptera	Parasitoid	Beneficial
6	*Bracon greeni* Ashm	Braconidae	Hymenoptera	Parasitoid	Beneficial
7	*Pristomerus sulci* Mahd and Kolub	Ichneumonidae	Hymenoptera	Parasitoid	Beneficial
8	*Eublemma amabilis* Moore	Noctuidae	Lepidoptera	Predatory	Detrimental
9	*Pseudohypatopa (=Holcocera) pulverea* Meyr.	Blastobasidae	Lepidoptera	Predatory	Detrimental
10	*Chrysopa* sp.	Chrysopidae	Neuroptera	Predatory	Detrimental

Others

1	Moth (Unidentified)	Noctuidae	Lepidoptera	Unknown	Unknown
2	Beetle (Unidentified)		Coleoptera	Unknown	Unknown



T. tachardiae Female



T. tachardiae Male



P.clavicornis Female



P.clavicornis Female



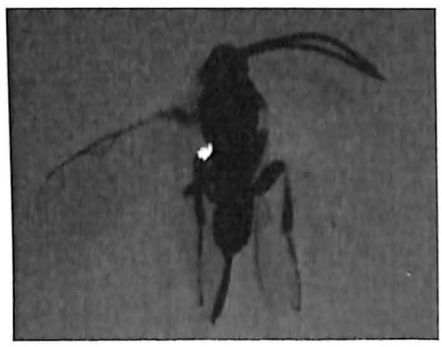
E.tachardiae Female



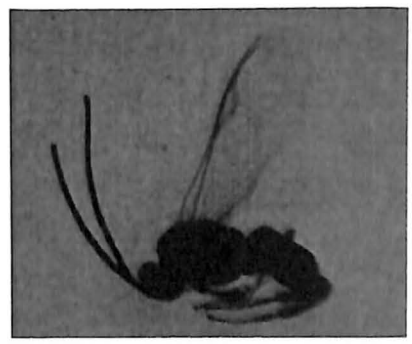
E.tachardiae Female

Fig. 12 Inimical parasitoids of *Kerria lacca* ecosystem of Odisha

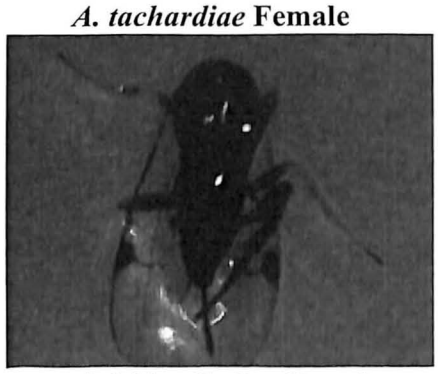
Central Library ACC No. OUAT, Bhubaneswar



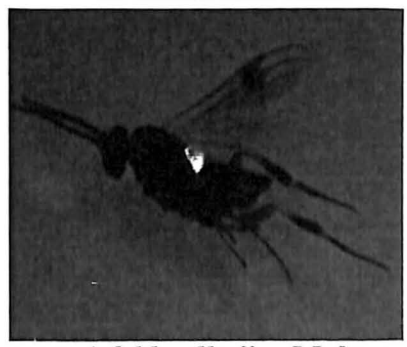
A. tachardiae Female



A. tachardiae Male



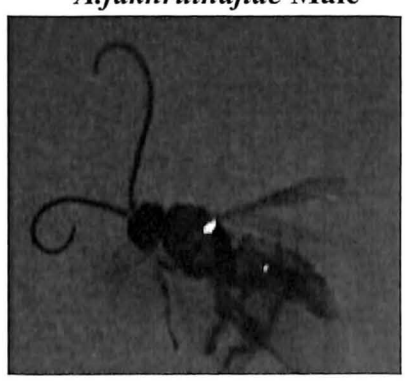
A.fakhrulhajiae Female



A.fakhrulhajiae Male



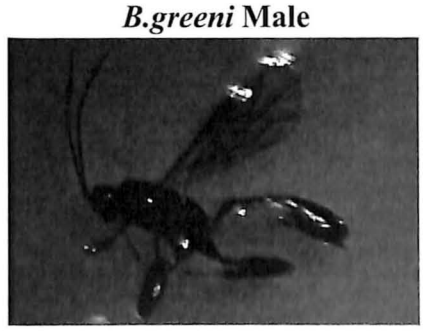
B.greeni Female



B.greeni Male



P.sulci Female



P.sulci Male

Fig. 13 Beneficial parasitoids of *Kerria lacca* eco system of Odisha

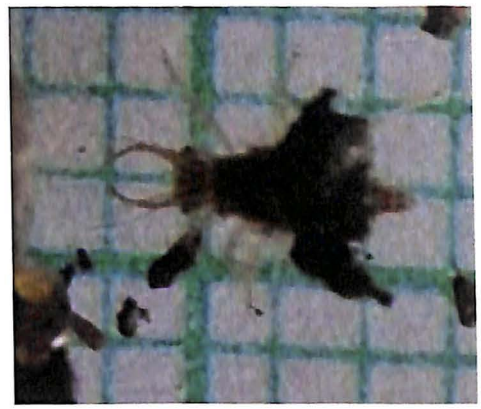


Adult moth of *Eublemma amabilis*



Adult moth of *Pseudohypatopa (=Holcocera) pulverea*





Nymphs of *Chrysopa* sp.

Fig. 14 Harmful enemies of Kerria *lacca* eco system



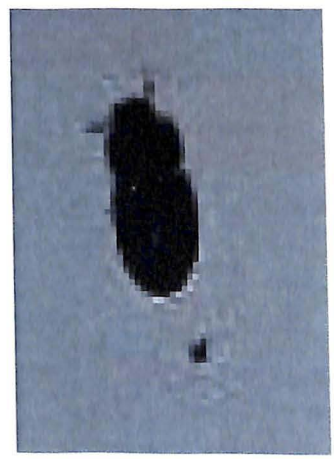


Fig. 15 Unidentified beetle and moth collected from *Kerria lacca* eco system

Results on occurrence of individual parasitoid indicated that *Tachardiaephagus tachardiae* (Howard) one of the inimical encyrtid parasitoid was very common and its number per 100 linear cm and number per 100gms of lac encrustation (Table -6) ranged between 12.26-20.94 and 17.05-33.33 respectively. Maximum number of this parasitoid recovered from brood lac sticks procured from Mayurbhanj district followed by Nabarangpur and Boudh. Similarly the population count (No.) of another inimical encyrtid, *Parechthrodryinus clavicornis* (Cameron) ranged between 4.71-14.78 and 6.79-23.52 per 100 linear cm and 100gms of lac encrustation respectively (Table -7). Unlike the former parasitoid, its occurrence was maximum in same Mayurbhanj district (14.78 per 100 linear cm and 23.52per100gms of lac encrustation) but lowest was in Nabarangpur district (4.71 per 100 linear cm and 6.79 per100gms of lac encrustation).

Observation on occurrence of the inimical eupelmidae parasitoid (Table -8) revealed that its number ranged between 11.07- 25.87per100 linear cm of brood lac maximum being in Mayurbhanj district (28.87) followed by Nabarangpur (11.14) and Boudh (11.07).Likewise the number per 100gms of lac encrustation (Table -8) ranged between 15.88-41.17 with same trend i.e. maximum being in Mayurbhanj followed by Nabarangpur and Boudh.

Table 6 : Occurrence of *Tachardiaephagus tachardiae* (Howard) in lac Eco systems of three tribal districts of Odisha.

Date of emergence	Number of parasitoids emerged		
	Fatiki, Nabarangpur	Chakiri, Mayurbhanj	Amthapada, Boudh
03.01.2012	-	6	-
04.01.2012	-	8	-
05.01.2012	-	5	-
06.01.2012	-	4	-
07.01.2012	-	4	-
10.01.2012	-	-	4
11.01.2012	-	1	-
14.01.2012	-	1	-
16.01.2012	-	2	3
24.01.2012	-	-	3
27.01.2012	2	-	-
30.01.2012	8	1	-
01.02.2012	3	-	-
02.02.2012	3	-	-
07.02.2012	9	-	4
08.02.2012	2	-	4
10.02.2012	-	-	2
12.02.2012	-	-	2
13.02.2012	2	-	2
15.02.2012	1	1	3
18.02.2012	-	1	2
Total	**30**	**34**	**29**
Total encrustation area(cm)	233.3	162.3	238.9
Total weight of lac encrustation (g)	162	102	170
No. of parasitoid per 100 linear cm. of encrustation	12.85	20.94	12.26
No. of parasitoid per 100g. of encrustation	18.51	33.33	17.05

Table 7 : Occurrence of *Parechthrodryinus clavicornis* (Cameron) in lac ecosystems of three tribal districts of Odisha

Date of emergence	Number of parasitoids emerged		
	Fatiki, Nabarangpur	Chakiri, Mayurbhanj	Amthapada, Boudh
06.01.2012	-	3	-
07. 01.2012	-	2	-
10. 01.2012	-	-	1
11. 01.2012	-	3	2
24. 01.2012	-	2	2
27. 01.2012	2	-	2
01. 02.2012	-	1	-
02. 02.2012	-	1	1
03. 02.2012	2	3	-
06. 02.2012	2	-	1
07. 02.2012	1	-	-
08. 02.2012	1	1	1
10. 02.2012	-	1	-
13. 02.2012	1	-	-
14. 02.2012	-	2	1
15. 02.2012	2	-	-
16. 02.2012	-	2	-
17. 02.2012	-	1	2
21. 02.2012	-	1	2
23. 02.2012	-	1	1
Total	**11**	**24**	**16**
Total encrustation area(cm)	233.3	162.3	238.9
Total weight of lac encrustation (g)	162	102	170
No. of parasitoid per 100 linear cm. of encrustation	4.71	14.78	6.71
No. of parasitoid per 100g. of encrustation	6.79	23.52	9.41

Table 8 : **Occurrence of *Eupelmus tachardiae* (Howard) in lac ecosystems of three tribal districts of Odisha.**

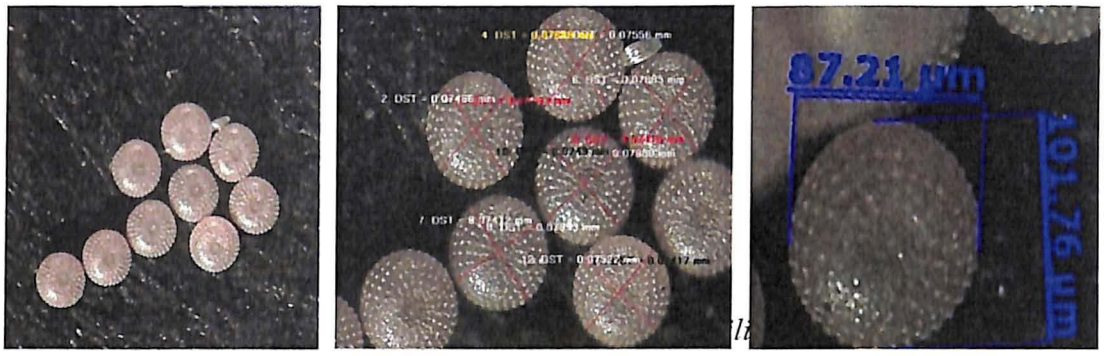
Date of emergence	Number of parasitoids emerged		
	Fatiki, Nabarangpur	Chakiri, Mayurbhanja	Amthapada, Boudh
03.01.2012	-	4	-
04.01.2012	-	8	-
05.01.2012	-	4	-
06.01.2012	-	4	-
07.01.2012	-	4	-
10.01.2012	-	2	3
11.01.2012	-	-	3
14.01.2012	-	-	4
16.01.2012	-	-	4
24.01.2012	-	-	3
27.01.2012	4	-	-
30.01.2012	8	-	-
01.02.2012	2	1	-
02.02.2012	-	1	-
03.02.2012	2	3	-
06.02.2012	-	2	-
08.02.2012	4	1	4
10.02.2012	-	1	-
13.02.2012	2	-	-
14.02.2012	-	2	-
15.02.2012	1	1	2
16.02.2012	-	1	2
17.02.2012	1	2	-
18.02.2012	1	-	-
21.02.2012	1	1	2
Total	**26**	**42**	**27**
Total encrustation area(cm)	233.3	162.3	238.9
Total weight of lac encrustation (g)	162	102	170
No. of parasitoid per 100 linear cm. of encrustation	11.14	25.87	11.07
No. of parasitoid per 100g. of encrustation	16.04	41.17	15.88

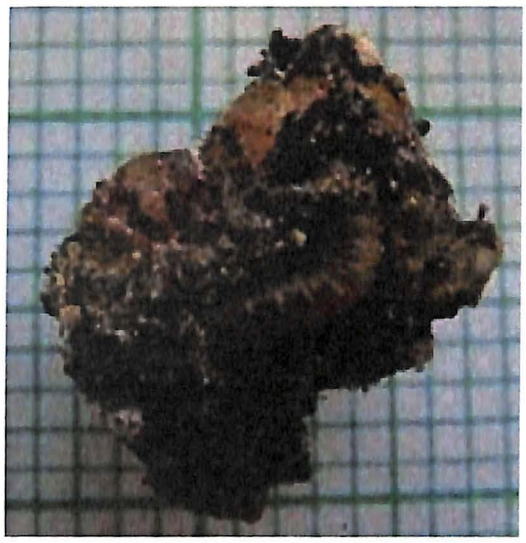
Contrasts to the above inimical parasitoids, the number of beneficial parasitoid attacking the lepidopterous predator of lac insect (Table -9) were relatively less. Out of four species (3 Braconids and 1 Ichneumonid) most common species was represented by the braconid, *Apanteles tachardiae.* The number of this parasitoid varied between 1.84 -5.86per100 linear cm of brood lac, maximum being in Boudh district (5.86) followed by Nabarangpur (3.42) and Mayurbhanj (1.84). Similarly the number per100gms of lac encrustation ranged from 2.94-8.23 with same trend i.e. maximum being in Boudh (8.23) followed by Nabarangpur (4.93) and Mayurbhanj (2.94).

During this present investigation three predators attacking to various stages of lac insects were also recorded. Only three nymphs of the lace wing bug (Fig. 13) of order Neuroptera were observed associated with brood lac stick collected from Mayurbhanj district. Further, it is observed that more number of small black moth, *Pseudohypatopa (=Holcocera) pulverea* Meyr (Blastobasidae: Lepidoptera) were more compared to the big white moth, *Eublemma amabilis* Moore (Noctuidae: Lepidoptera).It is revealed that (Table 10), the number of this *E. amabilis* adult varied between 3.69 - 7.95per100 linear cm of brood lac, maximum being in Boudh district (7.95) followed by Nabarangpur (6.42) and Mayurbhanj (3.69). Further, the number of *E. amabilis* adultper100gms of lac encrustation was found to vary between 5.88 -11.17 with identical trend i.e. maximum being in Boudh (11.17) followed by Nabarangpur (9.25) and Mayurbhanj (5.88).The occurrence of the blastobasidae predator, *P. pulverea,* (Table 11) on the other hand was different. Maximum number of *this P.*

pulverea adultper100 linear cm of brood lac was found in Mayurbhanj (8.62) followed by Boudh (7.53) and Nabarangpur (5.57). Similarly the numbers of P. pulverea adult per 100gms of lac encrustation were 13.72, 10.58, and 8.02 in Mayurbhanj, Boudh and Nabarangpur district respectively.

The larvae of the predators, *E.amabilis* and *H.pulverea* were also collected and maintained separately during the present investigation to gather additional information and also attempt was made to initiate the biology of the white moth, *E.amabilis* .The adult moths collected by rearing the larvae on lac encrustation could oviposit on corrugated papers under captive conditions in laboratory. The eggs obtained are white in colour, measuring 87.2µm-101.76µm and were beautifully sculptured. (Fig16)





Larva of *Eublemma amabilis*



Adult of *Eublemma amabilis*

Fig. 16 Life stages of *Eublemma amabilis*

Table 9 : Occurrence of *Apanteles tachardiae* Cam. in lac ecosystems of three tribal districts of Odisha.

Date of emergence	Number of parasitoids emerged		
	Fatiki, Nabarangpur	Chakiri, Mayurbhanj	Amthapada, Boudh
03.01.2012	2	-	-
08.01.2012	3	3	-
15.01.2012	2	-	-
19.01.2012	1	-	-
07.02.2012	-	-	3
08.02.2012	-	-	5
11.02.2012	-	-	2
14.02.2012	-	-	2
26.02.2012	-	-	2
Total	**8**	**3**	**14**
Total encrustation area(cm)	233.3	162.3	238.9
Total weight of lac encrustation (g)	162	102	170
No. of parasitoid per 100 linear cm. of encrustation	3.42	1.84	5.86
No. of parasitoid per 100g. of encrustation	4.93	2.94	8.23

Table 10 : Occurrence of *Eublemma amabilis* Moore .in lac ecosystems of three tribal districts of Odisha.

Date of emergence	Number of predators emerged		
	Fatiki, Nabarangpur	Chakiri, Mayurbhanja	Amthapada, Boudh
19.01.2012	-	-	2
23.01.2012	-	-	1
27.01.2012	1	-	-
31.01.2012	-	-	2
01.02.2012	1	-	1
02.02.2012	-	-	2
03.02.2012	1	-	-
04.02.2012	-	-	1
07.02.2012	-	-	1
08.02.2012	1	1	-
11.02.2012	3	-	1
13.02.2012	1	-	1
14.02.2012	1	-	-
17.02.2012	2	-	-
18.02.2012	1	1	-
19.02.2012	1	-	-
20.02.2012	1	-	-
21.02.2012	-	1	-
22.02.2012	-	-	1
27.02.2012	1	1	-
28.02.2012	-	-	1
01.03.2012	-	-	1
02.03.2012	-	1	1
03.03.2012	-	1	1
05.03.2012	-	-	1
12.03.2012	-	-	1
Total	**15**	**6**	**19**
Total encrustation area(cm)	233.3	162.3	238.9
Total weight of lac encrustation (g)	162	102	170
No. of predator per 100 linear cm. of encrustation	6.42	3.69	7.95
No. of predator per 100g. of encrustation	9.25	5.88	11.17

Table 11 : Occurrence of *Pseudohypatopa (=Holcocera) pulverea* Meyr. in lac ecosystems of three tribal districts of Odisha.

Date of emergence	Number of predators emerged		
	Fatiki, Nabarangpur	Chakiri, Mayurbhanja	Amthapada, Boudh
12.01.2012	-	-	1
13.01.2012	-	-	1
19.01.2012	-	-	1
23.01.2012	-	-	1
31.01.2012	1	-	2
01.02.2012	-	1	1
02.02.2012	-	3	-
07.02.2012	-	1	1
10.02.2012	-	-	1
11.02.2012	1	-	2
13.02.2012	-	1	1
14.02.2012	-	2	1
15.02.2012	-	1	-
16.02.2012	2	-	-
18.02.2012	3	-	-
19.02.2012	1	1	-
20.02.2012	-	1	-
21.02.2012	2	1	1
22.02.2012	-	-	1
23.02.2012	-	2	-
24.02.2012	1	-	-
27.02.2012	1	-	1
03.03.2012	-	-	1
05.03.2012	1	-	-
10.03.2012	-	-	1
Total	**13**	**14**	**18**
Total encrustation area(cm)	233.3	162.3	238.9
Total weight of lac encrustation (g)	162	102	170
No. of predator per 100 linear cm. of encrustation	5.57	8.62	7.53
No. of predator per 100g. of encrustation	8.02	13.72	10.58

from other Chalcidoidea by the possession of a medially concave mesonotum. They also have the unusual tendency to arch the body strongly upwards when dead, with the head and metasoma often nearly touching above the thorax. The group is apparently polyphyletic, though the different subfamilies may each be monophyletic, and may be elevated to family status in the near future. As presently defined, there are over 905 described species in 45 genera. The larvae of the majority are primary parasitoids, commonly on beetle larvae, though many other hosts are attacked, including spiders, some attack eggs and others are hyperparasites. They are found throughout the world in virtually all habitats. *Eupelmus tachardiae* recorded in the present investigation parasitized the lac insect and was the most abundant.

Braconidae is a family of parasitoid wasps of Super family-Ichneumonoidea, Suborder-Apocrita and Order -Hymenoptera of Class-Insecta and one of the richest families of insects. Between 50,000 and 150,000 species exist worldwide. The species are grouped into about 45 subfamilies and 1,000 genera. The morphological variation among braconids is notable. Braconids are often black-brown (sometimes with reddish markings), though some species exhibit striking coloration and pattern. They have one or no recurrent veins, unlike other members of the Ichneumonoidea which usually have two. Wing venation patterns are also divergent to apparent randomness. The antennae have 16 segments or more; the hind trochanters have 2 segments. Females often have long ovipositors, an organ that largely varies intraspecifically.

This variation is closely related to the host species upon which the wasp deposits its egg. Species that parasitize microlepidoptera, for instance, have longer ovipositors, presumably to reach the caterpillar through layers of plant tissue. Some wasps also have long ovipositors because of caterpillar defense mechanisms such as spines or hairs. Most braconids are primary parasitoids on other insects, especially upon the larval stages of Coleoptera, Diptera, and Lepidoptera, but also some hemimetabolous insects like aphids, Heteroptera or Embiidina. Most species kill their hosts, though some cause the hosts to become sterile and less active. The highly modified system of host immunosuppression specificity makes Braconids a very powerful and important biological control agent.

Ichneumonidae is a family of Super family-Ichneumonoidea, Suborder-Apocrita and Order -Hymenoptera of Class-Insecta. Insects in this family are commonly called ichneumon wasps or ichneumon flies or scorpion wasps due to the extreme lengthening and curving of the abdomen. Ichneumon wasps differ from typical wasps, which sting in defense (Aculeata: Vespoidea and Apoidea), in that the antennae have more segments; typically 16 or more, whereas the others have 13 or fewer. Female ichneumon wasps frequently exhibit an ovipositor longer than their body. Ovipositors and stingers are homologous structures; some Ichneumons inject venom along with the egg, but they do not use the ovipositor as a stinger. Ichneumon wasps are important parasitoids of other insects. Common hosts are larvae and pupae

of Coleoptera, Hymenoptera, and Lepidoptera. There are over 60,000 species worldwide. The distribution of Ichneumonidae is one of the most notable exceptions to the common latitudinal gradient in species diversity because it shows greater speciation at high latitudes than at low latitudes. Some species of ichneumon wasps lay their eggs in the ground, but most inject them directly into a host's body, typically into a larva or pupa.

4.4 Critical analysis of Lac ecosystem with reterence to Natural enemies

Lac ecosystem is observed to be a very complex ecosystem comprising of number of fauna during the present investigation. Due to hiding nature of the lac insect and its associated fauna it was very difficult to know the exact nature of association and relation between any two fauna. However, based on the keen observation and the available supporting literature, an attempt has been made to analyze the Lac ecosystem with special reference to diversity of the natural enemies complex.

During the present studies, leaving aside the Lac insect *Kerria lacca*, 25 different species of insects were found associated with the different lac ecosystems surveyed. This group comprised 6 species of pests attacking lac host plants (Grass hoppers, Mealy bugs, Thrips, Aphids, Termites and defoliators), 4 species of pollinator visiting lac host plants,3 different species of ant having symbiotic association with lac nymphs and 12 species (Table -5) of natural enemies.

Table 12. Density and dominance status of Natural enemies of lac insects in Fatiki,Nabarangpur(Fig.17)

Sl no	Name of the natural enemy	Family	Order	Mean No. of parasite in 100 linear cm. of encrustation	Dominance Status		Impact with respect to Lac cultivation	Feeding habit
					%	Category		
1	*Tachardiaephagus tachardiae*	Encyrtidae	Hymenoptera	12.85	27.78	D	Detrimental	Parasitic
2	*Parechthrodryinus clavicornis*	Encyrtidae	Hymenoptera	4.71	10.18	SD	Detrimental	Parasitic
3	*Eupelmus tachardiae*	Eupelmidae	Hymenoptera	11.14	24.09	D	Detrimental	Parasitic
4	*Apanteles tachardiae*	Braconidae	Hymenoptera	3.42	7.39	R	Beneficial	Parasitic
5	*Apanteles fakhrulhajiae*	Braconidae	Hymenoptera	0.43	3.51	R	Beneficial	Parasitic
6	*Bracon greeni*	Braconidae	Hymenoptera	0.43	6.41	R	Beneficial	Parasitic
7	*Eublemma amabilis*	Noctuidae	Lepidoptera	6.42	13.88	SD	Detrimental	Predatory
8	*Pseudohypatopa pulverea*	Blastobasidae	Lepidoptera	5.57	12.04	SD	Detrimental	Predatory
9	*Chrysopa* sp.	Chrysopidae	Neuroptera	1.28	2.77	R	Detrimental	Predatory
	TOTAL			46.25				

D-Dominant, SD- Sub dominant, R-Recedent

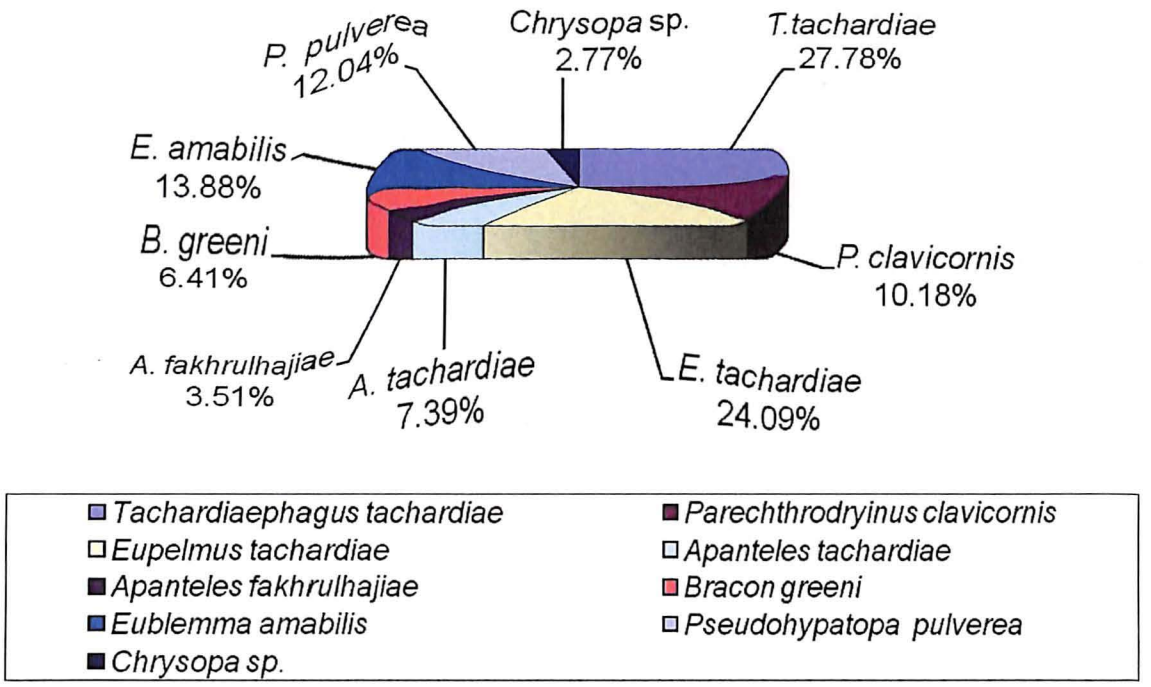


Fig. 17 : Dominance Status of different natural enemies fauna in lac ecosystem of Nabarangpur District.

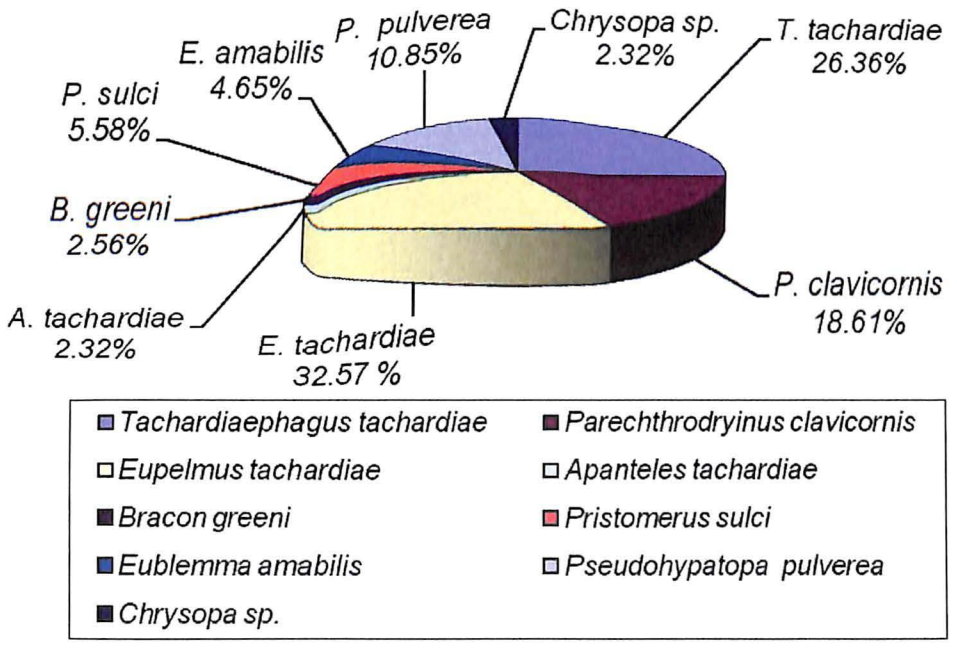


Fig. 18 : Dominance Status of different natural enemies fauna in lac ecosystem of Mayurbhanj District.

Likewise the mean density of nine species of natural enemies of village Chakiri of Mayurbhanj (Table-13, fig.18) ranged between 0.62-20.94 per 100 linear cm of the lac encrustation in lac ecosystem. Two species of parasitoids belong to family encyrtidae, 2 species from Braconidae, 1 species each from Eupelmidae, Ichneumonidae, Noctuidae, Blastobasidae and Chrysopidae comprised the natural enemy complex of lac ecosystem of this district. Out of these species, the inimical parasitoid *T. tachardiae* and *E. tachardiae* showed the dominant status where as the other inimical parasitoid, *P.clavicornis* and the predators *P. pulverea* of lac insect exhibited sub dominant status. Other five species prevailing with 2.32-5.88 per cent share fell into recedent category of dominance.

The natural enemies complex in lac ecosystem of Amthapada village of Boudh district is represented by only six species, the relative density of those varying from 5.86-12.26 per 100 linear cm of the lac encrustation(Table -14, fig. 19). Two species of parasitoids viz. *T. tachardiae* (Fam:Encyrtidae) and *E. tachardiae* (Fam:Eupelmidae) assumed the dominance status while the other four i.e. *P.clavicornis* (Fam.Encyrtidae), beneficial parasitoid ,*A. tachardiae* (Braconidae) and the two lepidopterous predator *E.amabilis* and *P.pulverea* assumed sub dominant status in the ecosystem.

Table 13. Density and dominance status of Natural enemies of lac insects in Chakiri Mayurbhanj(Fig.18)

Sl. No	Name of the natural enemy	Family	Order	Mean No. of parasite in 100 linear cm. of encrustation	Dominance Status		Impact with respect to Lac cultivation	Feeding habit
					%	Category		
1	*Tachardiaephagus tachardiae*	Encyrtidae	Hymenoptera	20.94	26.36	D	Detrimental	Parasitic
2	*Parechthrodryinus clavicornis*	Encyrtidae	Hymenoptera	14.78	18.61	SD	Detrimental	Parasitic
3	*Eupelmus tachardiae*	Eupelmidae	Hymenoptera	25.87	32.57	D	Detrimental	Parasitic
4	*Apanteles tachardiae*	Braconidae	Hymenoptera	1.84	2.32	R	Beneficial	Parasitic
5	*Bracon greeni*	Braconidae	Hymenoptera	1.23	2.56	R	Beneficial	Parasitic
6	*Pristomerus sulci*	Ichneumonidae	Hymenoptera	0.62	5.58	R	Beneficial	Parasitic
7	*Eublemma amabilis*	Noctuidae	Lepidoptera	3.69	4.65	R	Detrimental	Predatory
8	*Pseudohypatopa pulverea*	Blastobasidae	Lepidoptera	8.62	10.85	SD	Detrimental	Predatory
9	*Chrysopa* sp.	Chrysopidae	Neuroptera	1.84	2.32	R	Detrimental	Predatory
	TOTAL			79.43				

D-Dominant, SD- Sub dominant, R-Recedent

Table 14. Density and dominance status of Natural enemies of lac insects in Amthapada,Boudh(Fig. 19)

Sl no	Name of the natural enemy	Family	Order	Mean No. of parasite in 100 linear cm. of encrustation	Dominance Status		Impact with respect to Lac cultivation	Feeding habit
					%	Category		
1	*Tachardiaephagus tachardiae*	Encyrtidae	Hymenoptera	12.26	23.86	D	Detrimental	Parasitic
2	*Parechthrodryinus clavicornis*	Encyrtidae	Hymenoptera	6.71	13.06	SD	Detrimental	Parasitic
3	*Eupelmus tachardiae*	Eupelmidae	Hymenoptera	11.07	21.55	D	Detrimental	Parasitic
4	*Apanteles tachardiae*	Braconidae	Hymenoptera	5.86	11.41	SD	Beneficial	Parasitic
5	*Eublemma amabilis*	Noctuidae	Lepidoptera	7.95	15.47	SD	Detrimental	Predatory
6	*Pseudohypatopa pulverea*	Blastobasidae	Lepidoptera	7.53	14.66	SD	Detrimental	Predatory
	TOTAL			51.38				

D-Dominant, SD- Sub dominant, R-Recedent

Computation and analysis of overall scenario of natural enemies complex of lac ecosystem (Table -15 fig.20) of the state irrespective of locations indicated prevalence of 10 different species of natural enemies with wide diversity. The population density ranged from the level as low as 0.14 per 100 linear cm of the lac encrustation represented by the beneficial braconid A. *fakhrulhajiae* to as high as 16.03 per 100 linear cm of the lac encrustation in case of the eupelmid ,*E.tachardiae.* Among the natural enemies *E.tachardiae* and *T.tachardiae* each individually sharing over ¼th of the population crowned the dominance status followed by the sub dominant status assumed by *P.clavicornis* and the two lepidopterous predator *E.amabilis* and *P.pulverea* .The inimical lace wing of order neuroptera and all four beneficial species viz. *Apanteles tachardiae, Apanteles fakhrulhajiae, Bracon greeni* and *Pristomerus sulci* with negligible share i.e. 0.24 -1.76 per cent of the population exhibited the recedent status. In general it is observed that the *E.tachardiae* (Eupelmidae) dominated the community of natural enemies followed by two species of encyrtid *T. tachardiae* (26.01%) *and P.clavicornis* (14.8%).Though there was no much difference between the predators in their overall dominance status, still the small *black* moth *P.pulverea* was ahead of *E.amabilis.*

Table 15. Overall density and dominance status of natural enemies of lac insects in Odisha(Fig. 20)

Sl no	Name of the natural enemy	Family	Order	Mean No. of parasite in 100 linear cm. of encrustation	Dominance Status		Impact with respect to Lac cultivation	Feeding habit
					%	Category		
1	*Tachardiaephagus tachardiae*	Encyrtidae	Hymenoptera	15.35	26.01	D	Detrimental	Parasitic
2	*Parechthrodryinus clavicornis*	Encyrtidae	Hymenoptera	8.73	14.80	SD	Detrimental	Parasitic
3	*Eupelmus tachardiae*	Eupelmidae	Hymenoptera	16.03	27.15	D	Detrimental	Parasitic
4	*Apanteles tachardiae*	Braconidae	Hymenoptera	3.71	6.28	R	Beneficial	Parasitic
5	*Apanteles fakhrulhajiae*	Braconidae	Hymenoptera	0.14	0.24	SR	Beneficial	Parasitic
6	*Bracon greeni*	Braconidae	Hymenoptera	0.55	0.94	SR	Beneficial	Parasitic
7	*Pristomerus sulci*	Ichneumonidae	Hymenoptera	0.21	0.35	SR	Beneficial	Parasitic
8	*Eublemma amabilis*	Noctuidae	Lepidoptera	6.02	10.20	SD	Detrimental	Predatory
9	*Pseudohypatopa pulverea*	Blastobasidae	Lepidoptera	7.24	12.27	SD	Detrimental	Predatory
10	*Chrysopa* sp.	Chrysopidae	Neuroptera	1.04	1.76	SR	Detrimental	Predatory
	TOTAL			59.02				

D-Dominant, SD- Sub dominant, R-Recedent, SR –Sub recedent

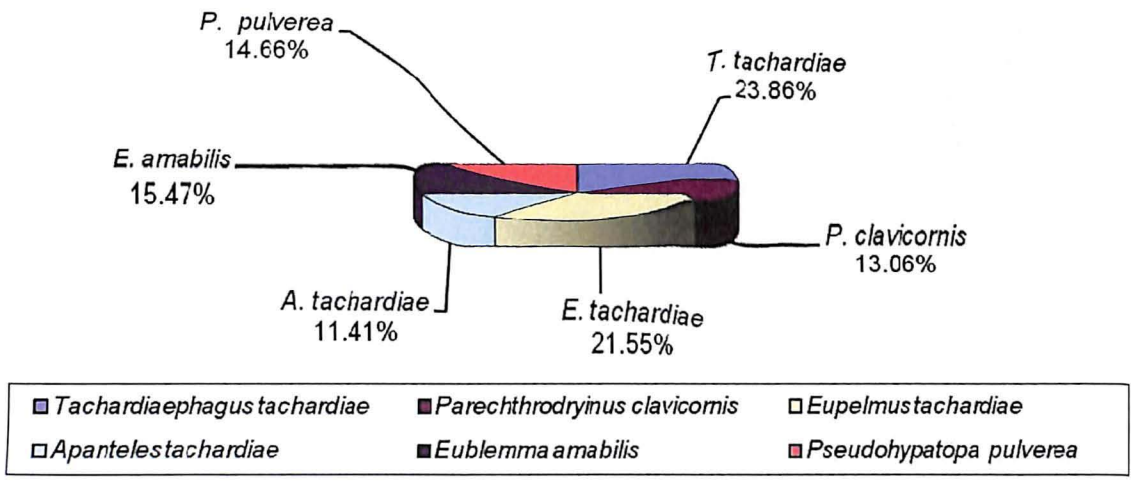


Fig. 19 : Dominance Status of different natural enemies fauna in lac ecosystem of Boudh District.

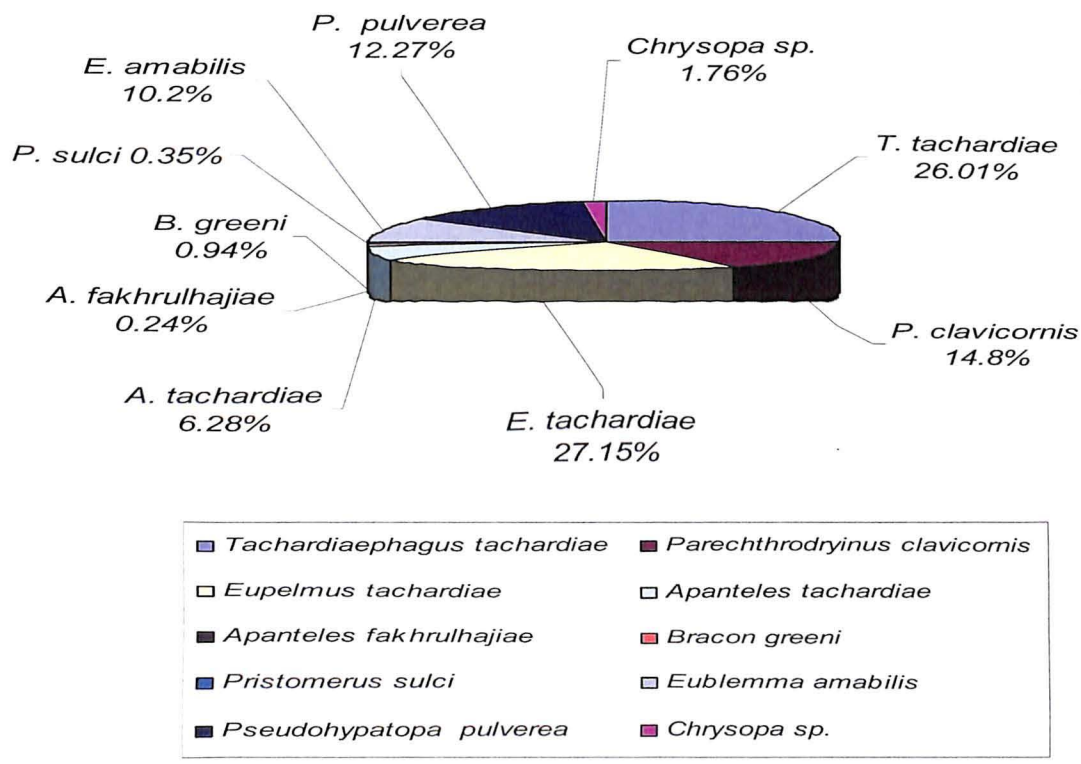


Fig. 20 : Overall density and dominance status of natural enemies of lac insects in Odisha.

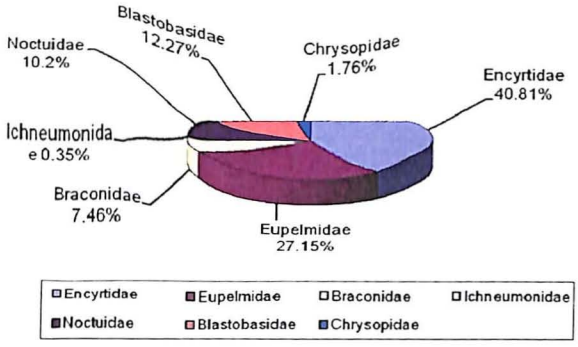
constituted the community guild super dominated by hymenoptera, followed by Lepidoptera which exhibited dominant status and neuropteran, the recedent status in the lac ecosystem. From feeding habit point of view, the natural enemies of two tropic levels were found. As primary feeder of lac insect parasitic species showed super dominant status while the predators showed dominant status. The secondary feeders feeding on the predators of lac insect with 7.81per cent assumed the recedent status. Thus, in nature they play a little role for natural control of harmful insect of lac ecosystem. Further, the beneficial fauna for enhanced lac production with 7.81 per cent share occupied the recedent status while the fauna detrimental to lac production assumed the super dominant status .This clearly indicates that appropriate IPM strategies are inevitable for suppression of these harmful fauna in the lac ecosystem to realize the potential yield of the lac crop.

The species diversity of natural enemies in lac eco system is measured with help of the indices like Simpson's index (D) and Simpson's index of diversity (SID).A deep insight to the analyzed data (Table - 16) showed that Nabarangpur and Mayurbhanj with more number of species (9) are rich compared to Boudh (6) but, greater diversity was found in Boudh (SID-0.837) because a community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance. Species richness even though more in case of overall lac ecosystem of the state but species diversity was relatively low

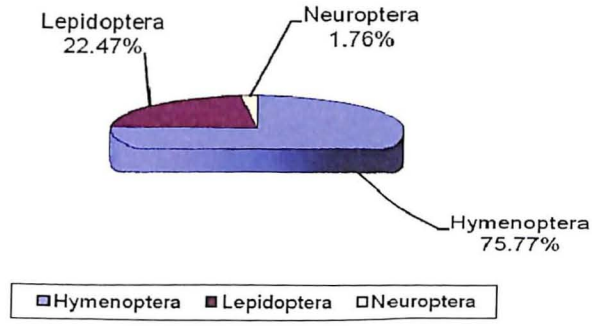
Community structure of the overall lac ecosystem (Fig.22)

A community structure (guild) is a group of species that exploit same class of environmental resources in the similar way. It focuses attention on sympatric species involved in competitive relationship. Guild structure may be more predictable and stable than either the abundance of individual species or species composition. A total of 10 different species of natural enemies of lac ecosystem were recorded from three tribal districts of Odisha during the present investigation. The community structure taking natural enemies alone into consideration was analysed with respect to family, order, feeding habit and impact on lac cultivation. The result (Table -17, Fig.21) revealed that the community comprised of 7 different families eudominated by encyrtidae and dominated by eupelmidae but the beneficial families were either recedent or sub recedent. This implies the beneficial forms are less important in suppressing the natural enemies population of lac insect. Insects of three orders

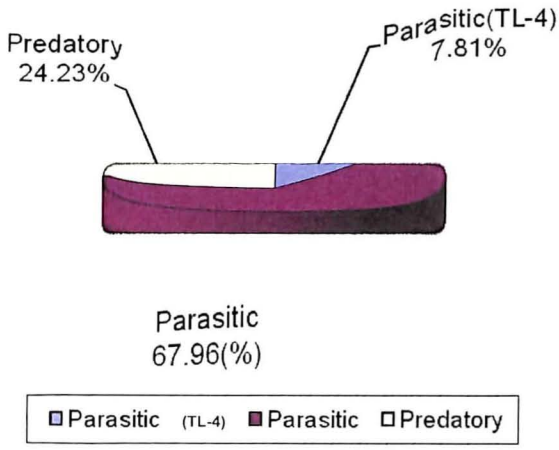
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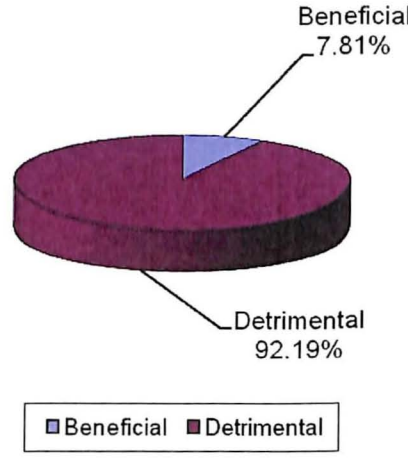
Dominance Status of Families of Natural enemies



Dominance Status of Order of Natural enemies



Dominance Status of different groups Based on feeding habit



Dominance Status of different groups based on impact on lac ecosystem

Fig. 21 : Guild structure of natural enemies component of Lac ecosystem of Odisha.

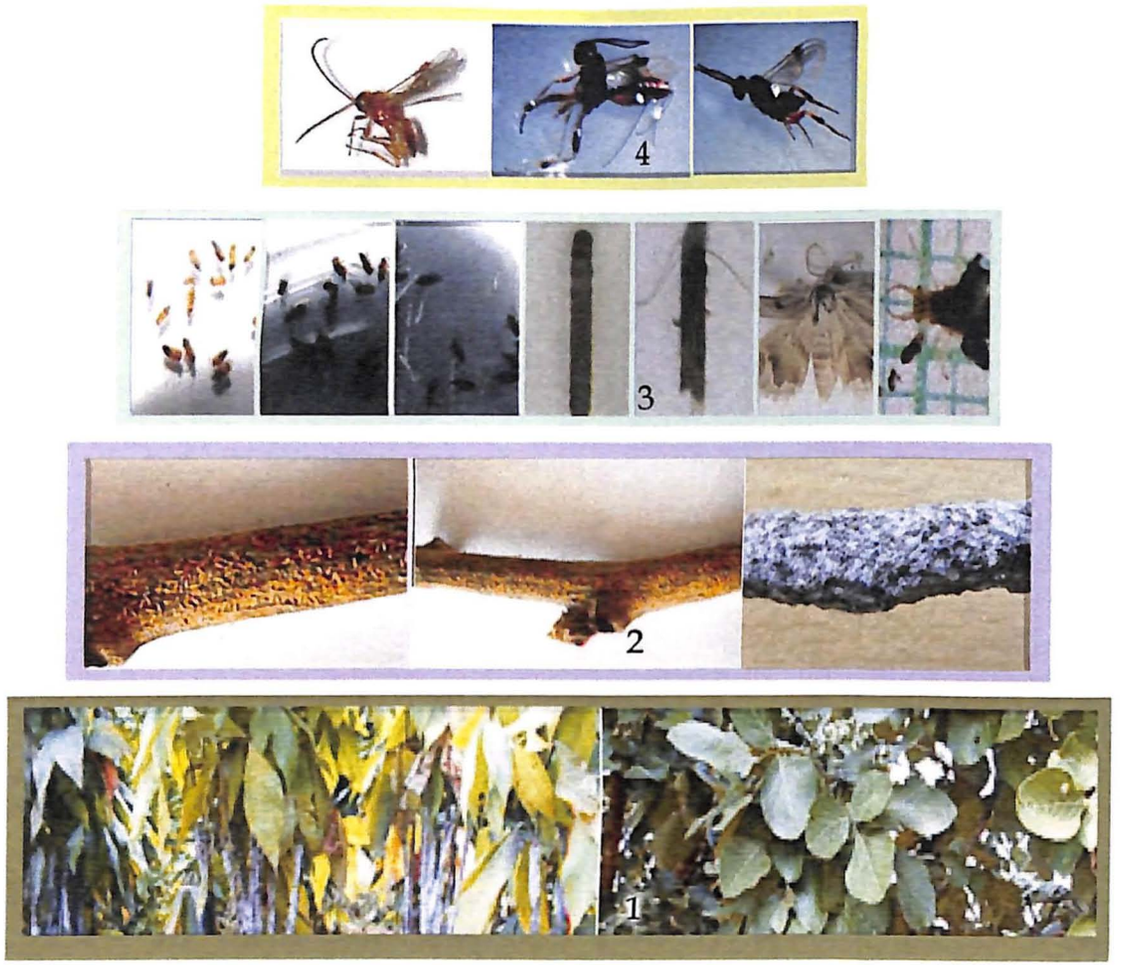
Table 16. Species diversity and evenness indices of Natural enemies of lac ecosystem of Odisha

	Survey locations Locations			
Parameters	**Fatiki, Nabarangpur**	**Chakiri, Mayurbhanja**	**Amthapada, Boudh**	**Overal**
Number of Individual/catch	46.25	79.43	51.38	59.02
Number of Species	9	9	6	10
Simpsons index-D	0.167	0.215	0.162	0.188
Simpsons index of diversity(SID)	0.832	0.784	0.837	0.811
Simpsons reciprocal index -1/D(SRI)	5.96	4.637	6.152	5.304

Table 17. : **Overall density and dominance status of natural enemies of lac insects in Odisha under different catagories**

Family	Order	Feeding habit	Impact with respect to Lac cultivation	Mean No. of parasite in 100 linear cm. of encrustation	Dominance Status	
					%	Category
Encyrtidae	-	-	-	24.08	40.81	ED
Eupelmidae	-	-	-	16.03	27.15	D
Braconidae	-	-	-	4.40	7.46	R
Ichneumonidae	-	-	-	0.21	0.35	SR
Noctuidae	-	-	-	6.02	10.20	SD
Blastobasidae	-	-	-	7.24	12.27	SD
Chrysopidae	-	-	-	1.04	1.76	R
TOTAL				59.02	**100.00**	
	Hymenoptera	-	-	44.72	75.77	SUPD
	Lepidoptera	-	-	13.26	22.47	D
	Neuroptera	-	-	1.04	1.76	R
TOTAL				59.02	**100.00**	
	-	Parasitic(TL-3)	-	4.61	7.81	R
	-	Parasitic	-	40.11	67.96	SUPD
	-	Predatory	-	14.30	24.23	D
TOTAL				59.02	**100.00**	
	-	-	Beneficial	4.61	7.81	R
	-	-	Detrimental	54.41	92.19	SUPD
TOTAL				59.02	100.00	

ED-Eudominant, D-Dominant, SD- Sub dominant, R-Recedent, SR –Sub recedent, SUPD- Super dominant



1. *Host plants* 2. *Lac insects* 3. *Primary feeders* 4. *Secondary feeders*

Fig. 22 : Tropic levels in Lac ecosystems.

Chapter – 5

SUMMARY AND CONCLUSION

Chapter - 5

Summary and Conclusion

LAC insects, *Kerria lacca* (Tachardiidae: Hemiptera) ,the crowning glory of India's rich insect fauna exploited for their products of commerce, viz. resin, dye and wax. Our country is the largest producer of lac in the world and at present, India produces approximately 20,000 metric tonnes of raw lac per annum.The lac ecosystem is a very rich ecosystem. Natural enemy, a part of the lac ecosystem comprised of 22 species of insect predators, 30 species of inimical parasitoids (Annexure-I); 33 species of parasitoids on lac predators which are beneficial (Annexure II) and 13 species as doubtful records (Vershney, 1976). However, due to lack of information on natural enemies complex of lac ecosystem of Odisha.The present work i.e., **"Studies on the lac insect, *Kerria lacca* (Kerr.) (Tachardiidae : Hemiptera) in Odisha with special reference to the natural enemies complex."** was undertaken during 2011-12 with the objectives to know the growth and development of lac insect on *Flemingia semialata* under Bhubaneswar agro- climatic conditions occurrence and relative abundance of different natural enemies in Bhubaneswar as well as other lac ecosystems of some selected lac growing tribal districts of Odisha and the lac ecosystem analysis thereof with special reference to faunal diversity in Odisha .The salient findings of the present investigation are summarized below.

1. The sequential developmental of lac insect *K.lacca* showing marked changes could be observed externally and the aghani crop of the *Kusumi*

strain could complete its life cycle in 158 - 163 days with a mean of 159.5±2.26 on *Flemingia semialata* in crop field under Bhubaneswar agro climatic conditions.

2. The first instar nymphs of *Kerria* were pinkish red in colour, oval in shape and settled firmly on host plant within 7 days of inoculation with density of 158 - 212 (Mean 173.4 ± 52.1) nymphs per cm^2 on *Flemingia* stem.

3. Emergence of parasitoids under field conditions at Bhubaneswar was noticed from fifth weeks of inoculation. Many cell showed holes indicating field parasitization of lac Insect.

4 During the course of investigation only three inimical parasitoides viz., *Tachardiaephagus tachardiae* (Howard), *Parechthrodryinus clavicornis* (Cameron) and *Eupelmus tachardiae* (Howard) belonging to Order Hymenoptera represented two families Encyrtidae and Eupelmidae were recorded. Encyrtidae constituted 63.3 per cent of the total parasitoids of which *Tachardiaephagus tachardiae* alone shared 53.3 per cent of the total natural enemies population.

5 In addition to the parasitoids mentioned above, three species of ants (one red and two black species) were found visiting frequently the lac insects for feeding on their honey dues excretion. Good number of pollinators including *Apis cerana indica* and *Trigona irridipenis* visited the host plant indicating the novel role of the plant in conservation of the pollinators.

6 Ten different species of natural enemies associated in lac ecosystems of Odisha .Out of these , three species were detrimental parasitoids of order hymenoptera represented by two families i.e., Encyrtidae and Eupelmidae; four were beneficial parasitoids of order hymenoptera represented by two families i.e., Braconidae and Ichneumonidae ; three were detrimental predators represented by two families i.e., Noctuidae and Blastobasidae of order Lepidoptera and a family Chrysopidae of Order Neuroptera.

7 *Tachardiaephagus tachardiae* (Howard), *Parechthrodryinus clavicornis* (Cameron) *Eupelmus tachardiae* (Howard) *Apanteles tachardiae* Cam among the parasitoids and *Eublemma amabilis* Moore and *Pseudohypatopa (=Holcocera) pulverea* Meyr among the predators were common natural enemies recorded from all the three ecosystems of Nabarangpur, Mayurbhanj and Boudh districts of Odisha.

8 *E. tachardiae* ,the inimical eupelmid parasitoid was most abundant and its number ranged between 11.07- 25.87/100 linear cm of brood lac maximum being in Mayurbhanj (28.87) followed by Nabarangpur (11.14) and Boudh(11.07).Likewise the number /100gms of lac ranged between 15.88-41.17 with same trend with respect to the locations.

9 The number of beneficial parasitoid attacking the lepidopterous predator of lac insect was relatively less. Out of four species (3 Braconids and 1 Ichneumonid) most common species was represented by the braconid, *Apanteles tachardiae*. The number of this parasitoid varied between 1.84 -

5.86/100 linear cm of brood lac, maximum being in Boudh district (5.86) followed by Nabarangpur (3.42) and Mayurbhanj (1.84). Similarly the number /100gms of lac encrustation ranged from 2.94-8.23 with same trend i.e. maximum being in Boudh (8.23) followed by Nabarangpur (4.93) and Mayurbhanj (2.94).

10 Computation and analysis of overall scenario of natural enemies complex of lac ecosystem of the indicated prevalence of 10 different species of natural enemies with wide diversity. The population density ranged from the level as low as 0.14 per 100 linear cm of the lac encrustation represented by the beneficial braconid A. *fakhrulhajiae* to as high as 16.03 per 100 linear cm of the lac encrustation in case of the eupelmid , *E.tachardiae*. Among the natural enemies *E.tachardiae* and *T.tachardiae* each individually sharing over ¼th of the population crowned the dominance status followed by the sub dominant status assumed by *P.clavicornis* and the two lepidopterous predators *E.amabilis* and *P.pulverea*.

11 The species diversity of natural enemies in lac eco system is measured with help of the indices like Simpson's index (D) and Simpson's index of diversity (SID) showed that Nabarangpur and Mayurbhanj with more number of species (9) were rich compared to Boudh (6) but, greater diversity was found in Boudh (SID-0.837).

12 Studies on the natural enemies component of the community structure (guild) alone indicated prevalence of 10 different insect species in lac ecosystem of Odisha. The community comprised of 7 different families

eudominated by encyrtidae and dominated by eupelmidae but the beneficial families were either recedent or sub recedent. Further, the guild was super dominated by hymenoptera, followed by lepidoptera and the neuropteran being of recedent status. From feeding habit point of view the primary parasitic species of lac insect showed super dominant status while the predators showed dominant status. The secondary feeders feeding on the predators of lac insect assumed the recedent status. The fauna detrimental to lac production assumed the super dominant status while the beneficial fauna occupied the recedent status

Conclusively, the winter aghani crop of kusumi strain of *Kerria lacca* (Tachardiidae:Hemiptera) can be successfully cultivated on *Flemingia semialata* under agro climatic condition of our state Odisha and lac cultivation has a lot of promise if *F. semialata* is taken as host plant. Further the lac ecosystem exhibited a wide diversity with regards to natural enemies fauna .In this ecosystem the primary parasitic species of lac insect showed super dominant status followed by the predators showing dominant status compared to recedent status displayed by the secondary feeders feeding on the predators of lac insect. As a whole, the fauna detrimental to lac production assumed the super dominant status and the beneficial fauna occupied the recedent status This clearly indicates that appropriate IPM strategies are inevitable for suppression of these harmful fauna in the lac ecosystem to realize the potential yield of the lac crop.

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Chapter – 6

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Chapter - 6

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Annexure -I

LIST OF PARASITES OF LAC INSECTS

REF.: Varshney (1976)

Sl. No	Insects	Order	Family	Reference
1.	*Aenasiella africa* Girault	Hymenoptera	(Nomen nudum)	Gowdey, 1917, p-187
2.	*Anicetus dodonia* Ferriere	Hymenoptera	Encyrtidae	Subha Rao, 1965, pp. 71-75.
3.	*Atropates hautefeuilli* (Mahdihassan)	Hymenoptera	Encyrtidae	Ferriore, 1935, pp 391, 400-401,. Thompson, 1944, pp 60-61.
4.	*Aphrastobracon flavipennis* Ashmead	Hymenoptera	Braconidae	Ayyar, 1927, P-73, Thompson, 1944, pp. 60-61.
5.	*Bracon sp.*	Hymenoptera	Braconidae	Miller, 1933, P. 12, Corbett & Miller, 1933, P-2, Thompson 1944,pp.60-61.
6.	*Bracon greeni* Ashmead	Hymenoptera	Braconidae	Varshney et al., 1967, P. 240.
7.	*Campyloneurus indicus* Ayyar	Hymenoptera	Braconidae	Ayyar & Margabandhu, 1934, pp. 430-446, Thompson-1944, pp. 60-61.
8.	*Cecidomyid sp.*	Diptera	Cecidomyiidae	Glover, 1937, P. 112
9.	*Coccophagus nigropleuron* Girault	Hymenoptera	Aphelinidae	Gowdey, 1917, P. 187
10.	*C. scutatus* Howard	Hymenoptera	Aphelinidae	Ferriere, 1928, pp., 171-176
11.	*C. tschirchi* Mahdihassan	Hymenoptera	Aphelinidae	Ferriere, 1928, pp. 173-174, 1935, p. 404; Majumdar et al., 1962, pp. 393-394.
12.	*Dentifibula lacciferi* Barnes	Diptera	Cecidomyiidae	Barmes, 1935, pp. 525-526, Miller, 1937; Glover, 1937, P. 112.
13.	*Erencyrtus dewitzi* (Mahdihassam)	Hymenoptera	Encyrtidae	Mahdihassan, 1924, P. 141, 1925, pp-64-65

14.	*Eupelmus tachardiae* (Howard)	Hymenoptera	Eupelmidae	Ferriere, 1935, pp. 391, 394-395. Takahashi, 1949,pp. 49-52.
15.	*Eurymyiocnema aphelinoides* Compere	Hymenoptera	Eupelmidae	Agarwal 1964, p. 334.
16.	*Holcopelte sp.*	Hymenoptera	Entedontidae	Howard & Ashmead, 1896, P-642, Cameron, 1913, p.1
17.	*Lyka lacca* Agarwal	Hymenoptera	Encyrtidae	Agarwal, 1962, pp. 278-281.
18.	*Marietta sp.*	Hymenoptera	Aphelinidae	Thompson, 1944, pp. 60-61
19.	*M. javensis* (Howard)	Hymenoptera	Aphelinidae	Glover, 1935, Ferriere, 1935, pp. 391, 404-405, Thompson, 1944,pp. 60-61. Narayanan, 1962, P. 101.
20.	*M. leopardina* Nietner	Hymenoptera	Aphelinidae	Green, 1922, P. 416, Ferriere, 1935, pp. 404-405
21.	*Parageniaspis indicus* Mashhood Alam	Hymenoptera	Encyrtidae	Mashhood Alam, 1963, p. 517, Sudha Mathur, 1969, p. 116.
22.	*Parechthrodryinus clavicornis* (Came.)	Hymenoptera	Encyrtidae	Cameron, 1913, pp. 11-12, Mahdihassan, 1925, p. 68
23.	*Protyndarichus submettalicus* M. Alam	Hymenoptera	Encyrtidae	Mashhood Alam, 1963, p. 517
24.	*Pteromalus sp.*	Hymenoptera	Pteromalidae	Thompson, 1944, pp. 60-61, Wadhi et al. 1972, p. 222.
25.	*Tachardiaephagus sp.*	Hymenoptera	Encyrtidae	Wadhi et al., 1972, p. 222
26.	*Tachardiaephagus tachardiae tachardiae* (Howard)	Hymenoptera	Encyrtidae	Ferriore, 1928, P. 171, 1935, pp. 391, 396. Thompson, 1944, pp. 60-61.
27.	*T. tachardiae somervillei* (Mahdihassan)	Hymenoptera	Encyrtidae	Mahdihassan, 1923, p. 71, 1925, p. 68, Glover, 1934, 1935; 1937, P. 101.
28.	*Tachardiobius nigricans* Timberlake	Hymenoptera	Encyrtidae	Timberlake, 1926, pp. 1-34.
29.	*Tetrastichus sp.*	Hymenoptera	Eulophidae	Mahdihassan, 1925, p.69
30.	*T. purpureus* (Cameron)	Hymenoptera	Eulophidae	Thompson, 1944, pp. 60-61.

Annexure -II

LIST OF PARASITES OF LAC PREDATORS

Sl. No	Insects	Order	Family	Parasitic host	Reference
1.	*Agathis bischoffi* Fabr.	Hymenoptera	Braconidae	*H. pulvurea*	Ferriere, 1935; Glover, 1937,p. 112
2.	*A. coryphe* Nixon	Hymenoptera	Braconidae	*H. pulvurea*	
3.	*A. festiva* Muesebeck	Hymenoptera	Braconidae	*H. pulvurea*	Gupta, 1964a, p. 220.
4.	*Anagyrus greeni* Howard	Hymenoptera	Encyrtidae	*Chrysopa madestes*	Mehra, 1965, P.406
5.	*Apanteles fakhrulhajiae* Mahd.	Hymenoptera	Braconidae	*H. pulvurea*	Mahdihassan, 1955, Pp. 99-103.
6.	*Apanteles tachardiae* Cam.	Hymenoptera	Braconidae	*H. pulvurea*	Mahdihassan, 1925, p.80. Wilkinson, 1932 P.337
7.	*Aphrastobracon flavipennis* Ashm.	Hymenoptera	Braconidae	*E. amabilis*	Mahdihassan, 1925, p.79, 1960, p.22
8.	*Brachycyrtus sp.*	Hymenoptera	Ichneumonidae	*Chrysopa madestes, C. lacciperda*	Mehra, 1965, p.406, 1966, P.217
9.	*B. eublemmae* (Rao)	Hymenoptera	Ichneumonidae	*Eublemma sp.*	Rao, 1952, P.177, Townes et al., 1961, P. 118
10.	*Brachymeria tachardiae* (Cam.)	Hymenoptera	Chalcididae	*H. pulverea*	Mahdihassan, 1925, P.80
11.	*Bracon greeni* Ashm	Hymenoptera	Braconidae	*E.amabilis*	Glover, 1937, P.108. Negi et al., 1945, P.37
12.	*B. hebetor* Say	Hymenoptera	Braconidae	*E.amabilis* *H. pulverea*	Glover & Chatterjee, 1936, P.195
13.	*B. tachardiae* Cam.	Hymenoptera	Braconidae	*E. amabilis*	Mahdihassan, 1923, P.69; 1925, PP.76-77
14.	*Brasema annulicaudis* Cam.	Hymenoptera	Eupelmidae	*E. amabilis*	Imms & Chatterjee, 1915; Mahdihassan, 1923, P.69; 1925, PP.64-88

15.	*Cedria paradoxa* Wlkn	Hymenoptera	Braconidae	*E. amabilis*	Glover, 1937, P. 109
16.	*Cheiloneurus sp.*	Hymenoptera	Encyrtidae	*Chrycopa madestes, C. lacciperda*	Mehra, 1965, P.406; 1966, P.217
17.	*Chelonus sp.*	Hymenoptera	Braconidae	*H. pulverea*	Glover, 1937, P.108
18.	*C. cyclopyrus* Franz	Hymenoptera	Braconidae	*H. pulverea*	Franz, 1930, P.47, Narayanan, 1962, P.106
19.	*Conostigmus sp.*	Hymenoptera	Ceraphronidae	*Chrysopa madestes*	Mehra, 1965, P-406
20.	*Elasmus albomaculatus* Gahan	Hymenoptera	Elasmidae	*H. pulverea*	Glover, 1937, P-108; 1940, P-245
21.	*E. claripennis* (Cam.)	Hymenoptera	Elasmidae	*E. amabilis*	Negi et al., 1945, P-37, Cameron, 1913, P-7
22.	*Elasmus colemani* Mahd	Hymenoptera	Elasmidae	*E. amabilis*	Mahdihassan, 1923, P-69
23.	*E. indicus* Rohwer	Hymenoptera	Elasmidae	*E. amabilis*	Rohwer, 1921 PP.123-135
24.	*Euplemus tachardiae* (Howard)	Hymenoptera	Eupelmidae	*E. amabilis* *H. Pulverea*	Mahdihassan, 1923; 1925, P.76, 1934a, P.260; 1935, P-562; 1938, P-117
25.	*Eurytoma pallidiscapus* Cam.	Hymenoptera	Eurytomidae	*H. Pulverea*	Mahdihassan, 1925, P.80; 1929, P-355
26.	*Perilampus sp.(Walk)*	Hymenoptera	Perilampidae	*Chrycopa lacciperda*	Mehra, 1966, P-217
27.	*Perisierola sp.*	Hymenoptera	Bethylidae	*H. Pulverea*	Glover, 1937, P.109
28.	*P. pulveriae* Kurian	Hymenoptera	Bethylidae	*H. Pulverea*	Narayanan, 1962, PP.106, 111
29.	*Pristomerus sulci* Mahd & Kolub	Hymenoptera	Ichneumonidae	*H. Pulverea*	Glover, 1937, P-108
30.	*Phaneratoma buchneri* Fabr.	Hymenoptera	Braconidae	*H. Pulverea*	Ferriere, 1935, Glover, 1937, P-112
31.	*Telenomus Sp.*	Hymenoptera	Scelionidae	*Chrysopa madestes* *C. lacciperda*	Mehra, 1965, P-406; 1966, P-217
32.	*Trichogramma Sp.*	Hymenoptera	Trichogrammatidae	*E.amabilis*	Mahdihassan, 1925, PP-64-88
33.	*Trichogrammtoidea nana* Zehnt	Hymenoptera	Trichogrammatidae	*E.amabilis*	Singh et al, 1938, P.189, Negi et al, 1945, P-37

Annexure -III

MONTHLY WEATHER RECORD FOR THE YEAR, 2011-12 OF BHUBANESWAR

Month and year	Rainfall (mm)	No. of rainy days	Relative humidity (%)		Temperature (°C)		Bright Sunshine hours
			Morning 7hr	Afternoon 14hr	Maximum	Minimum	
March' 11	1.8	1	89	42	35.3	21.9	7.9
April '11	28.2	7	87	45	36.4	23.9	7.1
May ' 11	142	9	89	55	37.3	26.1	7.7
June ' 11	180.3	18	90	65	35.1	25.5	3.5
July' 11	361.2	21	93	80	32.8	25.4	4.3
August' 11	419.5	24	95	83	32.4	25.4	2.8
September '11	290	17	95	80	31.4	24.8	3.5
October' 11	57	6	90	57	33.4	23.1	7.3
November' 11	0	0	89	40	32.3	18.1	7.7
December' 11	0	0	81	38	29	15.5	5.1
January'12	44	3	91	51	28.7	16.3	6.1
February'12	0	0	89	35	33.1	16.9	7.8
March' 12	0	0	94	35	37.4	22.8	6.6
April '12	85.9	5	88	52	38.2	25.1	7
May '12	12.2	2	88	49	39.3	27.2	7.8
June '12	117.2	11	88	60	37.6	26.8	2.9

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