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## Species composition and richness of entomo-fauna associated with lac insect, *Kerria lacca* Kerr in western plains of India

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**Abstract**

Objectives of the study were to find out the species of fauna associated with lac insect and to record their richness in western plains of India during 2015-2017. During the investigation 11 species of fauna associated with *Kerria lacca* Kerr. from 8 families under 3 were recorded representing predator species *E. amabilis*, *P. pulvereae*, *C. zastrowi*; primary parasitoids *T. tachardiae*, *A. purpureus*, *T. clavicornis*, *E. dewitzi* and hyperparasitoids *A. fakhrulhajiae*, *E. tachardiae*, *B. greeni*, *B. tachardiae*. Of these, 8 belong to Hymenoptera, 2 from Lepidoptera, and 1 from Neuroptera. Analysis of the data revealed that 27.27 per cent of the genera as well as species belonged to family Encyrtidae; 18.18 per cent to Braconidae and 9.09 per cent each to Eupelmidae, Chalcididae, Noctuidae, Blastobasidae, Chrysopidae, and Eulophidae. *E. dewitzi* recorded the most abundant parasitoid among all the associated fauna with average relative densities of 27.82, 39.91, 39.53, 32.89 per cent during different seasons (Oct 2015, July and Oct 2016 and July 2017, respectively) whereas in eastern India where lac cultivation is practiced *T. tachardiae* and *A. purpureus* are most harmful parasitoids of lac insect. *T. tachardiae* recorded more abundant during October than *A. purpureus* in July. Hyperparasitoid *E. tachardiae* found most prevalent in October whereas *A. fakhrulhajiae* during July.

**Keywords:** *Kerria lacca* Kerr, predators, primary parasitoids, hyperparasitoids, *Erencyrtus dewitzi*

**1. Introduction**

Lac, a natural resin, produced by tiny lac insects mainly *Kerria lacca* (Kerr) belonging to family Tachardiidae (Homoptera) <sup>[1-3]</sup>. Estimated sticklac production of India is around 21008 tons. About 70 per cent of the countries lac production is exported to different nations <sup>[1]</sup>. In India, the major lac producing states are Jharkhand, Chhattisgarh, Madhya Pradesh, Maharashtra and West Bengal, which contribute around 96 per cent of the total lac production <sup>[4]</sup>. Lac cultivation is an important source of income for livelihood of forest and sub-forest dwellers in different states; besides, it also generates employment for men and women in forest and subforest areas of different states. On an average around 28 per cent of total agriculture income of households of these states is contributed by lac cultivation <sup>[5]</sup>. Fast depleting forests are a serious threat to the biodiversity of lac insects. Many lac insects and associated fauna have become endangered where lac cultivation has been abandoned or its habitat destroyed. Promoting and encouraging lac culture not only check environmental degradation, but also conserve associated fauna and flora for posterity <sup>[6]</sup>.

*Rangeeni* and *kusmi* are the two strains of lac insect that are classified based on their life cycle and preference of the insect for specific host plants <sup>[7]</sup>. Lac insect ecosystem is a complex multi-trophic web of flora and fauna and representing a rich biodiversity which includes more than 22 lac predators, 30 primary parasites, 45 secondary parasites, a variety of pests of lac-hosts and several microbes <sup>[8]</sup>. Natural enemies *i.e.*, predators and parasitoids, have always been a major limiting factor in lac production. About 22 predators have been reported to be closely associated with the lac insect <sup>[1]</sup>. Among these, *Eublemma amabilis* Moore, *Pseudohypatopa pulvereae* Meyrick and *Chrysopa madestes* Banks are the major predators <sup>[6]</sup> and cause about 35-40 percent loss <sup>[9-10]</sup>. About 30 different species of parasites have been reported on lac insect <sup>[1]</sup>. Earlier studies indicated a parasitisation level of only 5-10 percent <sup>[11]</sup>, but with changing times and climatic scenario an increased parasitisation level of about 20-37 percent has been reported <sup>[12]</sup>, which have been noticed as one of the major limiting factors in complete failure of crop during last few years <sup>[6]</sup>. *Rangeeni* crop is more vulnerable to pest attack and damage is more in the rainy season crop and sometimes the whole crop is

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destroyed. During the year 2014-15, there was a decline of 41 per cent, 23 per cent and 6 per cent for *kusmi* summer season (*jethwi*), *rangeeni* summer season (*baisakhi*) and *raneegni* rainy season (*katki*) lac crops, respectively; with an overall decline of 19 per cent in comparison to lac production during 2013-14 [4].

In this study, we describe the different trophic status associated with *K. lacca* in western plains of India. More specifically, we recorded the species diversity and relative abundance of both predators and parasitoids *i.e.*, primary (inimical) parasitoids and secondary (beneficial) parasitoids of *K. lacca*.

## 2. Material and methods

Intensive surveys were carried out in states of western plain of India *i.e.*, Gujarat, Haryana and Rajasthan during the emergence period of lac insect *i.e.*, June - July and October-November of 2015 and 2017 under one of the co-operating centers (MPUAT, Udaipur) of Network Project on Conservation of Lac Insect Genetic Resources (funded by Indian Council of Agricultural Research, Govt of India), which is being implemented and executed by ICAR-Indian Institute of Natural Resins and Gums, Ranchi, Jharkhand. Lac insect samples collected from various parts of the region were caged for emergence of biotic fauna.

**2.1 Observation:** Samples of lac encrustation of one meter length were kept inside the 60-mesh nylon net bags and wet cotton swab (water) were put at both the ends of lac bearing twigs to maintain the turbidity of samples and for maintaining the lac insects. The mouth of net bags was tied and kept under room temperature for proper aeration. Fauna that emerged were collected and separated based on their identification under microscope. Species were confirmed from sample specimens sent to Prof Md Hayat, Eminent Taxonomist, Aligarh Muslim University, Aligarh (India) and Dr Shashank PR, Scientist, Indian Agricultural Research Institute, New Delhi (India).

**2.2 Analysis:** The following mathematical analyses were made for estimating the species richness and abundance:

### i. Mean density

$$\text{Mean density} = \frac{\sum Xi}{N}$$

Where,

$X_i$  = No. of insects or natural enemies in  $i^{\text{th}}$  sample

$N$  = Total No. of plants sampled (No of locations)

### ii. Relative density

$$\text{Relative density (RD \%)} = \frac{\text{Number of individual of one species}}{\text{Total number of individual of all species}} \times 100$$

### iii. Shannon-Weiner diversity index (H')

Shannon-Weiner diversity index ( $H'$ ) =  $-\sum p_i \ln p_i$ ; where,  $p_i$  = the decimal fraction of individuals belonging to  $i^{\text{th}}$  species.

## 3. Results

### 3.1 Fauna associated with lac insect, *Kerria* sp. during 2015 -- 2017

During the present investigation 11 species of associated

fauna (Table 1) including predators, primary parasitoids and hyper parasitoids were recorded on lac insect belonging to 8 families under 3 orders from the different locations surveyed. Of these, 8 belong to Hymenoptera, 2 from Lepidoptera, and 1 from Neuroptera. Analysis of the data revealed that 27.27 per cent of the genera as well as species belonged to family Encyrtidae; 18.18 per cent to Braconidae and 9.09 per cent each to Eupelmidae, Chalcididae, Noctuidae, Blastobasidae, Chrysopidae, and Eulophidae.

### 3.2 Numerical abundance of fauna associated with lac insect, *Kerria* sp. during 2015 - 2017.

Data collected on fauna associated with lac insect during October 2015 (Table 2) from 11 different locations were analyzed. It was observed that *E. amabilis* had the maximum mean density of 4.93 per cent among the predatory fauna. Among primary parasitoids of lac insect, *E. dewitzi* was the most abundant parasitoid with mean value of 27.82 per cent, followed by *T. tachardiae* (27.64 %). The hyperparasitoid *E. tachardiae* was most prevalent among all the hyperparasitoids with 3.32 per cent abundance. There was variation in the numerical abundance of different fauna at different locations. The Shannon Diversity Index obtained was 1.65 during October 2015 (Table 6).

Data pertaining to fauna associated with lac insect during July 2016 (Table 3) collected from 16 different locations were analyzed for the relative abundance of each insect population. Predator *E. amabilis* was the most abundant predator with mean density of 4.38 percent as compared to *P. pulvereae* (1.38 %) and *C. zastrowi* (0.09 %) among all associated fauna. Among all parasitoids of lac insect, *E. dewitzi* was the most prevalent parasitoid in terms of its numerical abundance with mean abundance of 39.91 per cent followed by *A. purpureus* (24.47 %). *A. fakhrulhajiae* was the most abundant hyperparasitoid in all hyperparasitoid with mean per cent value of 1.01 among all hyper-parasitoids. Thus, *E. dewitzi* was numerically the most abundant among all the associated fauna.

Data on fauna associated with lac insect during October 2016 (Table 4) recorded from 10 different locations was analyzed for each insect population individually for their relative density. Predator *E. amabilis* Moore was the most abundant predator as compared to *P. pulvereae* (0.91 %) with mean relative density of 2.96 percent among all associated fauna. Among all parasitoids of lac insect, *E. dewitzi* was the most prevalent parasitoid in terms of its numerical abundance among all the associated fauna with mean relative density of 39.53 per cent followed by *T. tachardiae* (34.08 %). *E. tachardiae* was the most abundant hyperparasitoid among the hyperparasitoids with mean per cent value of 2.17. The Shannon Diversity Index was 1.46 during the July 2016 and 1.42 during October 2016 (Table 6).

Relative numerical abundance of associated fauna recorded during July 2017 (Table 5) revealed that among all the predatory fauna associated with lac insect, *E. amabilis* was the most dominant with mean percent value of 6.90; whereas, population of *E. dewitzi* was maximum among all the parasitoids of lac insect and recorded mean numerical abundance of 32.89 percent as compared to all associated fauna. *A. fakhrulhajiae* (1.34) was recorded as the principal hyperparasitoid than *E. tachardiae* (1.34), *B. greeni* (0.00) and *B. tachardiae* (0.00) among all the associated fauna of lac insect. *E. dewitzi* represented the most prominent fauna among all the associated fauna. Shannon Diversity Index was 1.58 during the July 2017 (Table 6).

#### 4. Discussion

##### 4.1 Fauna associated with lac insect, *Kerria* sp. during 2015 – 2017

During the study 11 species of associated fauna *i.e.*, predators, primary parasitoids, hyperparasitoids under 8 different families of 3 orders from different places were recorded; of these, 8 belong to Hymenoptera, 2 to Lepidoptera, and 1 to Neuroptera. Results of the present study gets the complete support from earlier findings<sup>[13]</sup> which reported 14 species of parasitoids under 13 genera representing 10 families associated with *K. lacca*. The predator species under present study were represented by *Eublemma amabilis* Moore, *Pseudohypatopa pulverea* Meyrick, *Chrysopa zastrowi* (Esben-Petersen); Primary parasitoids of lac insect by *Tachardiaephagus tachardiae* Howard, *Aprostocetus purpureus* Cameron, *Tyndarichus (Parechthrodryinus) clavicornis* Mashhood alam, *Erencyrtus dewitzi* Mahdihassan; whereas, hyperparasitoid species were represented by *Apanteles fakhrulhajiae* Mahd, *Eupelmus tachardiae* Howard, *Bracon greeni* Ashmead, *Brachymeria tachardiae* Cameron. Findings of present study gets support from observation<sup>[14]</sup> which recorded *E. tachardiae*, *Parechthrodryinus* sp., *Tachardiaephagus* sp., *T. tachardiae*, *T. purpureus*, *Chrysopa* sp., *E. conspersa*, *E. roseonivea* and *Telsimia chujoi* as pests of lac insect from Taiwan. *Bracon greeni*, *B. hebetor*, *Aphrastobracon flavipennis*, *A. fakhrulhajiae* and *A. tachardiae* recorded as parasitoids of predator (*P. pulverea*) of *K. lacca*<sup>[15]</sup>. Two species of predators *viz.*, *E. amabilis* and *P. pulverea*, five primary parasitoids *i.e.*, *A. purpureus*, *E. dewitzi*, *P. clavicornis*, *T. tachardiae* and *T. somervilli* and two hyperparasitoids, *viz.*, *B. greeni* and *Pristomerus sulci* on *Kerria* sp. reported during surveying periods from the areas of Assam, Jharkhand, Karnataka and Tamil Nadu<sup>[16]</sup>. Further analysis of data from present study revealed that highest number of genera as well as species belong to family Encyrtidae, followed by Braconidae, Eupelmidae, Chalcididae, Noctuidae, Blastobasidae, Chrysopidae, and Eulophidae in descending order.

Results of the present findings are in complete agreement with the findings<sup>[17]</sup> who mentioned *E. amabilis* and *P. pulverea* as key pests causing 30 to 40 per cent loss to lac crop. 30 different parasitoids and 22 predators found closely associated with lac insect<sup>[1]</sup>. *E. amabilis*, *P. pulverea* and *Chrysopa* sp. are major predators, causing an average of 35-40 % damage<sup>[9]</sup>. More than 22 predators, 30 primary parasitoids, 45 secondary parasitoids reported in complex lac ecosystem<sup>[8]</sup>.

##### 4.2 Numerical abundance of fauna associated with lac insect, *Kerria* sp. during 2015 – 2017

Numerical abundance of fauna associated with lac insect collected during October 2015, July/October 2016 and July 2017 were analysed in which *E. dewitzi* outnumbered all fauna associated with lac insect and emerged as the most abundant parasitoid among all the inimical and beneficial fauna of this region.

Fauna associated with lac insect recorded were analyzed for each insect population individually for their relative density. Predator *E. amabilis* Moore was the most abundant predator as compared to *P. pulverea* and *C. zastrowi* among all the predators. *E. amabilis* got reported as a monophagous predator of lac insect, causing 20 - 25 per cent damage<sup>[11]</sup>. Among primary parasitoids of lac insect during 2015- 2017, *E. dewitzi* was the most abundant parasitoid among all parasitoids during all the seasons of both the years. Whereas, parasitoid *T. tachardiae* was recorded as the most abundant during the October month of 2015 and 2016; however, during July of 2016 and 2017, parasitoid *A. purpureus* was recorded as the most abundant parasitoid. This indicated *E. dewitzi* as most abundant parasitoid of lac crop, whereas *T. tachardiae* and *A. purpureus* during the winter season and summer season lac crop, respectively. The present findings gets support partly from the past studies where *A. purpureus* and *T. tachardiae* found most abundant constituting 55.82 per cent and 28.37 per cent, respectively of the total population of parasitoids<sup>[13]</sup>. However, this difference may be attributed due to different agro climatic conditions. Per cent parasitization of 18.40 was reported in the *kusmi* strain and 26.0 per cent in the *rangeeni* strain particularly during the rainy season, where *A. purpureus* alone caused 7.8 and 11.8 per cent parasitization, respectively<sup>[18]</sup>. Predators, primary parasitoids and hyperparasitoids constituted 68.0, 29.60 and 2.40 per cent of total associated fauna population, respectively<sup>[16]</sup>. Among predators, *E. amabilis* was the dominant species, while *A. purpureus* (63.70 %) and *T. tachardiae* (29.0 %) formed the bulk of primary parasitoid population. However, this difference may be attributed due to difference in agro climatic conditions. Among beneficial parasitoids of lac insect *E. tachardiae* was recorded as principal hyperparasitoid during October of 2015 and 2016; whereas *A. fakhrulhajiae* was the most prevalent during July 2016 and 2017 among all the hyperparasitoids. Present findings are in complete agreement with the observations of earlier studies where *A. tachardiae* and *A. fakhrulhajiae* found most abundant in Madhya Pradesh<sup>[19-20]</sup>.

Relative/ seasonal abundance of parasitoids associated with lac insect was studied by various workers<sup>[21, 12, 22, 13]</sup>. Average parasitization of 4.8-9.9 per cent was reported<sup>[11]</sup>; reinterpreted<sup>[12]</sup> and revealed mean parasitization of 20-37 per cent. 32.18 per cent and 28.13 per cent parasitization recorded for *rangeeni* and *kusmi* strain, respectively which was indicative of more percent parasitism of rainy season *rangeeni* crop as compared to *kusmi* crop<sup>[23]</sup>. Findings of the above workers support the present findings however *E. dewitzi* was reported as major parasitoid in this region as compared to *A. purpureus* and *T. tachardiae* in other lac growing regions.

However, there was variation in numerical abundance of different fauna at different locations. The Shannon Diversity Index recorded was 1.65 during October 2015. It was higher during the July as compared to October 2016; whereas, it was recorded 1.58 during the July 2017.

**Table 1:** Analysis of fauna associated with lac insect, *Kerria sp.* collected from the western plains of India during 2015 -- 2017.

S. No.	Trophic level status	Fauna	Order	Family	Total fauna	
					Genera	Species
1	Predators	<i>Eublemma amabilis</i> Moore	Lepidoptera	Noctuidae	1 (9.09)	1 (9.09)
		<i>Pseudohypatopa pulverea</i> Meyr		Blastobasidae	1 (9.09)	1 (9.09)
		<i>Chrysopa zastrowi</i> (Esben-Petersen)	Neuroptera	Chrysopidae	1 (9.09)	1 (9.09)
2	Primary parasitoids	<i>Aprostocetus purpureus</i> Cameron	Hymenoptera	Eulophidae	1 (9.09)	1 (9.09)
		<i>Tachardiaephagus tachardiae</i> Howard		Encyrtidae	3 (27.27)	3 (27.27)
		<i>Tyndarichus clavicornis</i> Mashhood alam				
		<i>Erencyrtus dewitzi</i> Mahdihassan				
3	Hyperparasitoids	<i>Apanteles fakhruhajiae</i> Mahd	Hymenoptera	Braconidae	2 (18.18)	2 (18.18)
		<i>Bracon greeni</i> Ashmead				
		<i>Eupelmus tachardiae</i> Howard		Eupelmidae	1 (9.09)	1 (9.09)
		<i>Brachymeria tachardiae</i> Cam		Chalcididae	1 (9.09)	1 (9.09)
Total			3	8	11	11

Figures in parentheses represent the percent equivalent.

**Table 2:** Numerical abundance of fauna associated with lac insect, *Kerria sp.* in western plains of India during October 2015.

Entomophagy status	Trophic level Status									Total
	Predators (mean /m lac stick)		Primary parasitoids (mean /m lac stick)				Hyperparasitoids (mean /m lac stick)			
Location	E a	P p	T t	A p	T c	E d	A f	E t	B g	
Silani chowk, Jhajjar	4.0 (3.06)	2.0 (1.53)	60.67 (46.43)	30.7 (23.47)	4.7 (3.57)	20.0 (15.31)	3.3 (2.55)	4.0 (3.06)	1.33 (1.02)	131
Dist lib Bhiwani	1.3 (0.88)	3.3 (2.19)	28.0 (18.42)	66.7 (30.70)	5.3 (3.51)	44.7 (29.39)	9.3 (6.14)	12.0 (7.89)	1.33 (0.88)	152
Rohdai mode Rewari	8.0 (3.59)	3.3 (1.50)	33.3 (14.97)	62.0 (27.84)	14.7 (6.59)	82.7 (37.13)	6.7 (2.99)	10.0 (4.49)	2.00 (0.90)	223
Dalanwas Matanhil Jhajjar	22.0 (17.28)	0.7 (0.52)	16.7 (13.09)	20.7 (16.23)	4.7 (3.66)	56.7 (44.50)	4.7 (3.66)	1.3 (1.05)	0.00 (0.00)	127
Govindgarh Jaipur	14.7 (10.05)	0.0 (0.00)	15.3 (10.50)	44.7 (30.59)	9.3 (6.39)	55.3 (37.90)	2.7 (1.83)	2.7 (1.83)	1.33 (0.91)	146
Rupamchauk Bhavnagar	4.7 (3.93)	3.3 (2.81)	62.00 (52.25)	10.0 (8.43)	3.3 (2.81)	26.0 (21.91)	5.3 (4.49)	3.3 (2.81)	0.67 (0.56)	119
Andharia farm Bhavnagar	0.0 (0.00)	2.0 (1.60)	52.0 (41.49)	26.7 (21.28)	2.7 (2.13)	28.7 (22.87)	7.3 (5.85)	6.0 (4.79)	0.00 (0.00)	125
Vasna chauk Ahmedabad	8.7 (8.07)	0.0 (0.00)	14.7 (13.66)	34.0 (31.68)	3.3 (3.11)	42.7 (39.75)	1.3 (1.24)	2.0 (1.86)	0.67 (0.62)	107
St Kanwar ram Chowk, Bhavnagar	4.7 (2.72)	2.0 (1.17)	61.3 (35.80)	52.0 (30.35)	4.0 (2.33)	37.3 (21.79)	6.0 (3.50)	4.0 (2.33)	0.00 (0.00)	171
Gir forest Junagarh	0.0 (0.00)	3.3 (2.14)	56.0 (35.90)	61.3 (39.32)	1.3 (0.85)	26.7 (17.09)	1.3 (0.85)	4.0 (2.56)	2.00 (1.28)	156
Surendranagar chaukri Rajkot	7.3 (10.58)	2.0 (2.88)	22.0 (31.73)	30.7 (44.23)	0.0 (0.00)	4.0 (5.77)	2.0 (2.88)	1.3 (1.92)	0.00 (0.00)	69
Total	75.3 (4.93)	22.0 (1.44)	422.0 (27.64)	419.3 (27.47)	53.3 (3.49)	424.7 (27.82)	50.0 (3.28)	50.7 (3.32)	9.3 (0.61)	1527

Figures in the parentheses represent Relative Density (%) of total associated fauna

Abv Ea: *Eublemma amabilis* Pp: *Pseudohypatopa pulverea* Tt: *Tachardiaephagus tachardiae* Ap: *Aprostocetus purpureus*  
Tc: *Tyndarichus clavicornis* Ed: *Erencyrtus dewitzi* Af: *Apanteles fakhruhajiae* Et: *Eupelmus tachardiae* Bg: *Bracon greeni*

**Table 3:** Numerical abundance of fauna associated with lac insect, *Kerria* sp. in western plains of India during July 2016.

Entomophagy status	Trophic level states										Total
	Predators (mean /m lac stick)			Primary parasitoids (mean /m lac stick)				Hyperparasitoids (mean /m lac stick)			
Location	E a	P p	Ch	T t	A p	T c	E d	A f	E t	B g	
Koderla, Sirohi	8.0 (10.00)	0.0 (0.00)	-	16.7 (20.83)	16.7 (20.83)	4.0 (5.00)	32.7 (40.83)	1.3 (1.67)	0.0 (0.00)	0.7 (0.83)	80.0
Sachin chaukri, Surat	1.3 (1.49)	0.0 (0.00)	-	27.3 (30.60)	18.0 (20.15)	2.7 (2.99)	39.3 (44.03)	0.7 (0.75)	0.0 (0.00)	0.0 (0.00)	89.3
Highway to Barauda entry	1.3 (1.61)	0.0 (0.00)	-	20.7 (25.00)	21.3 (25.81)	1.3 (1.61)	36.0 (43.55)	0.7 (0.81)	0.7 (0.81)	0.7 (0.81)	82.7
Diamond furniture, Umreth Anand	4.0 (6.00)	6.0 (9.00)	-	14.7 (22.00)	12.0 (18.00)	4.0 (6.00)	26.0 (39.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	66.7
Tapi hotel, Barauda	20.0 (19.61)	0.0 (0.00)	-	16.0 (15.69)	33.3 (32.68)	3.3 (3.27)	28.0 (27.45)	0.7 (0.65)	0.7 (0.65)	0.0 (0.00)	102.0
Aarogya thana, Modasa	2.7 (3.15)	0.7 (0.79)	-	29.3 (34.65)	26.7 (31.50)	1.3 (1.57)	22.7 (26.77)	0.7 (0.79)	0.0 (0.00)	0.7 (0.79)	84.7
Baisthan circle, Surat	4.7 (6.67)	0.0 (0.00)	-	21.3 (30.48)	18.0 (25.71)	3.3 (4.76)	22.0 (31.43)	0.7 (0.95)	0.0 (0.00)	0.0 (0.00)	70.0
Ayad puliya,Udaipur	0.7 (0.86)	0.0 (0.00)	1.33 (1.72)	15.3 (19.83)	18.7 (24.14)	4.0 (5.17)	37.3 (48.28)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	77.3
Naraul chaukri, Ahmedabad	4.7 (6.14)	3.3 (4.39)	-	18.7 (24.56)	20.0 (26.32)	2.0 (2.63)	27.3 (35.96)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	76.0
Dist Library,Bhiwani	2.0 (2.38)	0.0 (0.00)	-	19.3 (23.02)	17.3 (20.63)	3.3 (3.97)	39.3 (46.83)	2.7 (3.17)	0.0 (0.00)	0.0 (0.00)	84.0
Vidhya nagar, Anand	1.3 (2.33)	4.0 (6.98)	-	17.3 (30.23)	8.0 (13.95)	2.0 (3.49)	24.7 (43.02)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	57.3
HAU, Hiiar	0.7 (0.51)	0.0 (0.00)	-	24.7 (18.97)	35.3 (27.18)	5.3 (4.10)	60.0 (46.15)	3.3 (2.56)	0.7 (0.51)	0.0 (0.00)	130.0
Police line, Sirohi	4.7 (5.69)	2.7 (3.25)	-	15.3 (18.70)	20.0 (24.39)	3.3 (4.07)	35.3 (43.09)	0.0 (0.00)	0.7 (0.81)	0.0 (0.00)	82.0
Bijolia, Bhilwara	2.0 (1.24)	0.7 (0.41)	-	41.3 (25.62)	35.3 (21.90)	8.7 (5.37)	69.3 (42.98)	3.3 (2.07)	0.0 (0.00)	0.7 (0.41)	161.3
Bus stand, Chittorgarh	4.0 (2.65)	1.3 (0.88)	-	40.0 (26.55)	40.7 (26.99)	6.0 (3.98)	58.0 (38.50)	0.0 (0.00)	0.7 (0.44)	0.0 (0.00)	150.7
Nathdwara, Rajasamand	1.3 (2.53)	1.3 (2.53)	-	14.0 (26.58)	12.7 (24.05)	1.3 (2.53)	19.3 (36.71)	0.7 (1.27)	0.7 (1.27)	1.3 (2.53)	52.7
Total	63.3 (4.38)	20.0 (1.38)	(1.33) (0.09)	352.0 (24.33)	354.0 (24.47)	56.0 (3.87)	577.3 (39.91)	14.7 (1.01)	4.0 (0.28)	4.0 (0.28)	1446.7

Figures in the parentheses represent Relative Density (%) of total population.

Abv Ea: *Eublemma amabilis* Pp: *Pseudohypatopa pulvereae* Ch: *Chrysopa* Tt: *Tachardiaephagus tachardiae* Ap: *Aprostocetus purpureus*  
Tc: *Tyndarichus clavicornis* Ed: *Encyrtus dewitzi* Af: *Apanteles fakhruhajiae* Et: *Eupelmus tachardiae* Bg: *Bracon greeni*

**Table 4:** Numerical abundance of fauna associated with lac insect, *Kerria* sp. in western plains of India during October 2016.

Entomophagy status	Trophic level states										Total
	Predators (mean /m lac stick)			Primary parasitoids (mean /m lac stick)				Hyperparasitoids (mean /m lac stick)			
Location	E a	P p	T t	A p	T c	E d	A f	E t	B g	B t	
Kalander chowk, Karnal	0.0 (0.00)	0.0 (0.00)	28.7 (41.75)	13.3 (19.42)	4.0 (5.83)	22.0 (32.04)	0.0 (0.00)	0.0 (0.00)	0.7 (0.97)	0.0 (0.00)	68.7
KEM college Narwana, Jind	2.7 (2.67)	8.0 (8.00)	40.0 (40.00)	10.0 (10.00)	2.7 (2.67)	28.0 (28.00)	0.7 (0.67)	4.7 (4.67)	1.3 (1.33)	2.0 (2.00)	100.0
Sir suganram Mahendragar	4.7 (1.05)	0.0 (0.00)	96.7 (21.77)	62.0 (13.96)	12.7 (2.85)	241.3 (54.35)	0.0 (0.00)	26.7 (6.01)	0.0 (0.00)	0.0 (0.00)	444.0
Bagawas Jaipur	13.3 (8.03)	0.0 (0.00)	78.7 (47.39)	3.3 (2.01)	0.7 (0.40)	65.3 (39.36)	1.3 (0.80)	0.0 (0.00)	3.3 (2.01)	0.0 (0.00)	166.0
Daulatpura Jaipur	0.7 (0.34)	0.0 (0.00)	46.7 (23.65)	60.0 (30.41)	10.7 (5.41)	79.3 (40.20)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	0.0 (0.00)	197.3
HAU, Hisar	0.7 (0.77)	2.7 (3.08)	31.3 (36.15)	13.3 (15.38)	2.7 (3.08)	24.7 (28.46)	8.0 (9.23)	1.3 (1.54)	0.0 (0.00)	2.0 (2.31)	86.7
Kitlana Bhiwani	16.7 (8.28)	0.0 (0.00)	86.7 (43.05)	13.3 (6.62)	2.7 (1.32)	70.7 (35.10)	6.0 (2.98)	0.7 (0.33)	4.7 (2.32)	0.0 (0.00)	201.3
Salani Chowk Jhajjar	5.3 (2.56)	4.0 (1.92)	85.3 (40.89)	28.7 (13.74)	6.0 (2.88)	69.3 (33.23)	4.0 (1.92)	2.0 (0.96)	4.0 (1.92)	0.0 (0.00)	208.7
Premnagar Ambala	5.3 (3.21)	0.7 (0.40)	58.7 (35.34)	39.3 (23.69)	6.0 (3.61)	48.0 (28.92)	6.7 (4.02)	0.0 (0.00)	1.3 (0.80)	0.0 (0.00)	166.0
Harmada Jaipur	0.7 (1.30)	0.0 (0.00)	23.3 (45.45)	3.3 (6.49)	0.7 (1.30)	19.3 (37.66)	1.3 (2.60)	1.3 (2.60)	1.3 (2.60)	0.0 (0.00)	51.3
Total	50.0 (2.96)	15.3 (0.91)	576.0 (34.08)	246.7 (14.60)	48.7 (2.88)	668.0 (39.53)	28.0 (1.66)	36.7 (2.17)	16.7 (0.99)	4.0 (0.24)	1690.0

Figures in the parentheses represent Relative Density (%) of total population.

Abv Ea: *Eublemma amabilis* Pp: *Pseudohypatopa pulvereae* Ch: *Chrysopa* Tt: *Tachardiaephagus tachardiae* Ap: *Aprostocetus purpureus*  
Tc: *Tyndarichus clavicornis* Ed: *Encyrtus dewitzi* Af: *Apanteles fakhruhajiae* Et: *Eupelmus tachardiae* Bg: *Bracon greeni* Bt: *Brachymeria tachardiae*

**Table 5:** Numerical abundance of fauna associated with lac insect, *Kerria* sp. in western plains of India during July 2017.

Entomophagy status	Trophic level states								Total
	Predators (mean /m lac stick)		Primary parasitoids (mean /m lac stick)			Hyperparasitoids (mean /m lac stick)			
Location	E a	P p	T t	A p	T c	E d	A f	E t	
Highway to Barauda entry	5.33 (9.09)	2.67 (4.55)	14.00 (23.86)	17.33 (29.55)	4.00 (6.82)	13.33 (22.73)	0.67 (1.14)	1.33 (2.27)	58.7
Diamond furniture Umreth	5.33 (6.30)	2.00 (2.36)	16.67 (19.69)	22.67 (26.77)	4.00 (4.72)	31.33 (37.01)	2.00 (2.36)	0.67 (0.79)	84.7
Udaipur	5.33 (5.63)	1.33 (1.41)	17.33 (18.31)	27.33 (28.87)	2.67 (2.82)	39.33 (41.55)	0.67 (0.70)	0.67 (0.70)	94.7
Bhiwani	7.33 (8.33)	4.67 (5.30)	14.67 (16.67)	21.33 (24.24)	4.67 (5.30)	34.00 (38.64)	0.67 (0.76)	0.67 (0.76)	88.0
Hiiar	11.33 (10.97)	6.00 (5.81)	22.00 (21.29)	22.00 (21.29)	6.67 (6.45)	34.00 (32.90)	1.33 (1.29)	0.00 (0.00)	103.3
Sirohi	4.67 (4.32)	2.67 (2.47)	22.00 (20.37)	34.00 (31.48)	6.00 (5.56)	34.67 (32.10)	2.67 (2.47)	1.33 (1.23)	108.0
Bijolia, Bhilwara	6.00 (6.72)	2.00 (2.24)	24.00 (26.87)	30.67 (34.33)	4.67 (5.22)	20.00 (22.39)	2.00 (2.24)	0.00 (0.00)	89.3
Chittorgarh	6.00 (5.11)	1.33 (1.14)	27.33 (23.30)	34.67 (29.55)	8.00 (6.82)	38.00 (32.39)	0.00 (0.00)	2.00 (1.70)	117.3
Total	51.3 (6.90)	22.7 (3.05)	158.0 (21.24)	210.0 (28.23)	40.7 (5.47)	244.7 (32.89)	10.0 (1.34)	6.7 (0.90)	744.0

Figures in the parentheses represent Relative Density (%) of total population

Abv Ea: *Eublemma amabilis* Pp: *Pseudohypatopa pulvereae* Tt: *Tachardiaephagus tachardiae* Ap: *Aprostocetus purpureus*  
Pc: *Tyndarichus clavicornis* Ed: *Erencyrtus dewitzi* Af: *Apanteles fakhrulhajiae* Et: *Eupelmus tachardiae*

**Table 6:** Relative abundance of fauna associated with lac insect, *Kerria* sp. during 2015 - 17.

Fauna Associated	Oct-15			July-16			Oct-16			July-17		
	SM	MD	RD (%)	SM	MD	RD (%)	SM	MD	RD (%)	SM	MD	RD (%)
<i>Eublemma amabilis</i>	10.76	1.54	4.93	9.05	1.29	4.38	7.24	1.03	3.11	7.33	1.05	6.90
<i>Pseudohypatopa pulvereae</i>	3.14	0.45	1.44	2.86	0.41	1.38	2.29	0.33	0.98	3.24	0.46	3.05
<i>Chrysopa zastrowi</i>	0.00	0.00	0.00	0.19	0.03	0.09	0.00	0.00	0.00	0.00	0.00	0.00
<i>Tachardiaephagus tachardiae</i>	60.29	8.61	27.64	50.29	7.18	24.33	82.29	11.76	35.39	22.57	3.22	21.24
<i>Aprostocetus pupureus</i>	59.90	8.56	27.47	50.57	7.22	24.47	28.48	4.07	12.25	30.00	4.29	28.22
<i>Tyndarichus clavicornis</i>	7.62	1.09	3.49	8.00	1.14	3.87	6.95	0.99	2.99	5.81	0.83	5.47
<i>Erencyrtus dewitzi</i>	60.67	8.67	27.82	82.48	11.78	39.91	95.43	13.63	41.05	34.95	4.99	32.88
<i>Apanteles fakhrulhajiae</i>	7.14	1.02	3.28	2.10	0.30	1.01	4.00	0.57	1.72	1.43	0.20	1.34
<i>Eupelmus tachardiae</i>	7.24	1.03	3.32	0.57	0.08	0.28	5.24	0.75	2.25	0.95	0.14	0.90
<i>Bracon greeni</i>	1.33	0.19	0.61	0.57	0.08	0.28	0.00	0.00	0.00	0.00	0.00	0.00
<i>Brachymeria tachardiae</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.08	0.25	0.00	0.00	0.00
Shannon Index (H')	1.65			1.46			1.42			1.61		

Legend: SM: Seasonal Mean; MD: Mean Density; RD: Relative Density;

## 5. Conclusion

Fauna associated with lac insect were predators *E. amabilis*, *P. pulvereae*, *C. zastrowi*; primary parasitoids *T. tachardiae*, *A. purpureus*, *T. clavicornis*, *E. dewitzi* and hyperparasitoids *A. fakhrulhajiae*, *E. tachardiae*, *B. greeni*, *B. tachardiae*. *E. amabilis* had maximum density among all predators; *E. dewitzi* is the most abundant parasitoid in western part of India whereas in eastern part of India where lac cultivation is practiced *T. tachardiae* and *A. purpureus* are most harmful parasitoids of lac insect. *T. tachardiae* is more abundant during October than *A. purpureus* in July. Hyperparasitoid *E. tachardiae* is most prevalent in October whereas *A. fakhrulhajiae* during July.

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