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Tri-tropic interactions of lac, *Kerria lacca* (Kerr.), its host and associated natural enemies in arid western plains of India

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Abstract
The location specific studies was carried out in arid western plain agro ecological region covering the states of Haryana, Rajasthan, Gujarat and Dadar and Nagar Haveli during lac crop season of 2019 and 2020. The studies on lac insect associated fauna revealed that 11 species of predators, primary parasitoids and hyperparasitoids under 8 families of 3 orders; of these, 8 species belonged to Hymenopetra, 2 to Lepidoptera and 1 to Neuroptera were recoeded to infest the natural populations of lac insect. The predators recorded were *Eublemma amabilis*, *Pseudohypatopa pulverea* and *Chrysopa zastrowi*; primary parasitoids were *Tachardiaephagus tachardiae*, *Aprostocetus purpureus*, *Tyndarichus clavicornis*, *Erencyrtus dewitzii* and Hyperparasitoids were *Apanteles fakhrulhajiae*, *Eupelmus tachardiae*, *Bracon greeni* and *Brachymeria tachardiae*.

Keywords: Lac insect, Shannon diversity (H'), predators, primary parasitoids and hyperparasitoids

Introduction
Lac is a natural resin known since Vedic period for its use in India with many earlier references in Atherva Veda and Mahabharata. The lac is produced by tiny soft-bodied insect *Kerria lacca* (Kerr.) belonging to Coccid group of order Homoptera. Our country is one of the largest producers of lac in the world accounting about 60% of total production. The lac insect resources available throughout the country are on edge of disappearance due to lack of knowledge and awareness about this tiny insect. Moreover the change in agricultural patterns and environmental conditions are also favoring its extinction. The lac cultivation is not in wide practice in the region in spite of its abundant presence in nature all over the region. Hence in view of abundant availability of naturally grown lac host plants in forest and personal holding of the farmers, raising of lac insects or lac cultivation has great scope in the region. In the states of western arid plains, the forests comprise many lac host trees mainly of Ber (*Zizyphus sp*.), Palas (*Butea monosperma*), *Ficus sp.*, Kusum, *Acasia sp.*, *Shorea sp*., *Dalbergia sp.*, *Albizzia sp*. and bushy host plants like, *Grewia sp.* and *Cajanus cajan* L. The lac insects are naturally found in abundance on these vegetation both in forests and farm vicinities as well as in urban areas.

The life cycle of lac insect starts with the crawlers, after settlement the nymphs undergo three successive moults to become an adult. The first instar is mobile and crawls over the tender shoot of host trees and settles to feed on phloem sap by piercing its proboscis into phloem region of shoot. To avoid covering of these holes by resin, the lac insect secretes wax, which is white thread-like structure. The duration of each stage depends on the host plant species on which it feeds, lac crop and prevailing environmental conditions (Mohanta *et al.*, 2014) [5]. The lac ecosystem fauna includes 87 species of lac insect belonging to nine genera recorded from all over the world. Though different lac hosts have been recorded in Rajasthan, but it is not cultivated commercially. In Rajasthan lac insect naturally found in abundance on various hosts (Swami *et al.* 2017 and Swami *et al.* 2018) [14, 15].

Two species of lac insect namely *Rangeeni* and *Kusumi* are known to prevail dominantly in our country. *Aghani* crop of *Kusumi* contribute the most with the contribution of 32 % followed by *Jethwi* (26 %) of *Kusumi* strain and *Baisakhi* (24 %) and *Katki* (18 %) of *Rangeeni* strain in total lac production. This is the crop with high economic returns to farmers and also has a high value for foreign exchange through its export. However, after having the wide distribution of the lac insect through the country on diverse hosts, lac production is

limited because of environmental factors *viz*., biotic (predators and parasitoids) and abiotic (adverse climatic factors), causing hindrance in lac production. *Eublemma amabilis* Moore (Noctuidae; Lepidoptera), *Psuedohypatopa pulverea* Meyr (Blastobesidae; Lepidoptera), *Chrysopa lacciperda* Kimmins and *Chrysopa madestes* Banks (Chrysopidae; Neuroptera) are the major predators of regular occurrence causing severe losses to lac production (Sharma *et al*., 2006 and Kalahal *et al*., 2018) [11, 3]. Losses in lac production because of predators have been estimated around 35 to 40 per cent (Glover, 1937; Jaiswal *et al*, 2008) [1, 2] and 5 to 10 per cent by parasitoids (Varshney. 1976) [16] and these are more or less regular in occurrence but their frequency may vary from season to season, place to place and crop to crop. I, II and III instar larvae of *Chrysopa madestes* can consume 20, 24 and 74 mature females of lac insect per day, respectively (Mehra, 1965). Earlier the parasitisation level of only 5-10 per cent (Narayanan 1962) [6], but with changing climatic scenario this level is increased up to 20-37 per cent (Srivastava and Chauhan, 1984) [13], which have been noticed as one of the major restricting factor in the production of lac. *Rangeeni* crop is more vulnerable to pest attack and the damage is more in the rainy season crop which occasionally destroy whole crop.

Materials and Methods

The studies on the occurrence lac host and their associated natural enemies were carried out by conducting a detailed survey in arid western plain agro ecological region covering the states of Haryana, Rajasthan, Gujarat and Dadar and Nagar Haveli which are of significant importance as these states are habitat of various host trees on which the lac insects thrive naturally during lac crop season of 2019 and 2020. The various natural hosts were surveyed for the occurrence of lac insect and the prevailing population of lac insect on these hosts. The random samples of different host bearing natural lac populations were collected from different locations of each of the seven districts. The lac bearing twigs of 10 cm length were collected from various locations of the region and these samples were kept in 60-mesh nylon net bags for the emergence of natural enemies. The wet cotton swab was tied on both ends of twigs in Lac Laboratory to maintain the turbidity of samples and for maintaining the lac insects. The mouth of these bags were tied and kept under room temperature for the emergence of natural enemies from the samples. The nylon bags containing samples of different locations of seven districts were kept separately, district wise and were observed at regular intervals for the emergence of natural enemies. The observation on the population of natural enemies both predators and parasitoid were recorded from the initiation and upto completion of emergence.

Observations

The observations on the emergence of natural enemies both predator and parasitoids were recorded from each samples at an regular interval starting from the initiation of emergence of natural enemies up to six weeks till their number declined. The emerged population of predators and parasitoids were separated and counted. The emerged natural enemies were identified with the help of "Lac insect and associated fauna: A practical Manual" by Mohanasundaram *et al*., 2016 [4] and proper record of natural enemies population was maintained. The emerging natural enemies population were also segregated based on their morphological characters and were identified up to their order and family.

The following mathematical analyses were adopted for estimating the species richness and abundance:

i. Mean density

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

Where,

Xi = *No*. of insects or natural enemies in i^{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 pi*;

where, p*i* = the decimal fraction of individuals belonging to i^{th} species.

Results and Discussion

A two years survey conducted on bio-diversity of lac insect, *Kerria lacca* (Kerr) and associated fauna in arid western plain agro ecological region of India. The survey record of lac insects and its host plants revealed a total 21 host plants *i.e*., *Acacia auriculiformis*, *A. lebbeck*, *A. reticulate*, *A. senegal*, *Butea monosperma*, *Calliandra calothyrsus*, *Dalbergia sissoo*, *Delonix regia*, *Ficus religiosa*, *F. benghalensis*, *F. palmata*, *F. racemosa*, *F. benjamina*, *F. tsiela*, *Peltophorum ferrugineum*, *Pithecellobium dulce*, *Polyalthia longifolia*, *Prosopis cineraria*, *P. juliflora*, *Samanea saman*, and *Ziziphus mauritiana* during 2019 and 2020 under 14 genera from families *i.e*., Annonaceae, Caesalpiniaceae, Fabaceae, Mimosaceae, Moraceae and Rhamnaceae. Of these, family Mimosaceae comprised of highest number of species under different genera and least by family Rhamnaceae and Caesalpiniaceae. During both the years *F. religiosa* was the most abundant host (Table-1).

The associated fauna comprised 11 species of predators, primary parasitoids and hyperparasitoids under 8 families of 3 orders. Of these, 8 species belonged to Hymenopetra, 2 to Lepidoptera and 1 to Neuroptera. The predators were *Eublemma amabilis*, *Pseudohypatopa pulverea* and *Chrysopa zastrowi*; primary parasitoids were *Tachardiaephagus tachardiae*, *Aprostocetus purpureus*, *Tyndarichus clavicornis*, *Erencyrtus dewitzii* and Hyperparasitoids were *Apanteles fakhrulhajiae*, *Eupelmus tachardiae*, *Bracon greeni* and *Brachymeria tachardiae*. Maximum number of genera and species were recorded from family Encyrtidae, followed by Braconidae, Eupelmidae, Chalcididae, Noctuidae, Blastobasidae, Chrysopidae and Eulophidae in descending order (Table 3 & Plate 1).

Fauna associated with lac insect were recorded and analyzed, which revealed that *E. amabilis* had maximum mean relative density among all the predators. *E. dewitzii* was the most abundant parasitoid among all parasitoids during both years. However, *T. tachardiae* was most abundant during October, whereas *A. purpureus* was more prevalent in July during both years. The hyperparasitoid, *E. tachardiae* was most prevalent among all hyperparasitoids during both years; whereas, *A. fakhrulhajiae* was more abundant during July 2019 and 2020.

Predator *E. amabilis*, *P. pulverea* and *C. zastrowi* were the major predators; whereas, *T. tachardiae*, *A. purpureus* and *E. dewitzii* were the main inimical parasitoids.

The numerical abundance of the fauna associated with lac insect revealed that population of primary parasitoids belonging to family Encyrtidae (54.21%), Eulophidae (32.30%) were dominant among the total population of natural enemies. The predators *viz.*, *Eublemma*, *Pseudohytopa* and *Chrysopa* represented 8.44, 2.64 and 1.90 percent of the total population of fauna recorded to be associated with lac insect emerged from the collected samples under study. A small population of hyperparasitoids (0.59%) belonging to family Braconidae was also recorded to be associated with lac insect (Table- 3).

The shannon diversity (H') index indicated that the natural population of associated natural enemies found to be maximum in districts of Haryana (1.13) followed by Rajasthan (1.11); whereas, Gujrat had the minimum diversity index of 1.09. (Table-4)

Table 1: Important hosts trees identified in arid western plains of the country till date

S. No.	Name of host	Distribution
1.	*Butea monosperma* Lam. (Palas)	Rajasthan Gujarat
2.	*Zizyphus mauritiana* Lam. And *Z. jujube* Lam. (Ber)	Rajasthan Gujarat Haryana
3.	*Acacia nilotica* Willd. (Babul)	Rajasthan Gujarat
4.	*Ficus religiosa* Linn. (Peepal)	Rajasthan Gujarat Haryana
5.	*Ficus racemosa* Linn. (Gular)	Rajasthan
6.	*Ficus bengalensis* Linn. (Baragad)	Rajasthan Gujarat Haryana
7.	*Albizzia lebbek* Benth (Rain Tree, Siris)	Gujarat
8.	*Annona squamosa* Linn. (Custard Apple)	Rajasthan Gujarat
9.	*Ficus benjamina* Linn. (Weeping Fig)	Gujarat
10.	*Acacia catechu* Willd. (Khair)	Rajasthan Gujarat
11.	*Cajanus cajan* Linn. (Arhar)	Rajasthan
12.	*Acacia rabica* Willd. (Babool)	Rajasthan Gujarat
13.	*Cassia fistula* Linn. (Amaltas)	Rajasthan
14.	*Pithecellobium dulce* (Kikkar)	Rajasthan
15.	*Dalbargia sissoo* (Shisham)	Rajasthan Haryana
16.	*Prosopis cineraria* (Khejadi)	Rajasthan Haryana
17.	*Acacia auriculiformis* (Akashmani)	Rajasthan
18.	*Calliandra haematocephala* Benth (Calliandra)	Rajasthan
19.	*Polyalthia* spp. *pendula* (Ashoka)	Rajasthan
20.	*Ficus carica* (Anjeer)	Rajasthan
21.	*Prosophis juliflora* (Vilayati Babool)	Rajasthan

Table 2: Analysis of fauna associated with lac insect, *Kerria sp.* collected from the Western Plains of India during 2019 & 2020

S. No.	Trophic level states	Fauna	Order	Family
1.	Predators	*Eublemma amabilis* Moore	Lepidoptera	Noctuidae
		Pseudohypatopa pulverea Meyr	Lepidoptera	Blastobasidae
		Chrysopa zastrowi (Esben-Petersen)	Neuroptera	Chrysopidae
2.	Primary parasites	*Aprostocetus pupureus* Cameron	Hymenoptera	Eulophidae
		Tachardiaephagus tachardiae Howard	Hymenoptera	Encyrtidae
		Parechthrodryinus clavicornis Mashhood alam	Hymenoptera	
		Erencyrtus dewitzi Mahdihassan		
3.	Hyperparasites	*Apanteles fakhrulhajiae* Mahd	Hymenoptera	Braconidae
		Bracon greeni Ashmead		
		Eupelmus tachardiae Howard	Hymenoptera	Eupelmidae
		Brachymeria tachardiae Cam		Chalcididae
Total			**3**	**8**

Table 3: Relative abundance of natural enemies associated with lac insect, *Kerria sp*. during 2019 & 2020

Natural enemies	Seasonal Mean	Mean Density	Relative Density (%)
Eublemma amabilbis	8.53	0.28	8.44
Peudohypatopa pulverea	2.67	0.09	2.64
Chrysopa sp	1.92	0.06	1.90
Eulophidae	32.66	1.09	32.30
Encyrtidae	54.81	1.83	54.21
Braconidae	0.60	0.02	0.59

Table 4: Shannon Index (H')- Diversity index of natural enemies associated with lac insect at Arid Western Plains of India during 2019 & 2020

S. No.	State	Shannon Index (H')		Mean Diversity
		2019	2020	
1.	Haryana	1.09	1.16	1.13
2.	Rajasthan	1.10	1.11	1.11
3.	Gujarat	1.11	1.07	1.09

Plate 1: Predators and parasitoids emerged from the collected samples from different locations

Present findings are partly supported by Sharma *et al*., (1997) [9] who reported *A. purpureus* and *T. tachardiae* most abundant constituting 55.82 per cent and 28.37 per cent, respectively of the total population of parasitoids. However, this difference may be attributed due to different agro climatic conditions. Sharma *et al*., (2007) [12] reported that % parasitization of 18.40 in the *kusmi* strain and 26.0 % in the *rangeeni* strain particularly during the rainy season. *A. purpureus* alone caused 7.8 and 11.8 per cent parasitization, respectively. Sharma *et al*, (2008) [10] found that predators, primary parasitoids and hyper parasitoids constituted 68.0, 29.60 and 2.40 %, respectively. 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. Hyper parasite *E. tachardiae* found most prevalent among all the hyperparasites. Present findings are in complete agreement with Sah and Das Gupta, 1983: Sah, 1988 [8, 7] who found *A. tachardiae* and *A fakhrulhajiae* most abundant in M.P.

Findings of the workers support the present findings however *E. dewitzi* was have been reported as major parasitoid in this region as compared to *A. puprpeureus* and *T. tachardiae* in lac growing regions. However, there was variation in numerical abundance of different fauna at different locations.

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