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Variations in population of lac associated fauna in relation to different lac host plants, lac insect strains and seasons of cultivation

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Abstract
The present study was attempted to look in to variations in lac insect associated fauna in relation to different lac host plants for both *kusmi* and *rangeeni* strains of Indian lac insect, *Kerria lacca* (Kerr.) during 2012-2015. Among the fauna associated with lac insect, *Tachardiaephagus tachardiae* (How.) and *Aprostocetus purpureus* (Cam.) population were significantly higher during the month of November (14.7 and 62.7 respectively) and higher in *Ziziphus mauritiana* (ber) (50.2) during *katki* crop. During *baisakhi* crop, *rangeeni* strain these two associated fauna were significantly higher in the month of March (4.3 and 11.9, respectively). Parasitization recorded was significantly higher (9.5) on *Butea monosperma* (*palas*) followed by *ber* and red gram, is one of the major reasons of lac insect mortality at sexual maturity period during *baisakhi* crop. During *jethwi* crop of *kusmi* strain, *T. tachardiae* and *Eublemma amabillis* populations were significantly more in the month of August (12.5 and 8.6, respectively). Highest population of *A. purpureus* was recorded in the month of August (10.6) on *ber* followed by *Schleichera oleosa* (*kusum*). Population of *T. tachardiae and A. purpureus* were recorded maximum in the month of October (17.0 & 20.0), respectively. Among the three host plants (*ber*, *semialata* and *kusum*), *T. tachardiae* (3.3), *A. purpureus* (12.6) and *E. amabillis* were recorded more on *semialata* during *aghani* crop. The study concludes that the abundance of the parasitoids, predators and hyper parasitoids varied considerably with respect to the lac hosts, seasons of crop and the strain of lac insect. Occurrence of parasitization at the time of crop maturity and the sexual maturity period affects quality of broodlac and leads to crop failure, respectively.

Keywords: *Kerria lacca*, lac associated fauna, *kusmi*, *rangeeni*, lac host

Introduction
Lac is the resinous substances secreted as a protective covering by tiny Indian lac insect, *Kerria lacca* (Kerr.), (Hemiptera: Tachardiidae) [1]. Lac culture is a cash crop of importance and provides valuable income to resource constrained growers inhabiting tribal-dominated forest and sub-forest regions of Eastern India [2]. The lac crop is a low input/high value crop [3] and returns from lac cultivation are much higher than other agricultural crops, especially in drought conditions when other major agricultural crops fail. *K. lacca* is cultivated for its products, namely resin, dye and wax which find application in diverse areas such as food, pharmaceuticals, cosmetics, paints, varnishes etc [4]. Indian lac insect has been grouped into two strains based on its life cycle pattern *viz*. *kusmi* and *rangeeni*. *Kusmi* completes two life cycles per year each having six months duration namely *aghani* (winter season crop) and *jethwi* (summer season crop). Similarly, *rangeeni* strain completes two unequal life cycles per year namely *katki* (rainy season crop – four months) and *baisakhi* (summer season crop- 8 months) [5]. In view of bio-safety and stress on natural products the demand potential of lac is upbeat. Like other agricultural crops lac crop is also vulnerable to insect pest vagaries as it remains permanently attached to host plants from which it derives its nutrition. The sedentary behaviour of lac insect makes it more vulnerable to horde of enemies which include insect predators, parasitoids and diseases [6]. But in recent past, decline in lac production has been observed. One of the reasons of decreased lac production is attributed to increased incidence of parasitoids. Mohanasundaram *et al* [7] reported Relative abundance of lac associated fauna during *baisakhi* wherein, parasitoids alone constitute 93 and 89 per cent population during 2011-12 and 2012-13 among lac associated fauna, followed by predators and hyper parasitoid on *ber*.

Lac insects feed on different host plants and get infested by many predators and parasitoids which cause economic loss. Chowdhury *et al* [8] observed that the Density of population of lac insects influenced the degree of parasitisation by the chalcid parasites associated with lac. Host plants consumed by herbivores insects have long been known to affect the growth and development of parasitoids [9]. In a study on *Bt*-intoxicated *Helicoverpa armigera* larvae, reduced weight of the cocoons and adults of *Campoletis chlorideae* was observed, suggesting significant influence of host size on development and survival of the parasitoid. The adverse effects of *Bt* on the parasitoid were largely through early mortality of *H. armigera* larvae or poor quality of the host [10]. Host plant species and cultivars often differ in biochemical profile, thereby affecting host (herbivore quality). Campan *et al* [11] found that the two most important biotic factors that influence fitness of the parasitoids of herbivores are the host species that they attack and the plant species that the host feed on. Both host plant quality and genetic variation among populations were crucial factors in determining the nature and evolution of the interaction between parasitoids and their herbivorous hosts. Herbivore-induced volatiles emitted by the host plant are key signals that lead parasitoids to their hosts [12, 13]. Herbivore-infested host plants can selectively attract natural enemies and, in some cases when different plant species are infested with the same herbivore, some species may attract more parasitoids and their hosts [14, 15]. Different host plants may also have adverse consequences on subsequent trophic levels in lac ecosystem. Earlier studies were concentrated seasonal abundance and emergence profile of insects associated with the lac insect [16-19]. There is no clear picture of variation in lac associated fauna in relation to different host plants. In this study, population profiling of parasitoids, predators and hyper parasitoids was carried out on six different lac host plants inoculated with *rangeeni* and *kusmi* strains of lac insect. Since, this information is needed for developing a pest management programme, the study aimed to find variation in abundance and emergence profile of lac associated fauna in relation to lac host plants and their crop seasons.

Materials and Methods

Good quality broodlac of *kusmi* and *rangeeni* strain of lac insect were obtained from Institute Research Farm, ICAR-Indian Institute of Natural Resins and Gums, Ranchi (Jharkhand) and inoculated on different host plants. For growing *kusmi* strain host plants *viz. kusum,* (*Schleichera oleosa* Lour); *ber,* (*Ziziphus mauritiana* Lam). and *Flemingia semialata* Roxb were used. While, *palas,* (*Butea monosperma* Lamk)*; ber* and red gram, (*Cajanus cajan* L.) Millsp were used for growing *rangeeni* strain. Experiments were conducted at Institute Research Farm, ICAR-IINRG. Lac insect samples (one meter length of encrustation) were collected randomly from inoculated trees initially one month after inoculation and then at every 15 days interval till crop harvest with three replications. The samples were caged in parasitoid emergence cage (20×20×30cm), fitted with glass tubes to collect parasitoids by exploiting their phototropic behavior (Fig. 1) [20]. Lac associated fauna (parasitoids and predators) were collected from cage every day continuously upto one month. Three replications were used for all six host plants during three years consecutive crops of *rangeeni* (*baisakhi* 2013-15 and *katki* 2012-2014) and *kusmi* (*aghani* 2013-2015 and *jethwi* 2012-2014), respectively.

Fig 1: Parasitoid emergence cage

Statistical Analysis

Population abundance of lac associated fauna was recorded from different host plants for each crop season and the data were subjected to analysis of variance (ANOVA) for the significance (P=0.05) and the mean values were compared in accordance to Duncan's Multiple Range Test (DMRT) using statistical package AGRES

Results

Results of lac associated fauna according the crop season are mentioned below:-

Variation in lac associated fauna during *katki* crop

Table 1 describes the month-wise distribution of variations in lac associated fauna during *katki crop.* Among the associated fauna, *T. tachardiae* and *A. purpureus* populations were significantly higher in the month of November (14.7 and 62.7) followed by October (9.2 and 34.0), respectively. Among the three host plants, *T. tachardiae* and *A. purpureus* were recorded more (9.6, 46.3) on *ber* followed by on *palas* (7.5, 28.8), respectively. *Eublemma amabillis* was recorded more in the month of October (4.6) which are at par with *ber* (1.9) and *palas* (2.2). High population of lac associated fauna coincided with the time of crop maturity period (October and November). Table 2 describes host plant induced variation in lac associated fauna during *katki* in three consecutive years.

Lac associated fauna *viz., T. tachardiae, A. purpureus, Parechthrodryinus clavicornis, E. amabillis, Pseudohypatopa pulverea* and hyper parasitoids (*Bracon greeni, Eupelmus tachardiae* and *Elasmus claripennis*) were observed during *katki* crop. Among these *A. purpureus* (139.3) population was more followed by *T. tachardiae* (31.2) and other parasitoids, predators and hyper parasitoids on par with each other. Lac associated fauna population was recorded significantly more on *ber* (50.2) followed by *palas* and red gram.

Table 1: Month-wise variations in lac associated fauna on different host plants during *katki* crop (Mean value of three years).

Host	*Ber*	*Palas*	*Red gram*	Mean	*Ber*	*Palas*	*Red gram*	Mean	*Ber*	*Palas*	*Red gram*	Mean
Month	***T. tachardiae***				***A. purpureus***				***E. amabillis***			
August	0.11	0.33	0	0.15^{e}	5.7	20.2	0.0	8.7^{d}	0.0	0.0	0.0	0.0^{d}
September	7.2	5.4	2	4.9^{c}	54.1	13.0	4.2	23.8^{c}	1.9	2.3	0.0	1.4^{b}
October	14.1	12.8	0.66	9.2^{b}	49.9	44.2	7.9	34.0^{b}	5.6	7.6	0.5	4.6^{a}
November	23.4	16.1	4.4	14.7^{a}	108.4	55.0	24.6	62.7^{a}	2.0	0.6	0.0	0.9^{c}
December	3.3	2.9	0.8	2.3^{d}	13.4	11.9	5.1	10.1^{d}	0.1	0.7	0.0	0.3^{d}
Mean	9.6^{a}	7.5^{b}	1.6^{c}		46.3^{a}	28.8^{b}	8.4^{c}		1.9^{a}	2.2^{a}	0.1^{b}	
SEM (Month)				0.67				2.93				0.28
SEM (Host)				0.52				2.27				0.16
CD (Month) at 5%				1.33				5.82				0.41
CD (Host) at 5%				1.03				4.51				0.32

Table 2: Variations in population of lac associated fauna during *katki* crop on different host plants (Mean value of three years).

Lac Associated Fauna (LAF)	*Ber*	*Palas*	*Red gram*	Mean
T. tachardiae	48.2	37.6	7.9	31.2^{b}
A. purpureus	231.7	144.3	41.8	139.3^{a}
P. clavicornis	7.7	4.8	2.6	5.0^{c}
E. amabillis	9.6	11.1	0.6	7.1^{c}
P. pulverea	0.7	4.2	0.0	1.6^{c}
Hyper parasitoids	3.4	3.4	0.7	2.5^{c}
Mean	50.2^{a}	34.2^{b}	8.9^{c}	
SEM (LAF)				3.20
SEM (Host)				2.26
CD (LAF) at 5%				6.35
CD (Host) at 5%				4.49

Variation in lac associated fauna during *baisakhi* crop

Table 3 describes the month-wise distribution of variations in lac associated fauna during *baisakhi* crop. Only *T. tachardiae* and *A. purpureus* population were recorded and these parasitoids were recorded more in the month of March (4.3 and 11.9) followed by April. *T. tachardiae* (2.0) was recorded more on red gram whereas *A. purpureus* (5.9) was more on *palas. Baisakhi* lac crop could not survive due to lac insect mortality during the year 2013 and 2014 except 2015. Parasitization was more at sexual maturity period (February, March and April) which could be one of the major reasons of lac insect mortality.

Table 4 describes host plant induced variation in lac associated fauna during *baisakhi* crop. Lac associated fauna *viz*., *T. tachardiae*, *A. purpureus*, *P. clavicornis* and *E. amabillis* were observed upto the month of May during *baisakhi* crop in all three crop years. Among these *A. purpureus* (20.9) population was more followed by *T. tachardiae* (7.6) and other parasitoids & predators. Lac associated fauna populations were recorded significantly more on *palas* (9.5) followed by *ber* and red gram.

Table 3: Month-wise variations in lac associated fauna on different host plants during *Baisakhi* crop (Mean value of three years).

Host	*Ber*	*Palas*	*Red gram*	Mean	*Ber*	*Palas*	*Red gram*	Mean
Month	*T. tachardiae*				*A. purpureus*			
January	0.0	0.0	0.0	0.0^{c}	0.1	0.0	0.0	0.03^{c}
February	0.1	0.0	0.0	0.03^{c}	0.3	2.1	0.3	0.9^{c}
March	3.7	2.0	7.2	4.3^{a}	4.2	18.3	13.0	11.9^{a}
April	4.0	2.3	2.9	3.1^{b}	9.8	8.3	5.2	7.8^{b}
May	0.4	0.0	0.1	0.2^{c}	0.0	0.9	0.0	0.3^{c}
Mean	1.6^{b}	0.9^{c}	2.0^{a}		2.9b	5.9a	3.7b	
SEM (Month)				0.24				0.60
SEM (Host)				0.19				0.46
CD (Month) at 5%				0.47				1.19
CD (Host) at 5%				0.37				0.92

Table 4: Variations in population of lac associated fauna during *Baisakhi* crop on different host plants (Mean value of three years).

Lac Associated Fauna (LAF)	*Ber*	*Palas*	*Red gram*	Mean
T. tachardiae	8.2	4.3	10.2	7.6^{b}
A. purpureus	14.4	29.7	18.6	20.9^{a}
P. clavicornis	3.1	2.2	3.4	2.9^{c}
E. amabillis	0.8	1.7	0.1	0.9^{d}
Mean	6.6^{b}	9.5^{a}	8.1^{ab}	
SEM (LAF)				0.84
SEM (Host)				0.72
CD (LAF) at 5%				1.67
CD (Host) at 5%				1.45

Variation in lac associated fauna during *jethwi* crop

Table 5 describes the month-wise distribution of variations in lac associated fauna during *jethwi* crop. *T. tachardiae* and *E. amabillis* populations were significantly higher in the month of August (12.5 and 8.6) followed by July (6.5 and 4.0) respectively. Similarly, *A. purpureus* population was significantly higher in the month of August (10.6) but in the month of May and June on par with each other. Population of lac associated fauna was recorded more at the time of crop maturity (July-August). Among the three host plants, *T. tachardiae*, *A. purpureus* and *E. amabillis* were recorded more on *kusum* (8.6), *ber* (9.5) and *semialata* (5.1), respectively.

Table 6 describes host plant induced variation in lac associated fauna during *jethwi* crop. Lac associated fauna *viz*., *T. tachardiae*, *A. purpureus*, *P. clavicornis*, *E. amabillis*, *P. pulverea* and *B. greeni* were observed during *jethwi* crop in three consecutive years. Among these *A. purpureus* (28.9) population was more followed by *T. tachardiae* (19.2), *E. amabillis* (12.7) and other faunal populations *viz*., *P. clavicornis*, *P. pulverea*, *B. greeni* on par with each other. Lac associated faunal populations were recorded significantly more on *kusum* (12.1) whereas, on *semialata* and *ber* were at par with each other.

Table 5: Month-wise variations in lac associated fauna on different host plants during *Jethwi* crop (Mean value of three years).

Host	*Ber*	*Semialata*	*Kusum*	Mean	*Ber*	*Semialata*	*Kusum*	Mean	*Ber*	*Semialata*	*Kusum*	Mean
Month	***T. tachardiae***				***A. purpureus***				***E. amabillis***			
May	0.0	0.0	0.2	0.07^{c}	8.1	10.4	1.6	6.7^{b}	0.0	0.0	0.0	0.0^{c}
June	0.1	0.2	0.2	0.2^{c}	5.9	5.2	7.2	6.1^{bc}	0.0	0.1	0.0	0.03^{c}
July	1.8	2.8	14.9	6.5^{b}	2.6	4.8	9.2	5.5^{c}	2.0	6.6	3.6	4.0^{b}
August	12.8	5.6	19.1	12.5^{a}	21.4	6.4	3.9	10.6^{a}	1.7	13.6	10.6	8.6^{a}
Mean	3.7^{b}	2.2^{c}	8.6^{a}		9.5^{a}	6.7^{b}	5.5^{c}		0.92^{c}	5.1^{a}	3.5^{b}	
SEM (Month)				0.61				0.46				0.33
SEM (Host)				0.53				0.40				0.28
CD (Month) at 5%				1.22				0.92				0.66
CD (Host) at 5%				1.05				0.80				0.56

Table 6: Variations in population of lac associated fauna during *Jethwi* crop on different host plants (Mean value of three years).

Lac Associated Fauna (LAF)	*Ber*	*Semialata*	*Kusum*	Mean
T. tachardiae	14.7	8.6	34.4	19.2^{b}
A. purpureus	38.0	26.9	21.9	28.9^{a}
P. clavicornis	0.6	0.2	0.8	0.5^{d}
E. amabillis	3.7	20.2	14.1	12.7^{c}
P. pulverea	0.2	0.9	0.4	0.5^{d}
Bracongreeni	0.3	3.1	1.0	1.5^{d}
Mean	9.6^{b}	10.0^{b}	12.1^{a}	
SEM (LAF)				0.71
SEM (Host)				0.50
CD (LAF) at 5%				1.41
CD (Host) at 5%				0.99

Variation in lac associated fauna during *aghani* crop

Table 7 describes the month-wise distribution of variations in lac associated fauna during *aghani* crop. *T. tachardiae* population was significantly more in the month of October (17.0) followed by September (4.5) and other months. *A. purpureus* population was significantly more all these at par with each other in three consecutive months *viz*., October (20.0), November (18.7), December (18.5). *E. amabillis* was recorded more in the month of February (0.8) followed by March (0.3). Among the three host plants, *T. tachardiae* (3.3), *A. purpureus* (12.6) and *E. amabillis* (0.4) were recorded more on *semialata* during all the years.

Table 8 describes host plant induced variations in lac associated fauna during *aghani* crop. Major lac associated fauna observed during 2013, 2014 and 2015 were *T. tachardiae*, *A. purpureus*, *P. clavicornis*, *E. amabillis*, *P. pulverea* and *B. greeni*. Among these *A. purpureus* (89.5) population was maximum followed by *T. tachardiae* (19.7), *B. greeni* (5.0) and *P. clavicornis*, *E. amabillis* and *P. pulverea* were at par with each other. Lac associated fauna populations were recorded significantly more on *semialata* (22.8) than other hosts *viz*., *ber* and *kusum*. The summary of the current study is explained in Table 9.

Table 7: Month-wise variations in lac associated fauna on different host plants during *Aghani* crop (Mean value of three years).

Host	*Ber*	*Semialata*	*Kusum*	Mean	*Ber*	*Semialata*	*Kusum*	Mean	*Ber*	*Semialata*	*Kusum*	Mean
Month	***T. tachardiae***				***A. purpureus***				***E. amabillis***			
August	2.4	0.0	0.0	0.8^{f}	0.4	0.0	0.2	0.2^{d}	0.0	0.0	0.0	0.0^{c}
September	4.6	2.0	6.9	4.5^{b}	22.3	0.3	10.6	11.1^{b}	0.6	0.3	0.0	0.3^{b}
October	4.9	11.6	1.4	6.0^{a}	17.0	21.0	21.8	20.0^{a}	0.1	0.2	0.4	$0.3b^{c}$
November	3.2	4.9	1.3	3.1^{c}	15.1	24.7	16.3	18.7^{a}	0.0	0.0	0.0	0.0^{c}
December	2.6	2.1	1.2	2.0^{d}	12.8	28.6	14.2	18.5^{a}	0.4	0.1	0.0	0.2^{bc}
January	0.4	0.4	0.2	0.4^{f}	7.4	18.3	7.2	11.0^{b}	0.0	0.2	0.0	0.07^{bc}
February	2.1	3.0	0.4	1.9^{de}	11.5	6.8	8.6	9.0^{c}	0.3	1.8	0.2	0.8^{a}
March	0.8	2.2	0.2	1.1^{ef}	2.4	0.8	0.0	1.1^{d}	0.2	0.7	0.0	0.3^{b}
Mean	2.6^{b}	3.3^{a}	1.5^{c}		11.1^{b}	12.6^{a}	9.9^{c}		0.2^{b}	0.4^{a}	0.08^{b}	
SEM (Month)				0.38				0.80				0.13
SEM (Host)				0.23				0.49				0.08
CD (Month) at 5%				0.76				1.59				0.26
CD (Host) at 5%				0.46				0.97				0.16

Table 8: Variations in population of lac associated fauna during *Aghani* crop on different host plants (Mean value of three years).

Lac Associated Fauna (LAF)	*Ber*	*Semialata*	*Kusum*	Mean
T. tachardiae	21.1	26.2	11.8	19.7^{b}
A. purpureus	89.1	100.4	78.9	89.5^{a}
P. clavicornis	3.9	1.2	2.0	2.4^{d}
E amabillis	1.7	3.3	0.7	1.9^{d}
P. pulverea	0.8	0.4	0.3	0.5^{d}
Bracongreeni	6.1	5.3	3.4	5.0^{c}
Mean	20.4^{b}	22.8^{a}	16.2^{c}	
SEM (LAF)				1.06
SEM (Host)				0.75
CD (LAF) at 5%				2.10
CD (Host) at 5%				1.49

Table 9: Summary of finding from the study.

Associated fauna v/s crop season								
Associated fauna	**Observed Maximum (month)**				**Observed Minimum (month)**			
	***Rangeeni* strain**		***Kusmi* strain**		***Rangeeni* strain**		***Kusmi* strain**	
	Katki	*Baisakhi*	*Jethwi*	*Aghani*	*Katki*	*Baisakhi*	*Jethwi*	*Aghani*
T. tachardiae	November	March	August	October	August	January	May	January
A. purpureus	November	March	August	October	August	January	July	August
E. amabillis	October	Nil (Crop died before maturity)	August	February	August	Nil (Crop died before maturity)	May	August

Associated fauna v/s host plant								
Associated fauna	**Observed Maximum (Host)**				**Observed minimum (Host)**			
	***Rangeeni* strain**		***Kusmi* strain**		***Rangeeni* strain**		***Kusmi* strain**	
	Katki	*Baisakhi*	*Jethwi*	*Aghani*	*Katki*	*Baisakhi*	*Jethwi*	*Aghani*
T. tachardiae	*Ber*	Red gram	*Kusum*	*Semialata*	Redgram	*Palas*	*Semialata*	*Kusum*
A. purpureus	*Ber*	*Palas*	*Ber*	*Semialata*	Redgram	*Ber*	*Kusum*	*Kusum*
E. amabillis	*Palas*	Nil (Crop died before maturity)	*Semialata*	*Semialata*	Redgram	Nil (Crop died before maturity)	*Ber*	*Kusum*

Discussion

Among the parasitoids, *A. purpureus* was the most prevalent parasitoids followed by *T. tachardiae* and *P. clavicornis*. Among the predators *E. amabillis* was recorded more in all the four crops and considerable numbers of *B. greeni* observed in rainy/winter crops (*katki* and *aghani*) than summer (*baisakhi* and *jethwi*) crops. This was confirmed with earlier findings [17, 18].

In *katki* crop, population of lac associated fauna was more than the *baisakhi* crop which is conformity with observations of Pandey *et al* [21]. Similarly, in *aghani* crop, population of lac associated fauna was more than *jethwi* crop. It was also evident from the data of the different months that the incidence of lac parasitoids and predators was more abundant towards the later stage of development and this corroborate the earlier findings [8, 18] made in a two different stages of development and the incidence of chalcid parasites is more towards crop maturity. Srivastava *et al* [18] in the *katki* crop and Monobrullah *et al* [22] in the *baisakhi* crop observed that, larger peak of parasitoid population coincided with the time of crop maturity are in conformity with the present findings. Since, the lac associated fauna are most abundant at the time of crop maturity it affects fecundity and resin yield. Sharma and Ramani [23] also found that parasitization of lac insect affected the fecundity (32.55 and 34.71 %) and resin yield (17.92 and 17.44 %) of *kusmi* and *rangeeni* strains respectively during rainy season crop. However, in *baisakhi* crop, prasitoids population was more at sexual maturity period. This might lead to complete mortality of lac crop. Sharma *et al* [24] found that parasitization appears to be the major factor for causing pre-summer lac insects' mortality. The present results are in also in conformity with the finding of Mohanasundaram *et al* [7] who reported that, *A. purpureus* alone constituted 100 per cent population during critical/sexual maturity period causing complete lac insect mortality on *ber* and *palas* during *Baisakhi*.

It has been seen that the abundance of the parasitoids, predators and hyper parasitoids (Parasitoids of lac predators) varied considerably with respect to the lac hosts, stage of crop growth and strain of lac insect. The observed variation might be due to heavy infestation/ encrustation of lac insects on different lac host plants. Lac insects prefer and select the host plants depending upon quality of the plants. In case of agricultural crops, if herbivore population is more incidence of natural enemies are also more. Similarly, in lac crop, higher infestation/ lac encrustation leads to abundance of population of lac associated fauna. Healthy lac encrustation/density of lac insect is observed more on *ber*, *palas*, *semialata* and *kusum* during *katki*, *baisakhi*, *aghani* and *jethwi*, respectively. Therefore, relative abundance of lac associated fauna was also recorded more in numbers on these host plants in specific crop seasons. It seems that growth of lac insects depend upon host plants for various seasons. Srivatava *et al* [18] reported that the abundance of lac predators is very much dependent upon the availability of food as their number increases with the increase in the growth of lac insects. Jaiswal and Saha [25] reported that the density of lac insect on the shoot was identified as the key factor explaining highest variation in the incidence of *T. purpureus*, *T. tachardiae* and *P. clavicornis*. Location, host and crop season specific variations in the populations of parasitoids and predators have been reported by Monobrullah *et al* [18]. The present finding, however, contradict the report that no significant difference were observed in relative abundance and emergence pattern of parasitoids on the basis of variety, host and the location [19]. However, the trend of relative abundance of the lac associated fauna did not vary among the lac host plants. Similar results were found by Srivastava and Mehra [17]. Studies on tritrophic interactions involving sorghum genotypes, midge (*Stenodiplosis sorghicola*) and the predominant parasitoids (*Aprostocetus* spp.) at ICRISAT Asia Center were conducted using three midge resistant (ICSV 745, ICSV 89058 and IS 10712) and three susceptible (Swarna, CSH 9 and ICSV 112) genotypes during the post-rainy (1992/93) and rainy (1993) seasons. There were significant differences in parasitization level of midge by *Aprostocetus* spp. between resistant and susceptible sorghum genotypes, and season. Higher parasitization was observed on susceptible genotypes than on resistant ones during both post-rainy and rainy seasons [26].

Conclusion

The present study concludes that the pest management approaches to be followed for different crop season depending upon the nature of most abundant parasitoid/predators. It was observed that parasitoid and predator populations varied on different lac host plants *viz*., *ber*, *palas* and red gram. Among the parasitoids, *A. purpureus* was the most prevalent parasitoids followed by *T. tachardiae* and *P. clavicornis*. The results also indicate that *ber* and *semialata* are the most susceptible & red gram and *kusum* are the least susceptible host for the incidence of parasitization during *katki* and *aghani* season, respectively whereas no such trend has been observed during *baisakhi* and *jethwi*, as the incidence of

parasitization is even in all the studied host plants. One month before maximum emergence of parasitoids is the critical stage in each crop and seasons. In case of *katki* and *jethwi*, crop maturity period is considered as the most critical stage which is reflected in quality of broodlac whereas sexual maturity period is most critical stage for *baisakhi* and *aghani*, which is reflected in crop survival percentage upto full maturity. High incidence of parasitization during this period may leads to complete crop failure. The information regarding the most critical stage at which pest management strategy should be applied can also be inferred for all the four seasons from the current study. The variation of lac associated fauna vis a vis host plant indicates the suitability of host plant for various seasons of lac crop. The variation of associated fauna in lac ecosystem for both *kusmi* and *rangeeni* throws light in to the specific pest management strategies that can be applied for both the strains. Thus, current study provides knowledge base for strategic planning of pest management in lac ecosystem for sustained lac production.

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