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Biological and Productivity Linked Parameters of Lac Insect, *Kerria lacca* (Kerr.) on *Flemingia macrophylla* and *Flemingia semialata* in Punjab

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Abstract: The effect of the leguminous host plants, *Flemingia macrophylla* and *Flemingia semialata* was studied on the biological and productivity linked parameters of the lac insect, *Kerria lacca* during *Baisakhi* and *Katki* crops. In *Baisakhi* crop, the mean initial settlement density was 77.20 and 82.20 crawlers/cm^2 in *F. macrophylla* and *F. semialata*, respectively. During *Katki* crop, the respective density was 76.33 and 79.73 crawlers/cm^2. The mean initial mortality was 9.38 and 9.62 per cent in *F. macrophylla* and *F. semialata*, respectively during *Baisakhi* crop and in *Katki* crop, the mean mortality was 10.92 and 8.48 per cent, respectively. The total life period of lac females was 234.33 and 232.00 days in *Baisakhi* crop on *F. macrophylla* and *F. semialata*, respectively and in *Katki* crop was 106.67 and 108.33 days, respectively. The mean weight of female cells of lac insect was 8.66 and 8.94 mg on *F. macrophylla* and *F. semialata*, respectively during *Baisakhi* crop. Similarly, in *Katki* crop the mean weight of female cells was 7.48 and 7.65mg, respectively. The mean resin output during *Baisakhi* crop was 5.95 and 6.10mg per female cell on *F. macrophylla* and *F. semialata*, respectively, while the mean weight of resin output was 5.36 and 5.50mg on *F. macrophylla* and *F. semialata*, respectively in *Katki* crop. It is concluded that both *F. semialata* and *F. macrophylla* could be promising hosts for lac cultivation under Punjab conditions.

Keywords: Biology, *Kerria lacca, Flemingia macrophylla*, *Flemingia semialata*, Productivity

Lac resin, a natural substance of animal origin, is secreted by the lac insect, *Kerria lacca* (Hemiptera: Tachardiidae). The resin along with other lac products has an economic importance which finds its use in many industries. All the stages of lac insect except neonates are sedentary in nature and suck the plant phloem sap throughout their life from certain lac host plants (Ahmad et al., 2012). The neonates crawl, settling at specific parts of these plants, providing feed for the resting stages of the insects. Lac cultivation is practiced in many South Asian countries like India, Thailand China, Bangladesh and Indonesia. India is the largest producer of lac in the world wherein it is commercially produced in states like Chhattisgarh, Jharkhand, Madhya Pradesh, Orissa and West Bengal (Yogi et al., 2015). More than 400 plants are reported to serve as host for the survival and development of the lac insect. Certain host species as well as varieties thereof have been reported to support more specifically to lac insect (Sharma et al., 1997). The lac insect has been reported to thrive well on the tender shoots of various natural hosts like ber (*Ziziphus mauritiana*), palas (*Butea monosperma*) and kusum (*Schleichera oleosa*) in these states (Sharma 2017). However, the commercial production of lac is declining due to non-availability of its natural hosts owing to depletion of the forest covers. There is need to explore alternate host plants, showing promising results on the growth and development of lac insect. Leguminous plants, *Flemingia macrophylla* (Willd.) Merr. and *Flemingia semialata Roxb*. ex W. T. Aiton reported as potential alternative to lac insects' natural hosts (Jaiswal and Singh 2012; Kumar *et al*. 2017). These plants are quick growing and are suitable for lac cultivation. Both *F. macrophylla* and *F. semialata* are suitable for *Kusmi* as well as *Rangeeni* strains of the lac insect, *K. lacca*. Growing of various horticultural crops like aonla (*Phyllanthus emblica*), ber (*Ziziphus maurutiana*), guava (*Psidium guajava*), lime (*Citrus aurantifolia*) and seasonal vegetables in vertical hierarchy pattern was compatible with *F. semialata* (Singhal et al., 2014). Being the phloem feeders, the quantity as well as quality of food may determine the growth and survival of lac insect. Various host plant species have been reported to alter lac insect biological attributes (Sandeep et al., 2020). Apart from abiotic factors, lac production is affected by various biological and productivity linked parameters like initial density of settlement, mortality, sex-ratio, survival at maturity, food quality, etc (Mohanasundaram et al., 2014, Mohanta 2014). Thus keeping in mind the importance of host plant characteristics affecting lac insect growth and development, the present study was conducted to determine the effect of host plants *F. macrophylla* and *F. semialata* on biology and productivity linked parameters of *K. lacca* under Punjab conditions.

MATERIAL AND METHODS

Raising of the host plants: The initial seed culture of *F. macrophylla* and *F. semialata* was procured from ICAR-National Institute of Secondary Agriculture (NISA), Ranchi. The nursery plants were raised in the polythene bags (20 x 10 cm). A sandy loam soil + FYM mixture was prepared for raising nursery plants. Holes were made at the bottom of the polythene bags for proper drainage. The nursery was sown in the last week of April. The polythene bags were kept under partial shade conditions. Utmost care was taken for the irrigation requirements of the germinated plants, due to hot weather conditions during the summer months. The nursery plants were transplanted in the well drained field during the last week of June in a paired row system, wherein plant to plant distance of 1m was maintained. The row to row spacing of 0.5 m was maintained. The nutritional requirements of the plants were met with application of manures, taking into consideration the soil type, as well as the leguminous nature of the host plants. These plants were raised and maintained for the whole year and were used for further inoculations.

Brood lac inoculation: The brood lac from the previously maintained *Rangeeni* strain of the *K. lacca* was used for the inoculation. For this brood lac sticks (5 cm each), having mature female (brood) cells, were tied to the plants of *F. macrophylla* and *F. semialata* separately. The nymphs were allowed to emerge from mature females for about two weeks and the crawlers were allowed to settle. Thereafter, the *Phunki* lac (left over after the emergence of nymphs) was removed from the host plants. For *Katki* crop, broodlac stick was inoculated during July and inoculated shoots were monitored for the emergence of crawlers. Thereafter, various biological and productivity linked parameters were recorded till October before the harvesting of the crop. The brood lac sticks were inoculated during November for *Baisakhi* crop and the data on biological and productivity linked parameters were recorded till June next year. Once the crawlers emerged from brood cells, the following observations were recorded for different parameters:

Initial settlement density: Mean initial density (number per square cm) of settlement was recorded 7-10 days after the inoculation of brood lac. One square cm area of main stem of the plant infested with lac insect was selected on three sites (upper, lower, middle) on same plant and lac insect larvae settled were counted.

Initial mortality (%): The above process was repeated at 21 days after the inoculation of brood lac and initial mortality was calculated using following formula:

$$\text{Initial mortality} = \frac{\text{Initial density-Density after 21 days of settlement}}{\text{Initial density}} \times 100$$

Sex-ratio (% of male insects): After the differentiation of male and female cells, male cells were counted from three sites (upper, middle, lower) from the same plant and percentage male insects were calculated

Duration of pre-sexual stages: The time elapsed between date of inoculation to male and female cell differentiation was recorded.

Male emergence initiation (days): Time elapsed between date of inoculation and initiation of male emergence from cells was recorded.

Fecundity (number of young ones produced by the female insect): The collected mature female cells were stored individually into glass vials plugged with cotton for about a month and the emerged larvae were counted. Total count was taken as fecundity of the female lac insect.

Longevity of female cell (days): The time elapsed between the date of inoculation and crop harvesting (harvesting of brood sticks) was counted to work out the longevity/ life duration of the female lac insect.

Density at crop maturity (number per square cm): Surviving female lac insects (after initial mortality and emergence of male lac insects) counted as above at crop maturity (appearance of yellow spot).

Weight (in mg) of the female cell: Weight of individual female lac insect was recorded after larval emergence has completed.

Resin output: The resin produced by an individual female cell recorded after removing the dead insect body from the cell. Fifty cells (10 each from five plants/replicates) were collected for this purpose.

Statistical analysis: The data were subjected to appropriate statistical tools and mean standard error was worked out using functions of Windows MS Excel.

RESULTS AND DISCUSSION

Pre-harvest Biological Parameters on *F. macrophylla*

***Baisakhi* crop:** In *Baisakhi* crop, the mean initial density of settlement (no./cm^2) was 77.20 crawlers/ cm^2. The initial percentage mortality ranges from 4.12 to 12.57 per cent, while the mean initial mortality was 9.38per cent. The data presented in the table 1 revealed that the mean duration of female and male cell differentiation i.e. duration of pre-sexual stages was 116.67days. The male emergence was initiated at 155th day and it was recorded up to 159th day. The mean male emergence initiation was at 157.67±0.67 days. The sex-ratio (% male insects) ranged from 6.90 to 13.89 per cent, and the mean sex-ratio was 11.85. The mean density of surviving female lac insects was recorded as 4.80cm^2. The longevity of female cell ranged between 210 days to 240 days. The mean longevity of female cell was 234.33days.

Maximum crawlers emerged from a single female cell were 150, with a minimum of 99 crawlers per female cell. The mean number of crawlers per female cell was 121.12. The total life cycle of lac insect (*Rangeeni* strain) in *Baisakhi* crop was 210 to 240 days (Fig. 1). Swami et al. (2021) also recorded productivity linked parameters of *Rangeeni* strain of lac insect in *Baisakhi* season and initial settlement density on *F. macrophylla* was90.70/cm^2 with mean fecundity of 380 crawlers per female cell and mean initial mortality of 11.40 per cent.

***Katki* crop:** During *Katki* crop, the initial lac insect settlement density ranged from 59-95 crawlers/cm^2 and the mean initial settlement density was 76.33insects/ cm^2. The mean mortality was 10.92 per cent, while the initial mortality ranged from 8.53-17.06 per cent (Table 1). The mean duration of pre-sexual stages was 19.80days, ranging between 17-22 days. The mean lac insect males' emergence initiation was 44.00 days, with a range of 40-45 days. The mean sex-ratio (% male insects) was at 12.15 per cent and the sex-ratio ranged between 9.09-14.93 per cent. The surviving density of female lac insects recorded with a mean of 4.67, and ranged from 3-5/cm^2. Similarly, the mean longevity of female cell was 106.67days and the range of female cell longevity was between 99-110 days. The total life cycle of lac insect (*Rangeeni* strain) in *Katki* crop was 99 to110 days (Fig. 1). Maximum crawlers emerged from a single female cell were 120, while the minimum were 98 crawlers per female cell. The mean number of was 107.74 crawlers per female. Meena et al. (2019) observed mean initial density in the range of 70.67-116.00 crawlers per cm^2 of *K. lacca* on *F. macrophylla* during *Katki* crop. The mean mortality varied from 16.05 to 36.42 per cent, while the mean fecundity ranged between 285.40 to 644.60 crawlers per female.

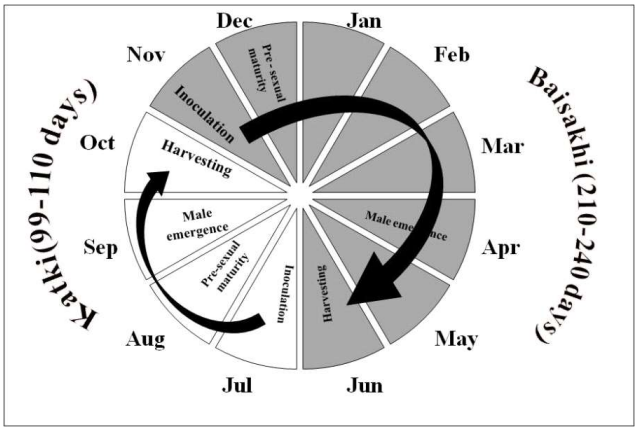

Fig. 1. Life cycle of lac insect (*Rangeeni* strain) on *Flemingia macrophylla*

Table 1. Biological and productivity linked parameters of lac insect (*Rangeeni* strain; *Baisakhi* and *Katki* crops) on *Flemingia macrophylla*

Parameters	*Baisakhi* crop	*Katki* crop
Initial density of settlement (no./cm^2)	77.20±1.17	76.33±1.33
Mortality (%)	9.38±1.33	10.92±2.10
Sex-ratio (% male insects)	11.85±1.18	12.15±0.93
Survival at maturity (no./cm^2)	4.80±0.23	4.67±0.21
Duration of pre-sexual stages (days)	116.67±1.20	19.80±1.11
Initiation of male emergence (days)	157.67±0.67	44.00±0.58
Longevity of female cell (days)	234.33±2.85	106.67±0.88
Fecundity/female (no.)	121.12±2.93	107.74±1.75
Female cell weight (mg)	8.66±0.25	7.48±0.18
Resin output (mg/female cell)	5.95±0.27	5.36±0.73

Means (±SE)

Post-harvest Productivity Parameters on *F. macrophylla*

Baisakhi* crop*: The mean weight of female cells of lac insect was 8.66±mg and ranged from 6.30-10.70 mg (Table 1). The mean weight of resin output by an individual female cell was 5.95mg, while the resin output ranged between 4.50-7.40 mg per female cell.

Katki* crop*: The female cell weight ranged from 6.50 to 8.90 mg. The mean weight of female cells of lac insect on *F. macrophylla* was 7.48±mg. The weight of resin output ranged between 4.00 to 6.70 mg and the mean resin output was 5.3673 mg from an individual female cell. Meena et al. (2019) also reported female cell weight ranging from 10.60 to 16.20 mg and mean resin output of 2.62-3.28 mg during on post-harvest productivity parameters *K. lacca* on *F. macrophylla*.

Pre-harvest Biological Parameters on *F. semialata*

Baisakhi* crop*: The initial density of lac insect settlement (no./cm^2) ranged from 65-97, with mean density of 82.20±insects/ cm^2. The mean initial percentage mortality was 9.62with a range of 7.73-13.58 per cent (Table 2). The mean duration of female and male cell differentiation i.e. duration of pre-sexual stages was 113.67days. The duration of pre-sexual stages ranged from 110 to 120 days. The male emergence was initiated after 154 to 159 days, with mean male emergence initiation at 158.00 days. The mean sex-ratio (% male insects) was 12.85ranging from 8.33 to 15.58 per cent. The mean density of surviving female lac insects (after initial mortality and emergence of male lac insects) was observed to be 4.93/cm^2, and ranged from 3.00 to 7.00/cm^2. The longevity of female cell ranged between 216 d to 239 days. The mean longevity of female cell was 232.00 days. The maximum crawlers emerged from a single female cell on *F. semialata* were 154, while minimum crawlers per female cell were 101. The mean fecundity of 128.92 crawlers was recorded from single female cell. The total life cycle of lac insect (*Rangeeni* strain) in *Baisakhi* crop was 216 to 239 days

(Fig. 2). Swami et al. (2021) recorded initial settlement density on *F. semialata* (64.87/cm^2) in the *Baisakhi* crop on *F. semialata.* The mean fecundity of 368 crawlers per female cell and initial mortality of 15.64 per cent was also reported.

***Katki* crop:** The mean initial settlement density (no. of crawlers/cm^2) of lac insect was 79.73insects/ cm^2 and ranged from 59-95 crawlers/cm^2. The initial percentage mortality ranged from 5.12-12.36 per cent, while the mean per cent mortality was 8.48 (Table 2). The mean duration of pre-sexual stages was 20.20days, ranging between 18-22 days. The initiation of the mean male emergence was 42.33days. The sex-ratio (% male insects) ranged between 7.69-15.15 per cent with mean of 11.91per cent. The mean density of surviving female lac insects was 4.73±0.39. The mean longevity of female cell was 108.33days. The longevity of female cell ranged between 98-112 days. The mean fecundity per female was 110.14crawlers, with maximum crawlers with range of 98- 129 crawlers per female cell. The total life cycle of lac insect (*Rangeeni* strain) in *Katki* crop varied from 98 to112 days (Fig.2). Mishra *et al.* (1999), also observed fecundity in the range of 253-565 crawlers per female cell on *F. semialata* during investigating intra-specific variation in host-plant affecting productivity of the lac insect, *K. lacca*.

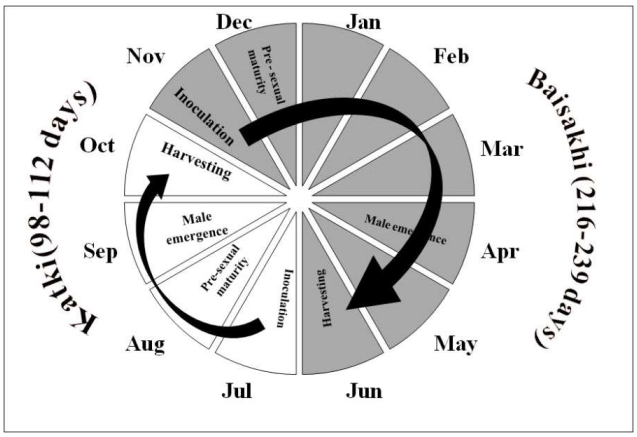

Fig. 2. Life cycle of lac insect (*Rangeeni* strain) on *Flemingia semialata*

Table 2. Biological and productivity linked parameters of lac insect (*Rangeeni* strain; *Baisakhi* and *Katki* crops) on *Flemingia semialata*

Parameters	*Baisakhi* crop	*Katki* crop
Initial density of settlement (no./cm^2)	82.20±3.52	79.73±3.74
Mortality (%)	9.62±1.41	8.48±1.95
Sex-ratio (% male insects)	12.85±1.21	11.91±1.28
Survival at maturity (no./cm^2)	4.93±0.29	4.73±0.39
Duration of pre-sexual stages (days)	113.67±1.86	20.20±0.95
Initiation of male emergence (days)	158.00±0.58	42.33±1.20
Longevity of female cell (days)	232.00±4.04	108.33±3.18
Fecundity/female (no.)	128.92±4.42	110.14±2.27
Female cell weight (mg)	8.94±0.22	7.65±0.18
Resin output (mg/female cell)	6.10±0.19	5.50±0.27

Means (±SE)

Post-harvest Productivity Parameters on *F. semialata*

***Baisakhi* crop:** The maximum female cell weight during *Baisakhi* crop was 11.00 mg and minimum was 7.04 mg (Table 2). The mean weight of female cells of lac insect on *F. semialata* was 8.94±0.22mg. The mean weight of resin output was be 6.10mg and ranged between 4.98-6.80 mg during *Baisakhi* crop.

***Katki* crop:** During Katki crop, the mean weight of female cells of lac insect was 7.65mg and ranged from 6.5-8.6 mg of the female cell weight (Table 2). Resin output in the range of 4.30-7.0 mg while the mean weight of resin output was 5.50 mg. Mishra *et al.* (1999) recorded female cell weight in the range of 8.00 to 19.00 mg on *F. semialata*.

CONCLUSION

Both *F. semialata* and *F. macrophylla* were found to be promising for lac cultivation under Punjab conditions as *Rangeeni* strain of lac insect thrives well on these hosts both during *Katki* and *Baisakhi* crops. Moreover, these two leguminous plants may be utilized to develop integrated model for lac cultivation in potential agricultural and horticultural farming systems.

AUTHORS CONTRIBUTION

Conceptualization was done by PSS and KSS; methodology by PSS and SS; experimentation by AT and HM; data analysis by PSS and RK. All authors have read the manuscript.

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