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Life Cycle and Productivity-Linked Parameters of Lac Insect, *Kerria lacca* (Kerr.) (*Rangeeni* strain; *Baisakhi* crop) on *Butea monosperma* (Lam.)

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***Abstract*:** A three-year study (2021–22, 2022–23, and 2023–24) was conducted to investigate the life cycle and productivity-linked parameters of lac insect, *Kerria lacca* (Kerr.) (*Rangeeni* strain: *Baisakhi* crop) on *Butea monosperma* (Lam.). The mean initial settlement density was 91.70 insects/cm², with a mortality rate of 7.72 percent. The mean sex-ratio (male percentage) was 12.20, and density at crop maturity was 4.82 insects/cm². The mean pre-sexual developmental period was 114.0 days, while the average longevity of female cell was 230.34 days. The mean female cell weight, resin output, and fecundity were 8.32 mg, 5.35 mg, and 146.91 eggs/female, respectively. The results confirmed *B. monosperma* as a suitable host for the *Rangeeni* strain during the *Baisakhi* season, ensuring satisfactory survival, fecundity, and resin yield.

***Keywords*:** *Kerria lacca*, *Rangeeni* strain, *Baisakhi* crop, *Butea monosperma*, Lac productivity, Biology.

1. INTRODUCTION

Lac is a natural resin secreted by the lac insect *Kerria lacca* (Kerr.) (Hemiptera: Kerridae), which plays a vital role in the livelihood of forest-dependent rural populations in India. The country contributes the largest share of global lac production, with two major strains, *Rangeeni* and *Kusmi* being cultivated on different host plants. Lac insects are predominantly associated with woody dicotyledonous angiosperms. Globally, more than 400 plant species have been reported to harbour lac insect, of which approximately 113 species in India serve as successful hosts. Among these, the principal host plants namely *Schleichera oleosa* (Lour.), *Ziziphus mauritiana* (Lam.), and *Butea monosperma* (Lam.) collectively account for nearly 95 percent of the country's commercial lac production (Kumar and Kumar, 2013).

In India, lac insects occur in two well-defined strains, *kusmi* and *rangeeni* distinguished by their preferred host plants and developmental durations. The *kusmi* strain performs optimally on *S. oleosa* (Kusum) and requires approximately six months to complete its life cycle, thereby yielding two high-quality crops annually (*Aghani* and *Jethwi*). In contrast, the *Rangeeni* strain proliferates on host plants other than Kusum, particularly *B. monosperma* (Palas) and *Z. mauritiana* (Ber), and is characterized by two distinct life cycles, *Katki* (four months) and *Baisakhi* (eight months) (Mohanasundaram and Sharma, 2018).

Butea monosperma (Leguminosae: Papilionoideae), a striking tree famed for its vibrant orange-red blooms, is popularly known as the Flame of the Forest. A member of the Fabaceae family, carries a rich diversity of regional names, including *palas, palash*, *mutthuga, bijasneha, dhak, khakara,* and *chichra***,** while internationally referred to as Bastard Teak, Bengal Kino**,** and Nourouc**.** This species occurs widely throughout India, Myanmar, and Sri Lanka, thriving in most ecological zones except the driest, highly arid tracts (Jaiswal and Singh, 2014). It is traditionally preferred for lac cultivation especially *Rangeeni* strain due to its widespread distribution, favourable bark texture, and high compatibility with lac insect biology (Sharma et al., 2015). However, lac productivity is influenced by several biological and environmental factors, including settlement success, developmental duration, mortality, and fecundity. The present investigation was carried out to study the life cycle and productivity-linked parameters of *K. lacca* (*Rangeeni* strain; *Baisakhi* crop) on *B. monosperma* over three consecutive years, under natural field conditions, to establish baseline biological and productivity data under Punjab conditions.

2. MATERIALS AND METHODS

The investigation was carried out on healthy *B. monosperma* trees of uniform age and vigour during the 2021-22, 2022-23 and 2023-24 *Baisakhi* crop (*Rangeeni*

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strain) at Regional field Gene Bank (30º89.33'N, 75º80.38'E), Department of Entomology, Punjab Agricultural University, Ludhiana.

2.1 Broodlac Inoculation

The broodlac from the previously maintained *Rangeeni* strain of *K. lacca* was used for inoculation. For this, broodlac sticks (10 cm each), having mature female (brood) cells, were tied to branches of trees. The nymphs were allowed to emerge from mature females for about two weeks and the crawlers were allowed to settle. Thereafter, *phunki* (left over sticks after the emergence of nymphs) were removed from the host trees. The inoculation was done during first week of November month every year. Once the crawlers emerged from brood cells, the following observations were recorded for different parameters:

2.2. 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 infested with lac insect was selected on three sites (upper, lower, middle) on same tree and lac insect larvae settled were counted.

2.3. Initial Mortality (%)

To estimate initial mortality, the number of live lac insect larvae present within the previously selected one square cm areas at the upper, middle, and lower portions of the main stem was recorded 21 days after inoculation of brood lac. The initial mortality was calculated using following formula (eq 1):

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

2.4. Duration of Pre-sexual Stages

Male and female cells differed markedly in shape and could be readily distinguished as male cells are elongated and cigar-shaped, whereas female cells are larger and globular. The time elapsed between date of inoculation to male and female cell differentiation was recorded.

2.5. Sex-Ratio (% of male insects)

After the differentiation of male and female cells, male cells were counted from three sites (upper, middle, lower) and percentage of male insects were calculated.

2.6. 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.

2.7. 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).

2.8. 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.

2.9. Weight of the Female Cell and Resin Output (mg)

Weight of individual female lac insect was recorded after larval emergence has completed. 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/replicate) were collected for this purpose.

2.10. Statistical Analysis

Mean values along with their standard errors were calculated using statistical functions of Microsoft Excel (Windows 10 Pro).

3. RESULTS AND DISCUSSION

3.1 Establishment, Mortality, and Survival Dynamics

Across the three *Baisakhi* crop cycles, variation was observed in the biological and productivity-linked parameters of lac insects (Table 1). The initial density of settlement ranged from 84.66 to 101.11 insects/cm², with the highest density during 2022-23 (101.11) and the lowest during 2023-24 (84.66). The overall mean settlement density (91.70) indicates favourable initial colonization and host suitability in all three seasons, though fluctuations likely reflect annual variability in climatic conditions and host plant physiology. Comparable settlement densities for *Rangeeni* lac on *B. monosperma* have been reported in earlier studies, confirming the species' consistent ability to support high initial nymph establishment (Sharma and Ramani, 2011; Mohanta et al., 2014; Swami et al., 2021; Biyani et al., 2022).

The mortality rate during settlement ranged from 5.82 to 8.77 per cent (Table 1). The relatively narrow range of mortality across seasons further indicates stable establishment conditions for the lac insect. Such mortality levels are typical for the *Rangeeni* strain on robust hosts and suggest favourable microclimatic and nutritional conditions during early development. The overall low mortality (7.72%) indicates a stable and supportive host-insect association, suggesting that *B. monosperma* provides favourable microclimatic buffering that enhances the survival of lac insects. Previous research has shown that *B. monosperma* generally supports lower early-instar mortality due to its stable physiological condition during the *Baisakhi*

crop (Swami et al., 2021; Biyani et al., 2022).

The sex ratio (percentage of males) remained consistent across years, varying between 11.57 and 12.63 per cent (Table 1). Such a balanced and stable male proportion is favourable for normal population development, as extreme male-biased ratios can negatively influence brood lac production. The limited year-to-year variation suggests that sex differentiation was not significantly affected by environmental fluctuations. Similar sex-ratios have been documented for *Rangeeni* lac on *B. monosperma* and other compatible hosts by Biyani et al. (2022).

The survival at crop maturity also remained stable, ranging from 4.60 to 5.00 insects/cm², with a mean of 4.82 (Table 1). Although initial settlement densities were comparatively high, only about 5 insects/cm² survived to maturity, which is typical for lac populations where natural thinning occurs due to competition, host resource limitations, and natural mortality factors. The narrow survival range across all years indicates consistent crop performance and comparable host plant carrying capacity. The survival at crop maturity remained constant (4.60-5.00 insects/cm²), supporting the widely known phenomenon of natural thinning during lac development (Sharma & Ramani, 2011; Swami et al., 2021; Biyani et al., 2022).

Overall, the *Baisakhi* crop maintained stable survival, sex ratio, and low mortality across the three years, despite variations in initial settlement density. This stability highlights the resilience of the lac insect under the prevailing agro-climatic conditions and reflects strong host-insect compatibility and the suitability of this host for sustained lac production.

3.2. Duration of Developmental Stages

The duration of pre-sexual developmental remained highly consistent across the three *Baisakhi* crop years. The pre-sexual period ranged narrowly between 113.66 and 114.67 days, with a mean of 114.00 days (Table 2). This uniformity indicates that early developmental processes of the lac insect were not significantly influenced by inter-annual fluctuations in weather or host condition. These findings align with earlier reports that *B. monosperma* provides stable nutritional and physiological conditions conducive to pre-sexual development in the *Rangeeni* strain (Sharma and Ramani 2011; Biyani et al., 2022). The mean longevity of female was 230.34 days (Table 2). Longevity reflects the physiological robustness of the insect-host interaction, and the consistently high values recorded in this study reaffirm the ability of *B. monosperma* to sustain prolonged resin secretion and reproductive activity. These

Table 1. Initial density of settlement, per cent mortality, sex-ratio and survival at maturity of lac insect (*Rangeeni* strain; *Baisakhi* crop) on *Butea monosperma*

Parameters	*Baisakhi* crop*			
	2021-22	2022-23	2023-24	Mean
Initial density of settlement (no./cm²)	89.33 (83-96)	101.11 (98-105)	84.66 (82-89)	91.70
Mortality (%)	8.77 (4-11)	8.56 (5-11)	5.82 (5-7)	7.72
Sex-ratio (% male insects)	12.40 (10.0-13.0)	11.57 (8.96-14.29)	12.63 (12.0-13.50)	12.20
Survival at crop maturity (no./cm²)	5.00±0.23 (3-7)	4.60 (4.33-5.0)	4.86 (4.33-5.33)	4.82

Mean of 3 replications; Figures in parentheses are range values

Table 2. Duration of pre-sexual stages and longevity of female cells (*Rangeeni* strain; *Baisakhi* crop) on *Butea monosperma*

Parameters	*Baisakhi* crop*			
	2021-22	2022-23	2023-24	Mean
Duration of pre-sexual stages (days)	113.66 (110-116)	114.67 (113-116)	113.67 (112-117)	114.00
Longevity of female cell (days)	230.33 (216-245)	231.0 (219-243)	229.7 (215-244)	230.34

Mean of 3 replications; Figures in parentheses are range values

Table 3. Female cell weight, resin output and fecundity of lac insect (*Rangeeni* strain; *Baisakhi* crop) on *Butea monosperma*

Parameters	*Baisakhi* crop*			
	2021-22	2022-23	2023-24	Mean
Fecundity/female (no.)	139.7 (119-167)	161.17 (154-166)	139.87 (123-165)	146.91
Female cell weight (mg)	8.66 (6.30-9.85)	7.87 (7.40-8.68)	8.43 (7.50-9.32)	8.32
Resin output (mg)	5.81 (4.00-7.55)	4.74 (4.60-4.87)	5.51 (5.20-5.82)	5.35

Mean of 10 replications; Figures in parentheses are range values

observations corroborate earlier findings that emphasize extended female cell duration as a hallmark of favourable host suitability (Monobrullah et al., 2015; Biyani et al., 2022). Overall, key developmental timings, i.e. pre-sexual duration, male emergence initiation, and female cell longevity were remarkably stable across years for the *Rangeeni* strain on *B. monosperma*. This consistency reflects the suitability of the host species for lac insect development and highlights the host's reliability for maintaining synchronized development, healthy female longevity, and predictable crop progression. The results confirm the robustness of this host species for sustaining optimal lac insect development under *Baisakhi* crop conditions (Monobrullah et al., 2015; Swami et al., 2021).

3.3. Productivity-linked Traits

The reproductive and productivity traits of the *Rangeeni* strain on *B. monosperma* exhibited moderate but consistent patterns over the three *Baisakhi* crop seasons (Table 3). The fecundity fluctuated noticeably across seasons, maximum was 161.17 in 2022-23. The pooled mean fecundity was 146.91 indicating strong evidence of the biological suitability of *B. monosperma* as a host for the lac insect. High fecundity levels reflect favourable nutritional quality and host-mediated physiological support, which are essential for egg maturation and successful oviposition. The consistency of this fecundity across the study period indicates that *B. monosperma* not only sustains normal reproductive output but also provides a stable microenvironment conducive to maximizing the reproductive efficiency of the *Rangeeni* strain (Monobrullah et al., 2015; Swami et al., 2021). Such reproductive performance is a key determinant of long-term lac yield potential, thereby reaffirming the suitability of this host species for sustained and economically viable lac production.

The female cell weight remained relatively stable across the three seasons, with a pooled mean of 8.32 mg (Table 3) The consistency observed in female cell weight indicates reliable nymphal establishment and effective nutrient assimilation from the host. This uniformity indicates that *B. monosperma* maintains adequate vigour and nutritional quality throughout the *Baisakhi* crop cycle, thereby providing a stable resource base essential for optimal growth and development of the lac insect. The resin output exhibited only moderate variation, ranging from 4.74 to 5.81 mg across years (Table 3). Resin secretion is closely linked with female physiological status and host-insect interaction dynamics; therefore, stability in resin output suggests favourable host compatibility and suitable environmental conditions during the study period. The relatively higher resin yield observed in 2021-22 may be attributed to better initial settlement and slightly higher female biomass, a relationship previously reported by Sharma and Ramani (2011). Overall, the findings reinforce the significance of *B. monosperma* as a dependable host for *Rangeeni* lac production. The consistent female development and resin secretion across crop seasons indicate that the host-insect association remains strong, even under variable climatic conditions. The observed variations, though moderate, highlight the importance of continuous monitoring of environmental factors, host health, and strain performance to optimize lac productivity.

4. CONCLUSION

The present study established that *B. monosperma* is a highly suitable and reliable host for the *Rangeeni* strain (*Baisakhi* crop) of *K. lacca* under Punjab conditions. Consistent developmental durations, stable survival rates, and favourable productivity parameters confirm its strong host potential. The results also highlight the adaptability of the strain to the regional agroclimatic conditions. The findings provide essential baseline information optimizing lac cultivation practices and improving regional lac production in Punjab.

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Authors' Contributions

PSS designed the experiment, involved in execution, investigation and manuscript preparation; AT and SK performed the experiment, data analysis and involved in the preparation of tables and figures for the manuscript.

Conflict of Interest

The authors declare no potential conflict of interest.

Declaration of Generative AI and AI-assisted technologies

No use of AI tools have been used in the writing process.

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