

Evaluation of Lac Productivity Parameters of Lac Insect (*Kerria lacca*) on Kusum (*Schleichera oleosa*) Host Tree

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Abstract: The present study evaluated the productivity-linked parameters of the *kusmi* strain of lac insect (*Kerria lacca*) on Kusum (*Schleichera oleosa*) host trees during the *aghani* season of 2020–21 and 2021–22 at farmers' fields. Initial crawler settlement densities varied from 60.0–95.0 crawlers/cm² across lower, middle, and upper portions of twigs with maximum mortality observed in the upper portions (10.49–13.39%). The mean duration of male emergence ranged from 11.4–12.3 days, while sex ratio analyses revealed a higher proportion of males in the upper portions of twigs (9.96–12.40%). At crop maturity, female cell densities were highest in the lower portion of twigs (8.40–11.60 cells/cm²). Fecundity of individual female cells ranged from 246–342 crawlers, with an overall mean of 294.53 and 312.1 crawlers in 2020–21 and 2021–22, respectively. The average weight of female cells was 13.32–16.48 mg, producing resin output of 6.33–9.67 mg per cell. Female cell longevity averaged 189–190 days. Fresh sticklac weights per 10 twigs ranged from 57.60–60.47 g, while scraped lac ranged from 47.13–49.37g. The mean fresh and dry weights of 100 lac cells were 6.53–7.08 g and 5.77–6.12g, respectively. Total sticklac yield per plant varied between 49.25–54.03 kg. These results highlight that Kusmi lac exhibits consistent productivity under *aghani* season conditions with lower twigs portion favoring female development and resin production, and upper portions supporting male emergence. The findings provide critical insights into lac insect biology and host interactions, informing improved cultivation strategies and sustainable lac production.

Keywords: Lac insect, *Kerria lacca*, Productivity Parameters, Lac Host Plant, Kusmi Lac.

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I. INTRODUCTION

Lac cultivation is an important agro-based activity that supports the livelihoods of millions of forest and sub-forest dwellers in India. It is primarily practiced in states such as Jharkhand, Chhattisgarh, Madhya Pradesh, West Bengal, Maharashtra, Odisha, and parts of Uttar Pradesh, Andhra Pradesh, Gujarat, and the Northeast Hill (NEH) region. As a labor-intensive and economically rewarding enterprise, lac cultivation provides employment opportunities to both men and women, contributing significantly to household incomes and the rural economy. A survey indicates that lac cultivation contributes, on average, around 28% of total agricultural income (Jaiswal *et al.*, 2006). Approximately 3 to 4 million people are engaged in lac production in India (Rao and Singh, 1990). Additionally, it plays a crucial role in India's foreign exchange earnings through exports, as India remains the

largest global producer and exporter of lac and its value-added products.

The lac insect, *Kerria lacca* (Kerr), belonging to the family Lacciferidae, is a sap-feeding hemipteran insect (Colton, 1984) known to infest more than 400 plant species (Ramani *et al.*, 2008). Among the commonly cultivated host trees, Palas (*Butea monosperma*), Ber (*Ziziphus mauritiana*), Kusum (*Schleichera oleosa*), and Semialata (*Flemingia semialata*) are the most significant for commercial lac production (Sharma *et al.*, 1997; Pal, 2009; Singh *et al.*, 2009; Mohanta *et al.*, 2014). Additionally, *K. lacca* has been reported on *Acacia tortilis* and *Calliandra surinamensis* (Ramani and Sharma, 2010). The insect undergoes four developmental stages- egg, larva, pupa, and adult during which the female secretes lac, a resinous substance that forms encrustations on twigs (Ogle *et al.*, 2006). This natural resin

is widely used in industries such as food, cosmetics, pharmaceuticals, and varnish production.

India produces over 20,000 tons (Sharma *et al.*, 2006; Ogle *et al.*, 2006; Pal *et al.*, 2009 and 2011) of lac annually, with Jharkhand being the leading producer, followed by Chhattisgarh, Madhya Pradesh, Maharashtra, and West Bengal. The *aghani* season contributes the highest share of lac production, followed by Jethwi, Katki, and Baisakhi. Approximately 75% of the total lac produced is exported to more than 100 countries, with key international markets including Indonesia, Germany, the U.S.A., Spain, Bangladesh, Italy, Switzerland, the U.A.E., and the U.K. The Rangeeni strain accounts for 80–85% of total production, primarily harvested from *Butea monosperma* and *Ziziphus mauritiana*, whereas the Kusmi strain, mainly obtained from *Schleichera oleosa*, produces the highest-quality resin (Paul *et al.*, 2013).

Given its economic importance and vast potential for rural employment generation, the study of lac productivity and its influencing parameters is crucial for improving yield and sustainability. This research aims to analyze key productivity-linked factors, including crawler settlement, mortality rates, sex ratio, female cell density, resin weight, fecundity, and overall production efficiency of the Kusmi strain of lac insect under field conditions. Understanding these parameters can aid in optimizing lac cultivation practices, thereby enhancing productivity and profitability for farmers.

II. MATERIALS AND METHODS

The study was conducted in selected lac-growing farmers where host plant Kusum (*Schleichera oleosa*) was cultivated for lac production during the *aghani* season of 2020-21 and 2021-22. The selected host trees were healthy and of uniform size to ensure consistency in observations. Ten twigs selected before the inoculation of brood lac in three sets (each set three trees) of plant healthy brood lac weighing 6kg has to be use per tree of Kusum. brood lac is make into the bundles of 100g each bundle and were kept in 60 mm nylon net then inoculated on the succulent branch of the host. Larvae (crawlers) of lac insect from brood lac settled on the tree in three weeks from the date of its inoculation. After the emergence of newly hatched nymphs the phunki lac stick bundles were removed from host plants. Observations commenced immediately after inoculation. The observations were recorded as per the standard procedure prescribed by Mohanasundaram *et.al.*2016 as detailed below:

➤ *Initial Density of Settlement (No. of crawlers/cm²)*

Seven days after inoculation, the settlement of first-instar crawlers were recorded. One cm² area on the host plant stem was randomly selected from the upper, middle, and lower sections of the plant. The number of settled crawlers was counted and recorded.

➤ *Initial Mortality (%)*

After 21 days, the density of settled crawlers was re-evaluated. The crawlers which are not able to find suitable sites for settlement die due to starvation. Observation at this stage is the true indication of the number of crawlers actually settled and that have started feeding. The initial mortality percentage was calculated using the formula:

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

➤ *Final Density of Settlement (No. of crawlers/cm²)*

The final density of settled crawlers was determined using the formula:

$$\text{Final density of settlement} = \text{Initial density of settlement} - \text{Initial mortality}$$

➤ *Initiation of Male Emergence (days)*

The time taken for male lac insects to emerge was recorded as the number of days elapsed from inoculation to the first observed emergence of males.

➤ *Sex Ratio (%)*

Male and female lac cells were identified and counted from three different sites (upper, middle, lower) of the same plant. The sex ratio was calculated as follows:

$$\text{Male (\%)} = \frac{\text{Number of male insects}}{\text{Total number of insects}} * 100$$

➤ *Density At Crop Maturity (No. of Female cells/cm²)*

At crop maturity when the lac crop matures with appearance of yellow spot on cell, the number of mature female cells/cm² was recorded using a graph paper with one cm² window to determine crop density.

➤ *Fecundity (No. of Young Ones Produced by the Female Insect)*

Mature female lac cells were individually placed in cotton-sealed vials for about a month. The number of crawlers emerging from each female cell was counted and recorded as the fecundity rate.

➤ *Weight (mg) of the Female Cell and Resin Output*

The weight of individual female lac cells was measured using an electronic balance after larval emergence has completed. The resin output from each female cell was measured after removing the dead insect body from the cell.

➤ *Life Period of Female (days)*

The total lifespan of female lac insects was determined as the duration from inoculation to harvest.

➤ *Fresh Weight (g) of Stick Lac (30 cm Stick)*

The fresh weight of 30 cm lac sticks was measured at harvest for each plant.

➤ *Fresh Weight (g) of Scrapped Lac (30 cm stick)*

After scraping the lac resin from 30 cm lac sticks, the fresh weight of the scrapped lac was recorded.

➤ *Fresh and Dry Weight (g) of 100 lac Cells*

Fresh weight of 100 lac cells were collected from different plant sections (upper, middle, lower) and weighed immediately. Dry weight of the same cells were shade-dried for 7 days and weighed again to determine moisture content.

➤ *Total Yield (kg)*

The total yield (kg per plant) of sticklac was recorded at the time of harvest per tagged plants for each set of experiment.

All experiments were conducted in triplicate for statistical accuracy. The collected data were analyzed using ANOVA (Analysis of Variance) and mean comparisons to assess variations in lac productivity.

III. RESULT AND DISCUSSION

➤ *Initial density of settlement (No of crawlers/cm²)*

The initial density of settlement of first instar crawlers of *Kerria lacca* was assessed on lower, middle, and upper portions of selected twigs during the *aghani* seasons of 2020–21 and 2021–22 across three experimental sets (Table 1). In both years, a consistent vertical gradient in settlement density was observed, with the lower portion of twigs recording the highest mean density, followed by the middle and upper portions. During 2020–21, mean initial settlement densities in set I were 95.00, 78.20, and 60.10 crawlers/cm² on the lower, middle, and upper portions, respectively. Similar trends were recorded in sets II (87.40, 89.60, and 66.00 crawlers/cm²) and III (88.50, 69.40, and 60.00 crawlers/cm²). The observed ranges further supported this pattern, with the lower portion frequently exceeding 85–105, 67–110 and 71–101 crawlers/cm² in set I, II and III, while the upper portion generally remained below this threshold. In 2021–22, the same distribution pattern persisted. In set I, mean densities were 88.20 and 70.10 crawlers/cm² on the lower and middle portions, respectively, with comparatively lower density on the upper portion. Sets II and III similarly demonstrated higher settlement on the lower portion (91.40 and 90.60 crawlers/cm², respectively) relative to the middle and upper portions. Across all sets and both years, category-wise analysis (20–50, 50–80, and ≥80 crawlers/cm²) revealed that the majority of lower twigs consistently fell into the ≥80 category, whereas the upper portion had a greater representation in the lower density classes (Table 2). Overall, the data indicate a stable and reproducible pattern of preferential crawler settlement on the lower canopy region of Kusum trees, irrespective of year or experimental set.

The present study demonstrates a clear vertical stratification in the settlement pattern of first instar crawlers of *Kerria lacca*, with significantly higher densities on the lower portions of twigs across two consecutive seasons. This consistent trend suggests that microhabitat conditions within the canopy strongly influence crawler establishment. The preference for lower portions may be attributed to favorable

microclimatic conditions such as reduced solar radiation, moderated temperature, and relatively higher humidity. First instar crawlers are highly delicate and vulnerable to desiccation; hence, shaded microhabitats likely enhance survival and successful settlement. The reduced density observed on upper twigs, which are more exposed to direct sunlight and environmental fluctuations, further supports this ecological interpretation. The findings align with earlier studies. Kalahal *et al.* (2017) reported similar vertical variation in crawler settlement on pigeonpea, with higher densities on lower plant portions. Sharma and Ramani (2015) observed comparatively lower mean settlement density in the rangeeni strain relative to kusmi strains, indicating that strain-specific biological traits may also influence settlement intensity. Higher settlement densities reported by Mohanta *et al.* (2014) and Monobrullah *et al.* (2016) further highlight the role of host species and ecological conditions in modulating crawler establishment. The reproducibility of the settlement gradient over two years strengthens the ecological validity of the results and underscores the importance of canopy position as a determinant of lac insect population dynamics. From a management perspective, understanding vertical distribution patterns may aid in optimizing brood lac inoculation strategies and improving yield through better placement on host plants.

➤ *Initial Mortality (%)*

The mean per cent initial mortality of first instar crawlers of the *kusmi* strain of *Kerria lacca* was recorded 21 days after broodlac inoculation during the *aghani* seasons of 2020–21 and 2021–22 on Kusum trees. Mortality at this stage represented crawlers that failed to establish successfully after emergence and dispersal (Table 3). During 2020–21, mean mortality (%) in set I was 9.18, 9.35, and 10.49 on the lower, middle, and upper portions of twigs, respectively. In set II, corresponding values were 7.76, 8.22, and 9.71%, while in set III, mortality was 9.73, 11.16, and 10.81% on lower, middle, and upper portions, respectively. Across all sets, mortality was consistently lowest on the lower portion and comparatively higher on the upper portion of twigs. A similar pattern was observed during 2021–22. In set I, mean mortality was 8.96, 11.02, and 11.78% on lower, middle and upper portions, respectively. In set II, mortality values were 8.98, 11.86, and 12.74%, whereas in set III they were 9.53, 11.98, and 13.39% on the respective twig portions. The upper portion consistently recorded the highest mortality in all three sets during the second year as well.

The present investigation demonstrates a distinct vertical gradient in initial mortality of first instar crawlers of *Kerria lacca*, with comparatively lower mortality on the lower portions of twigs and higher mortality on the upper portions. This pattern was consistent across two consecutive seasons and three experimental sets, suggesting that canopy position plays a significant role in early-stage survival. Higher mortality on upper twigs may be attributed to greater exposure to direct sunlight, elevated temperature, and reduced humidity, which can increase desiccation stress in newly settled crawlers. Adverse microclimatic conditions may impair feeding establishment and increase mortality. In contrast, the relatively shaded and humid microenvironment

of the lower canopy likely enhances crawler survival. The present findings are in partial agreement with Kalahal *et al.* (2017), who reported mean initial mortality ranging from 6.46% to 12.58% in the *rangeeni* strain across different canopy levels. Similarly, Divakara (2013) documented variation in mortality across host species, with values ranging from 12.48% to 27.88%, highlighting the influence of host suitability and seasonal factors. Further, Swami *et al.* (2021) reported relatively lower mean mortality (8.84–14.61%) on hosts such as ber, babool, and palas, but higher mortality (15.64%) on *Flemingia semialata*, emphasizing host environment interactions. The comparatively lower mortality recorded in the present study suggests that Kusum remains a favorable host for the kusmi strain during the *aghani* season. However, the consistent increase in mortality towards the upper canopy underscores the importance of microclimatic regulation in lac insect survival. These findings have practical implications for broodlac placement, suggesting that inoculation on lower or moderately shaded portions of host plants may enhance crawler establishment and overall lac yield.

➤ Final Density of Settlement (No. of crawlers/cm²)

The mean final density of settlement of first instar crawlers of the kusmi strain of *Kerria lacca* was recorded on lower, middle, and upper portions of selected twigs during the *aghani* seasons of 2020–21 and 2021–22 (Table 1). During 2020–21, in set I the final settlement density ranged from 77–96, 62–91, and 41–73 crawlers/cm² on lower, middle, and upper portions, respectively, with corresponding means of 86.20, 70.70, and 53.90 crawlers/cm². In set II, mean final densities were 78.60 (lower), 77.10 (middle), and 57.00 (upper) crawlers/cm². Set III showed mean values of 80.10, 61.70, and 53.50 crawlers/cm² on lower, middle, and upper portions, respectively. Across all sets, the lower canopy consistently recorded higher final settlement compared to the upper portion. A similar pattern was observed during 2021–22. The final settlement density ranged between 69–93 crawlers/cm² on the lower portion, 39–90 on the middle portion, and 53–78 on the upper portion across the three sets. Mean final densities in sets I, II, and III were 80.10, 80.00, and 82.10 crawlers/cm² on the lower portion; 62.30, 62.30, and 59.00 on the middle portion and 61.90, 61.50, and 54.80 crawlers/cm² on the upper portion, respectively. Thus, in both years, the lower portion of twigs consistently supported the highest final settlement density. Category-wise analysis (20–50, 50–80, and ≥80 crawlers/cm²) further substantiated this trend. In most cases, the majority of lower twigs fell into the ≥80 crawlers category, whereas the upper portion showed greater representation in the 20–50 and 50–80 categories. Very few or no upper twigs were recorded in the ≥80 category during 2020–21, although a moderate shift towards higher categories was observed in some sets during 2021–22 (Table 2).

The results clearly indicate a stable vertical gradient in final crawler settlement of *Kerria lacca*, with the lower portion of the canopy consistently supporting higher densities across experimental sets and years. This pattern mirrors the trend observed in initial settlement and survival, suggesting that canopy microclimate exerts a sustained influence on

crawler establishment and retention. Higher final densities on the lower portions may be attributed to favorable micro environmental conditions, including moderated temperature, reduced solar radiation, and relatively higher humidity. Conversely, upper twigs, being directly exposed to sunlight and desiccating conditions, may limit sustained settlement, resulting in comparatively lower final densities. The present findings are in agreement with earlier studies. Divakara (2013) reported a maximum settlement density of 77.8 crawlers/cm² under favorable under storey conditions, emphasizing the role of shade and host microhabitat. Similarly, Kalahal *et al.* (2017) observed final settlement densities ranging from 17 to 114 crawlers/cm² in the *rangeeni* strain on pigeonpea, demonstrating wide variability influenced by host and environmental factors. Swami *et al.* (2021) also documented higher final settlement densities on ber (106.03 crawlers/cm²) and babool (103.07 crawlers/cm²), underscoring host suitability as a critical determinant.

➤ Initiation of Male Emergence (days)

The duration of male emergence of the kusmi strain of *Kerria lacca* was calculated as the interval between initiation and completion of adult male emergence during the *aghani* seasons of 2020–21 and 2021–22 (Table 4). During 2020–21, the mean duration of male emergence was 12.3, 12.2, and 12.2 days in sets I, II, and III, respectively, with an overall mean of 12.23 days. In 2021–22, the mean duration of male emergence was slightly lower, with values of 11.9, 11.4, and 11.4 days across the three sets, and an overall mean of 11.57 days.

The present findings indicate that male emergence in the kusmi strain of *Kerria lacca* is a synchronized and temporally compact event, typically lasting around 11–12 days under *aghani* season conditions. The slightly shorter mean duration observed in 2021–22 compared to 2020–21 may be attributed to minor seasonal or microclimatic variations influencing developmental rates. These results are consistent with the findings of Kalahal (2017), who reported mean male emergence durations of 11.30–11.60 days in different experimental sets during the *Katki* season on pigeonpea, with a similar range of 10–14 days. The close agreement suggests that the duration of male emergence is relatively stable across hosts and seasons, provided environmental conditions remain favorable. Earlier studies have documented variation in the timing of male emergence after broodlac inoculation (BLI). Patel (2013) reported adult male emergence of the kusmi strain at 70 days after BLI on *Ziziphus mauritiana*. Saikia *et al.* (2019) observed that male emergence commenced around 45 days after inoculation and continued for approximately 12 days. Vajpayee *et al.* (2019) recorded male emergence between the 129th and 143rd day after BLI, indicating that total crop duration and season significantly influence the onset of emergence. Sharma (1991) reported male emergence in the *rangeeni* strain at 6–7 weeks after inoculation, while Jaiswal and Sharma (2011) noted that adult male longevity in the *rangeeni* strain was limited to about two days. Collectively, these findings suggest that although the onset of male emergence may vary depending on strain, host, and season, the duration of the emergence period itself remains relatively consistent, typically spanning about 10–14 days. This

synchronized emergence is biologically significant, as it ensures effective mating within a narrow window, thereby enhancing reproductive success and crop uniformity. Understanding this temporal pattern is critical for scheduling crop monitoring and predicting subsequent developmental stages in lac production systems.

➤ Sex Ratio (%)

The sex ratio, expressed as per cent male insects, was determined by counting male and female cells/cm² on lower, middle, and upper portions of ten twigs in each of the three experimental sets during the *aghani* seasons of 2020–21 and 2021–22 on Kusum trees infested with the *kusmi* strain of *Kerria lacca* (Table 4). During 2020–21, the mean per cent male insects ranged from 6.07% (lower portion) to 12.40% (upper portion). In set I, the male percentage was 9.05, 10.15, and 12.40% on lower, middle, and upper portions, respectively. In set II, corresponding values were 6.07, 11.13, and 11.97%, while in set III they were 6.39, 7.23, and 11.23%. Across all sets, the upper portion of twigs consistently recorded a higher proportion of males compared to middle and lower portions.

A similar trend was observed during 2021–22. In set I, male percentages were 8.29, 10.45, and 10.81% on lower, middle, and upper portions, respectively. In set II, the values were 7.73, 8.94, and 11.11%, and in set III, 4.48, 5.26, and 9.96% on respective portions. Thus, in both years, the upper canopy region consistently exhibited a relatively higher male proportion, whereas the lower portion showed the least.

The present investigation demonstrates a consistent increase in the proportion of male insects toward the upper canopy region in the *kusmi* strain of *Kerria lacca*. The relatively lower male percentage on the lower portion and higher proportion on the upper portion suggest that micro environmental factors within the canopy may influence sex differentiation or differential survival of male and female individuals. Male lac insects are smaller, short-lived, and non-feeding at the adult stage. It is possible that comparatively harsher conditions in the upper canopy such as greater exposure to sunlight and fluctuating temperatures may differentially affect female survival, resulting in a relatively higher proportion of males. Alternatively, spatial differences in nutrition or physiological stress may influence sex allocation patterns. The findings are in agreement with Swami *et al.* (2017), who reported variation in male percentage across canopy levels in the *rangeeni* strain on pigeonpea during the *Katki* season. Similarly, Sharma *et al.* (2018) observed differences in mean per cent male insects across upper, middle, and lower portions of ber, pigeonpea, and *Flemingia* hosts, indicating that canopy position significantly affects sex ratio expression. However, the male percentages recorded in the present study (generally below 13%) were comparatively lower than those reported by Divakara (2013), who observed up to 26.86% males on ber, and Meshram (2018), who documented values exceeding 23% in *kusmi* and *rangeeni* strains on different hosts. These differences may be attributed to host species, strain characteristics, seasonal conditions, and regional climatic variations.

➤ Density at Crop Maturity (No. of Female cells/cm²)

During 2020–21, set I recorded mean female cell densities of 11.60, 9.80, and 8.90 cells per cm² on lower, middle, and upper portions, respectively. In set II, the corresponding values were 11.50, 8.80, and 6.60 cells per cm² while set III recorded 8.40, 7.40, and 6.50 cells/cm². Across all sets, the density of female cells consistently followed a descending gradient from lower to upper canopy. A similar trend was observed during 2021–22. In set I, mean densities were 9.20, 7.10, and 6.70 cells/cm² on lower, middle, and upper portions, respectively. In set II, the values were 9.30, 8.40, and 6.20 cells/cm², whereas in set III, they were 8.60, 7.90, and 5.20 cells/cm². Thus, in both years, the lower portion of twigs consistently supported a greater density of mature female cells compared to middle and upper portions.

The present investigation demonstrates that canopy position significantly influences the final density of mature female cells of *Kerria lacca*. The consistently higher density recorded on the lower portions of twigs across both years suggests that favorable microclimatic conditions in shaded regions enhance survival and growth of female insects up to maturity. The reduction in density from initial settlement to crop maturity indicates cumulative mortality due to several biotic and abiotic stresses during the life cycle. Early-stage mortality, failure of successful feeding establishment, predation, parasitism, climatic stress, and natural death of males after fertilization may collectively contribute to the observed decline. Additionally, as female cells grow in size during development, adjacent cells may fuse or occupy larger surface area, thereby reducing the apparent per cm² density at maturity. The findings are in partial agreement with Kalahal (2017), who reported maximum female cell density of 11 cells/cm² and minimum of 1 cell/cm² in the *rangeeni* strain on pigeonpea. Similarly, Mohanta *et al.* (2014) documented a density range of 3.38–12.67 female cells/cm² at maturity on palas. The values obtained in the present study fall within this reported range, confirming the influence of host and environmental conditions on female survival and growth. Since the density of mature female cells directly determines lac yield and broodlac potential for the next generation, it represents a critical productivity parameter. The higher densities observed on the lower canopy emphasize the importance of strategic broodlac placement in shaded portions of host plants to maximize survival, cell development, and ultimately lac production.

➤ Fecundity (No. of Young Ones Produced by the Female Insect)

Fecundity of the *kusmi* strain of *Kerria lacca* was assessed by isolating ten mature female cells from each experimental set in individual glass vials and counting the number of crawlers emerged over a period of one month (Table 4). During 2020–21, the mean number of crawlers emerged per female cell was 320.3, 317.2, and 246.1 in sets I, II, and III, respectively, with an overall mean of 294.53 crawlers per female cell. In 2021–22, fecundity values were comparatively higher. The mean number of crawlers per female cell was 341.8, 325.4, and 269.1 in sets I, II, and III, respectively, with an overall mean of 312.1 crawlers.

The present investigation confirms that the *kusmi* strain of *Kerria lacca* exhibits substantial reproductive potential under *aghani* season conditions on Kusum. Typically, a mature female produces 300–1000 eggs within the lac cell, many of which hatch within a short period, resulting in rapid crawler emergence. The findings are consistent with earlier reports. Kong *et al.* (1984) documented reproductive potential ranging from 224–307 eggs in the first generation and 160–240 eggs in the second generation. Similarly, Mishra *et al.* (1999b) reported fecundity ranging from 253–565 and 297–477 larvae per female cell on *Flemingia semialata* and *F. macrophylla*, respectively. Kumar *et al.* (2007) observed the highest fecundity on ber (525.20 and 450.60 larvae) and comparatively lower fecundity on pigeonpea (409.00 and 315.40 larvae). Kalahal (2017) also reported a wide range in crawlers emergence (95–430 crawlers per female cell), with a mean of 249.56 crawlers in the rangeeni strain during the *katki* season. The moderate to high fecundity recorded in the present study indicates favorable host suitability and environmental conditions for reproductive development. Slightly higher fecundity during 2021–22 may be attributed to improved microclimatic conditions or better female cell development. Since fecundity directly determines crawler availability for the next generation and influences broodlac quality, it serves as a crucial parameter for assessing lac crop productivity.

➤ *Weight (in mg) of the Female Cell and Resin Output*

The weight of mature female cells and corresponding resin output of the *kusmi* strain of *Kerria lacca* were determined by randomly selecting ten female cells from each experimental set. After crawler emergence, individual cells were weighed, and resin weight was measured by removing the dead insect body from the mature cell (Table 5). During 2020–21, the mean weight of female cells in sets I, II, and III was 15.70, 16.20, and 17.53 mg, respectively, with an overall mean of 16.48 mg. The corresponding mean resin weights were 7.63, 7.70, and 7.97 mg, with an overall mean of 7.77 mg. Resin weight ranged from 7.00 mg (minimum) to 9.67 mg (maximum) per female cell. In 2021–22, the mean female cell weight was comparatively lower, with values of 12.87, 13.43, and 13.67 mg across the three sets and an overall mean of 13.32 mg. The minimum and maximum female cell weights were 11.33 mg (set III) and 15.67 mg (set II), respectively. The mean resin weight across sets was 7.27, 7.47, and 7.57 mg, giving an overall mean of 7.44 mg. Resin output ranged from 6.33 to 8.67 mg per cell.

The present study indicates that both female cell weight and resin output of *Kerria lacca* are influenced by seasonal conditions, though resin yield per cell showed comparatively less variation than total cell weight. The higher mean cell weight recorded during 2020–21 suggests more favorable growth conditions, possibly linked to microclimatic or nutritional factors affecting host–insect interactions. Kumar *et al.* (2007) documented cell weights ranging from 10.12–14.21 mg on ber and 9.40–13.60 mg on pigeonpea. Similarly, Mishra *et al.* (1999) reported dry cell weights of 8–19 mg and 9–18.83 mg on *Flemingia semialata* and *F. macrophylla*, respectively. Kalahal (2017) also recorded a mean single female cell weight of 13.06 mg, with a range of 6–24 mg,

further supporting the variability observed in the present investigation. Anonymous (1998, 1999) and Sharma *et al.* (2010) documented genetic variability in resin production ranging from 6.48 to 20.94 mg per cell. Sharma *et al.* (2007) reported higher resin output in the *kusmi* strain (16.96 mg) compared to the rangeeni strain (8.07 mg), indicating strain-specific differences. Monobrullah *et al.* (2016) observed resin weights of 16.03–16.97 mg in the rangeeni strain on palas and ber, while Kalahal (2017) reported a mean resin weight of 10.70 mg (range 4–19 mg) on pigeonpea during the *katki* season. The comparatively moderate resin output recorded in the present study may be attributed to agro-climatic factors, host plant characteristics, and inherent genetic variability. Since resin production is the primary economic trait of lac insects, even small variations in per-cell resin weight can significantly influence total yield at harvest. Therefore, understanding seasonal and host-mediated effects on female growth and resin secretion is essential for optimizing lac productivity.

➤ *Life Period of Female (Days)*

The life period of female cells of the *kusmi* strain of *Kerria lacca* was recorded by calculating the time elapsed between inoculations and harvesting (Table 4). During the 2020–21 *aghani* season on Kusum trees, the mean life period ranged from 188 to 190 days across experimental sets, with an overall mean of 189.00 days. In the 2021–22 season, the mean life period ranged from 189 to 191 days, with an overall mean of 190.00 days. These results indicate that female cells maintained relatively uniform longevity across both years.

The results show that female cells of the *kusmi* strain exhibit a long life period, averaging approximately 189–190 days during the *aghani* season. This extended longevity is consistent with the physiological role of female lac insects, which act as the primary sources of lac secretion over several months. The slight variation in life period between sets and years could be attributed to microclimatic differences, host plant condition, or minor environmental fluctuations. The recorded life period in the present study is longer than some previous reports for other strains and hosts. For instance, Kalahal (2017) reported a female cell life span of 116–118 days in the rangeeni strain, whereas Mohanta *et al.* (2014) observed that rangeeni strain on *Butea monosperma* completed its life cycle in approximately 3 months and 16 days. Sharma (1991) also reported 120–137 days for rangeeni strain maturation. These differences underscore the influence of strain, host plant, and seasonal conditions on female longevity.

➤ *Fresh Weighing (g) of 30 cm Stick Lac and Scrapped Lac*

The fresh weight of 30 cm sticklac and scraped lac of the *kusmi* strain of *Kerria lacca* on Kusum trees was recorded from 10 twigs in three experimental sets during the *aghani* seasons of 2020–21 and 2021–22. In 2020–21, the mean sticklac weight across sets I, II, and III was 60.47, 59.07, and 57.60 g, respectively, with an overall mean of 59.05 g. Correspondingly, the mean weight of scraped lac from the same twigs was 49.37, 47.86, and 47.19 g, respectively, with an overall mean of 48.19 g. During 2021–22, sticklac weights for sets I, II, and III were 60.07, 59.27, and 58.93 g, with an

overall mean of 59.42 g. Scraped lac weights in the three sets were 48.89, 48.16, and 47.13 g, respectively, with an overall mean of 48.06 g.

The recorded weights indicate that the kusmi strain consistently produced higher sticklac and scraped lac across both years, with a slight reduction in weight observed in set III in each year. This variation may reflect micro-environmental conditions, twig vigor, or local differences in lac settlement. The observed sticklac weights (57.60–60.47g in 2020–21 and 58.93–60.07g in 2021–22) are comparatively higher than those reported for rangeeni strains, corroborating the higher productivity of kusmi strain observed in previous studies. Comparable findings include Janghel (2013), who recorded 28.74–58.91g per 30 cm lac stick in rangeeni strain on *Butea monosperma*, and Patel *et al.* (2014), who reported 24.26–80.59g in kusmi strain on *Ziziphus mauritiana*, highlighting strain and host dependent differences. Namdev (2014) also noted 16.88–92.03g per 30 cm lac stick in kusmi strain on *Z. mauritiana*, while Meshram (2018) reported highest fresh sticklac weight on Kusum (47.68g) among multiple hosts. Scraped lac followed a similar trend, with kusmi consistently yielding higher weights than rangeeni strains, in agreement with Patel *et al.* (2014) and Meshram (2018). The findings indicate that the kusmi strain on Kusum is highly productive, producing both heavier sticklac and scraped lac, likely due to higher settlement density, female fecundity, and efficient resin secretion. These results reinforce the importance of host selection and strain management in optimizing lac yield for commercial production.

➤ Fresh and Dry Weight (g) of 100 Lac Cells

The fresh and dry weights of 100 lac cells of the kusmi strain of *Kerria lacca* on Kusum trees were recorded from ten selected twigs in three experimental sets during the *aghani* seasons of 2020–21 and 2021–22. In 2020–21, the mean fresh weight of 100 lac cells in sets I, II, and III was 7.05, 6.99, and 6.97g, respectively, with an overall mean of 7.00g. The corresponding mean dry weight of 100 lac cells was 6.47, 5.91, and 5.99g, with an overall mean of 6.12g. During 2021–22, the mean fresh weight of 100 lac cells in sets I, II, and III was 7.08, 6.83, and 6.53g, with an overall mean of 6.81g. The mean dry weight of 100 lac cells across the three sets was 6.03, 5.98, and 5.77g, with an overall mean of 5.93g.

The data indicate that the kusmi strain produces consistently higher fresh and dry weights per 100 lac cells, reflecting good biomass accumulation and potential resin content. Slight reductions in weight in set III across both seasons suggest minor variability due to environmental factors, host twig conditions, or local microclimatic differences. The observed fresh weight of 100 lac cells (6.53–7.08g) aligns closely with the findings of Namdev *et al.* (2015), who reported 6.14–8.02g in kusmi strain on *Ziziphus mauritiana*, and Meshram (2018), who recorded 7.31 g in Kusum. These values are higher than those reported by Janghel (2013) and Patel (2013) for both kusmi and rangeeni strains, indicating superior biomass accumulation in the present study. Dry weight of 100 lac cells (5.77–6.47g) similarly falls within the range reported for kusmi strain by

Namdev *et al.* 2015 (4.25–7.84g) and Meshram 2018 (6.86g on Kusum) and is higher than the reported dry weights for rangeeni strains (2.24–3.72g). The relatively higher dry weight supports higher resin accumulation per cell, consistent with the higher sticklac and scraped lac yield observed in this study. Overall, these findings reinforce that Kusum is a highly suitable host for kusmi strain of lac insect, providing favorable conditions for female cell growth, biomass accumulation, and potential resin production. The consistency across both years also indicates reliability of the kusmi strain for commercial lac production.

➤ Total Yield of Stick Lac (kg/Plant)

The total sticklac yield (kg/plant) of the kusmi strain on Kusum during the *aghani* season was assessed across three experimental sets (each comprising three plants) during 2020–21 and 2021–22 (Table 6). In 2020–21, Set I recorded sticklac yields of 54.03, 51.10, and 50.76 kg/plant from Plants 1, 2, and 3, respectively. In Set II, yields were 53.24, 52.26, and 50.21 kg/plant, while in Set III they were 52.34, 49.92, and 49.89 kg/plant. The maximum yield (54.03 kg/plant) was recorded in Set I, whereas the minimum yield (49.89 kg/plant) was observed in Set III. The overall mean sticklac yield across sets for Plants 1, 2, and 3 was 53.20, 51.09, and 50.29 kg/plant, respectively. Similarly, during 2021–22, Set I produced 53.29, 51.20, and 50.53 kg/plant from Plants 1, 2, and 3, respectively. In Set II, the yields were 52.89, 50.45, and 50.12 kg/plant, while in Set III they were 52.34, 49.75, and 49.25 kg/plant. The highest yield (53.29 kg/plant) was recorded in Set I, and the lowest (49.25 kg/plant) in Set III. The overall mean yield across sets for Plants 1, 2, and 3 was 52.84, 50.47, and 49.97 kg/plant, respectively. Across both years, yield variation among sets was relatively narrow, and Set I consistently recorded the highest production. Inter-annual differences were minimal, indicating stability in sticklac productivity under the prevailing agro-climatic conditions.

The data indicate that kusmi strain on Kusum trees consistently produces high sticklac yields, with maximum production observed in set I in both seasons. This high productivity aligns closely with findings by Meshram *et al.* (2018), who reported a maximum yield of 54.94 kg per tree for Kusum during the *aghani* season. The present yields are considerably higher than earlier reports from India Green (1995) recorded 6–10 kg/tree on *Schleichera oleosa*, 1.5–6 kg for *Ziziphus mauritiana*, and 1–4 kg for *Butea monosperma*. Internationally, Ferdousee *et al.* (2010) reported yields ranging from 8 kg to 80 kg/tree in Bangladesh depending on the host species. Borah and Garkoti (2020) observed even higher yields (120–200 kg/tree) in *Ficus religiosa* and *F. benghalensis*. Variation in sticklac yield across studies can be attributed to several factors, tree size, growth and age, lac insect strain, climatic conditions, management practices, and host plant characteristics. The high yield in the present investigation demonstrates that Kusum trees combined with the kusmi strain under the given agro-climatic conditions are highly suitable for commercial lac production.

IV. CONCLUSION

The present investigation demonstrates that the kusmi strain of *Kerria lacca* exhibits high biological performance and yield stability on Kusum during the *aghani* season. A consistent vertical gradient was observed, with lower canopy portions supporting greater crawler settlement, reduced initial mortality, higher mature female density, and superior yield attributes. Key productivity parameters, including fecundity, resin output, sticklac weight, and total per-plant yield remained stable across two consecutive years, indicating strong host suitability and ecological compatibility. These findings highlight the importance of canopy-position-based broodlac placement and confirm the potential of Kusum-based kusmi cultivation systems for enhancing lac productivity and commercial sustainability under comparable agro-climatic conditions. Future studies should explore genetic and environmental factors influencing lac productivity.

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Table 1:- Mean Initial and Final Density of Settlement of First Instar Crawlers and Mean Density of Mature Female Cells (per cm²) of Kusmi Strain on *Schleichera oleosa* During *aghani* Season 2020-21 to 2021-22.

Set No.	Statistical tools	Initial density of settlement (Crawlers/cm ²)						Final density of settlement (Crawlers/cm ²)						Mean density of mature female (cells/cm ²)					
		2020-21			2021-22			2020-21			2021-22			2020-21			2021-22		
		L	M	U	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U
Set-I	Mean (x)	95.00	78.20	60.10	88.20	70.10	70.00	86.20	70.70	53.90	80.10	62.30	61.90	11.60	9.80	8.90	9.20	7.10	6.70
	SD (σ)	6.70	13.55	13.40	12.79	20.40	12.80	5.57	10.86	12.77	10.13	17.78	11.48	1.07	1.81	1.19	1.32	1.73	1.64
	SE	2.12	4.28	4.25	4.05	6.46	4.05	1.76	3.44	4.04	3.20	5.62	3.63	0.34	0.57	0.38	0.42	0.55	0.52
	Range (R)	85-105	68-104	42-82	67-107	43-103	49-87	77-96	62-91	41-73	69-93	39-90	53-78	10-13	7-13	7-11	7-11	4-10	4-9
Set-II	Mean (x)	87.40	89.60	66.00	91.40	79.40	75.60	78.60	77.10	57.00	80.00	62.30	61.50	11.80	8.60	6.60	9.30	8.40	6.20
	SD (σ)	14.13	8.77	11.50	12.79	11.20	12.80	15.11	8.14	9.98	10.41	9.36	11.50	1.71	1.32	1.43	1.34	1.35	1.75
	SE	4.47	2.77	3.65	4.05	3.54	4.05	4.78	2.57	3.15	3.29	2.96	3.64	0.54	0.42	0.45	0.42	0.43	0.55
	Range (R)	67-110	71-101	47-81	67-107	58-101	49-87	59-108	63-94	44-72	70-94	55-89	50-79	9-14	7-11	5-9	7-11	6-10	4-9
Set-III	Mean (x)	88.50	69.40	60.00	90.60	66.6	75.60	80.10	61.70	53.50	82.10	59.00	54.80	8.40	7.40	6.50	8.60	7.90	5.20
	SD (σ)	12.38	16.47	11.90	8.39	14.50	12.80	12.94	14.72	10.63	9.55	14.97	16.18	1.50	1.26	1.90	0.97	1.37	1.75
	SE	3.91	5.21	3.78	2.65	4.47	4.05	4.09	4.65	3.36	3.02	4.73	5.11	0.48	0.40	0.60	0.30	0.43	0.55
	Range (R)	73-105	48-101	43-78	81-107	41-91	49-87	61-99	47-87	41-65	72-101	34-87	34-87	6-11	6-10	3-9	7-10	6-10	3-8

*L-Lower portion of twigs *M-Middle portion of twigs *U-Upper portion of twigs

Table 2:- Category Wise Mean Initial and Final Density of Settlement (Per cm²) of First Instar Crawlers of Strain on *Schleichera oleosa* During *aghani* Season 2020-21 to 2021-22

Initial density of settlement (crawlers/cm ²)																					
2020-21									2021-22												
Category	Set -I			Set -II			Set -III			Set -I			Set -II			Set -III					
	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U			
20-50	0	0	3 (45.33)	0	0	3 (4.00)	0	1	4 (8.00)	0	2	1 (4.00)	0	0	1 (4.00)	0	0	1 (4.00)	0	1	3 (4.00)
50-80	0	7	6 (70.3)	3	6	7 (6.67)	3	6	7 (6.67)	3	6	6 (6.67)	3	5	7 (6.67)	3	8	5 (6.67)	0	0	7 (6.67)
80 and above	10	3	1 (95.00)	7	9	1 (91.43)	7	9	0 (9.00)	7	2	7 (9.00)	7	4	7 (9.00)	7	2	4 (9.00)	10	6	2 (90.00)
Final density of settlement (crawlers/cm ²)																					

2020-21										2021-22								
Category	Set - I			Set - II			Set - III			Set - I			Set - II			Set - III		
	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U	L	M	U
20-50	0 (0.00)	0 (0.00)	5 (43.20)	0 (0.00)	0 (0.00)	3 (4.67)	0 (0.00)	3 (4.53)	4 (41.75)	0 (0.00)	3 (42.33)	1 (41.00)	0 (0.00)	0 (0.00)	2 (45.50)	0 (0.00)	3 (41.00)	3 (33.33)
50-80	2 (78.50)	8 (70.71)	5 (64.60)	7 (71.00)	8 (73.28)	7 (62.28)	5 (62.20)	5 (62.20)	6 (61.33)	5 (72.00)	5 (63.40)	9 (64.22)	6 (73.50)	9 (64.11)	8 (65.50)	6 (75.50)	6 (62.17)	7 (64.00)
80 and above	8 (88.12)	3 (65.87)	0 (0.00)	3 (96.33)	2 (89.00)	0 (0.00)	5 (90.80)	2 (85.00)	0 (0.00)	5 (82.20)	2 (89.50)	0 (0.00)	4 (89.75)	1 (89.00)	0 (0.00)	4 (92.00)	1 (87.00)	0 (0.00)

*L-Lower portion of twigs *M-Middle portion of twigs *U-Upper portion of twigs
 *Figures in parenthesis are average final density of settlement of crawlers (No/cm²)

Table 3:- Mean % Mortality of Crawlers and (%) Male Lac Insect in Kusmi Strain on *Schleichera oleosa* During *aghani* Season 2020-21 to 2021-22

Mean % mortality (crawlers/cm ²)							(%) male lac insect					
2020-21			2021-22				2020-21			2021-22		
	L	M	U	L	M	U	L	M	U	L	M	U
Set - I	9.18	9.35	10.49	8.96	11.02	11.78	9.05	10.55	12.40	8.29	10.45	10.81
Set - II	7.76	8.22	9.71	8.98	11.86	12.74	6.07	11.13	11.97	7.73	8.94	11.11
Set - III	9.73	11.16	10.81	9.53	11.98	13.39	6.39	7.23	11.23	4.48	5.26	9.96

*L-Lower portion of twigs *M-Middle portion of twigs *U-Upper portion of twigs

Table 4:- Mean Duration of Male Emergence (Days), Mean Fecundity (Per Female Cell) and Mean Life Period of Female (Days) in Kusmi Strain on *Schleichera oleosa* During *aghani* Season 2020-21 to 2021-22

Mean duration of male emergence (days)		Mean fecundity (per female cell)		Mean life period of female (days)		
Set	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
I	12.3	11.9	320.3	341.8	188	189
II	12.2	11.4	317.2	325.4	189	190
III	12.2	11.4	246.1	269.1	190	191
Over all mean	12.23	11.57	294.53	312.1	189.00	190.00

Table 5:- Mean Weight of Female Cell (mg) and Resin Weight Per Cell (mg) of Kusmi Strain of Lac Insect on Kusum Tree (*Schleichera oleosa*) During *aghani* Season 2020-21 to 2021-22.

Parameters	2020-21				2021-22			
	Set- I	Set - II	Set - III	Over all mean	Set-I	Set- II	Set - III	Over all mean
Female cell weight (mg)	15.70	16.20	17.53	16.48	12.87	13.43	13.67	13.32
Resin weight (mg)	7.63	7.70	7.97	7.77	7.27	7.47	7.57	7.44
Mean fresh weight (g) of 100 lac cell	7.05	6.99	6.97	7.00	7.08	6.83	6.53	6.81
dry weight(g) of 100 lac cell	6.47	5.91	5.99	6.12	6.03	5.98	5.77	5.93
Fresh weight (g) of 30 cm stick lac	60.47	59.07	57.60	59.05	60.07	59.27	58.93	59.42
Fresh weight (g) of Scrapped lac (30 cm stick lac)	49.37	47.86	47.19	48.14	48.89	48.16	47.13	48.06

Table 6. Total Yield of Stick Lac of Kusmi Strain of Lac Insect on Kusum Tree (*Schleichera oleosa*) During *aghani* Season 2020-21 to 2021-22.

Set	Total Yield (Kg/plant)					
	2020-21			2021-22		
	Plant 1	Plant 2	Plant 3	Plant 1	Plant 2	Plant 3
I	54.03	51.10	50.76	53.29	51.20	50.53
II	53.24	52.26	50.21	52.89	50.45	50.12
III	52.34	49.92	49.89	52.34	49.75	49.25
Mean	53.20	51.09	50.29	52.84	50.47	49.97