Effect of Population Density of *Kerria lacca* Kerr. on its Growth and Survival


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**A B S T R A C T**

A field experiment on effect of population density of lac insect *Kerria lacca* Kerr. on its growth and survival was conducted on *Cajanus cajan*, with seven treatments replicated thrice, during the year 2018-19. Lac insect population of 40, 50, 60, 80, 100, natural population per 2.5cm² as well as no insect were the seven treatments the highest survival of lac insect from brood lac inoculation to harvest was 81.53 percent in the population density of 40 insects per 2.5cm². Highest of male insects was 6.67 per 2.5cm² in the natural population settlement of 127.39 lac insects per 2.5cm², while least 1.39 was in 60 lac insects per 2.5cm². Male emergence was observed between 129th and 143rd day after brood lac inoculation.

**Key words**

Pigeon pea, Insects, Economical, Competition, Production

**Introduction**

Growth and survival of an organism depends on the population density, food, and shelter or protection (Basiago, 1999) available in the ecosystem. Intra-specific as well as inter-specific competition (Grosholz, 1992) for food and survival is well acknowledged. Both these factors have an effective role in the population density also (Hansen *et al.*, 1999).

Lac insect *Kerria lacca* Kerr. is a minute scale insect belonging to the family Tachardiidae (Kerriidae), superfamily Coccoidea of the order Hemiptera (Pal 2009 and Mohanta *et al.*, 2012). It is economically important insect specially due to lac it produce and lac is a minor forest produce (Shah *et al.*, 2015), cash crop (Ramani *et al.*, 2007) and an export commodity (Anon, 2005). Lac production and productivity depends on its host management, quality of brood use (Shah *et al.*, 2015) and live lac insects settled (Khobragade *et al.*, 2012, Rathore 2011, Jhangel *et al.*, 2013, Namdev *et al.*, 2015, Sharma *et al.*, 2015, Ghugal *et al.*, 2015 and Sahu *et al.*, 2016) till the maturity of the lac crop. Quantity of brood to be use for effective inoculation of lac insect
have been studied (Kumar et al., 2017) in the past, but effective population density at initial settlement for maximum live lac insect at maturity of lac crop is as an important information gap. Thus, the present field study was conducted to generate data to fill the existing knowledge gap on lac insects.

Materials and Methods

The present field trial was conducted in Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh between June 2018 to May 2019. The topography of the experimental area was fairly uniform. The Randomized Block Design experiment had seven treatments and three replication of Cajanus cajan variety TJT- 501. The plant to plant and row to row spacing was 6ft x 6ft. There were three plants per replication of each of the seven treatments.

Climate

The climate of Jabalpur district is typically Sub humid, featured by hot dry summer and cool dry winter. Jabalpur is situated between 23º 09' North latitude and 79º 58' East longitudes at an altitude of 411.78 meters above the mean sea level. Jabalpur district lies in the Agro-climatic zone VII i.e. Kymore Plateau and Satpura Hills and Agro-ecological region number 10 [Central Highlands (Malwa and Bundhelkhand)], Sub region number 10.1, [hot sub-humid eco-region (Malwa Plateau, Vindhyan scarp land and Narmada Valley)].

Weather conditions were almost favourable for the growth and development of pigeon pea. The monsoon commenced in the first week of July and terminated in the 1st week of October. The total rainfall received during the crop season was 1162.90 mm, which was equally distributed in 58 rainy days from July to last week of May. Minimum and maximum mean temperature ranged from 4.80 °C to 24.90 °C and 28.50 to 41.80 °C, respectively. The relative humidity ranged between 82 to 87 percent in the morning and 29 to 55 percent in the evening. The sunshine hours varied between 0.50 to 10.30 hours per day. The details of the treatment are given in Table 1.

Nursery raising of C. cajan

Nursery of C. cajan was raised in the month of May 2018 on the substrate (Kapu + FYM) filled polythene bag (18 x 16 cm) by sowing seeds treated with Trichoderma viridae, Rhizobium and PSB. Polythene bags were perforated to drain out excess irrigation water applied at weekly intervals. Polythene bags were kept in shade.

The seedlings were sprayed with insecticides to prevent insect pest incidence. The growing tips of the seedlings were nipped at 8-12 days interval till its transplantation. Nipping was done to train the seedlings to a bush form.

Layout of the field

The layout of the experiment was planned in the main field to accommodate 63 C. cajan plants. The spacing between plant to plant and row to row in the main field was six feet apart. The spacing between replications was maintained at a spacing of 10 feet.

Substrate

The seedlings of C. cajan was transplanted in used polypropylene bags(PPB) of size 93cm x 61cm filled with substrate consisting of a mixture of 45kg river bed basin soil (Kapu) and 20kg well rotten Farmyard manure (FYM). The Kapu and FYM in the above ratio were thoroughly mixed with the help of a spade to obtain a homogenized substrate. The physio-chemical property of the substrate is mentioned in the. The substrate was gradually filled into the PPB with help of a tasala...
followed by constant shaking the bag to ensure proper settlement and compactness of the substrate. The 65 kg substrate filled PPB attains a dimension of 46 cm height and 125 cm circumference.

The PPB was filled with substrate on the designated spot in the layout of the experiment, such that it is not disturbed in future Table 2.

**Treatment of the substrate**

PPB filled with substrate that was placed in the designated spot as per the experimental design, and was treated with microbes as per the treatments. The microbes were thoroughly mixed in the substrate.

**Transplantation of C. cajan saplings**

*C. cajan* saplings on attaining a height varying from 1.5 feet to 2 feet were transported to the main field. Each of the 63 saplings were place at the base of substrate filled PP.

The polythene bag of the *C. cajan* saplings was carefully removed without disturbing the root system. The sapling with substrate base is carefully transplanted in the PPB and pressed tightly from all corners, followed by watering. The transplantation was done in the evening hours of 15th August 2018.

**Irrigation**

Each of the PPB with *C. cajan* plant was irrigated at regular intervals. Between August to October 2018, it was at 30 days interval while from November 2018 to February 2019 the interval of irrigation was 15 days, but from March 2019 to May 2019, the irrigation schedule was at 10 days interval. Approximately 10 liters water was given per plant during each irrigation with the help of polyethylene pipe fitted to the tap in the field.

**Nipping**

The transplanted *C. cajan* was again nipped at 8-10 days interval till the last week of September, 2018.

**Application of pesticides**

Three sprays of pesticides on *C. cajan* pants were carried out as mentioned in Table 3.

**Brood lac inoculation**

*Rangeeni* brood lac purchased from Adarsh Lac Samiti, Jamankhari village, Tehsil Barghat, district Seoni, M.P. on 02.11.2018 was sorted for quality and predator free brood, before its inoculation on *C. cajan*.

Brood lac stick weighing 15 g was tied at the base of each *C. cajan* in the PPB on 03.11.2018 with the help of a twine as per the treatments.

**Lac insect count**

Lac insects were counted per 2.5 cm² (2.5cm length and 1.0cm width) space on the stem or branch as the case may be.

**Marking of slot**

Once lac insect inserts its stylet into the phloem, it becomes sedentary. Thirty days after BLI, branches with good lac insect settlement were selected for marking of slot of 2.5cm x 1cm size on the bark.

Three slots were made on plant each of 2.5cm². Each slots were designated as S₁, S₂, and S₃. Later stretching a thread between the index fingers of both the hands the lac insect settlements adjacent to the boundaries of the slot is carefully removed to make the slot differentiate from the rest of the lac settlement on the branch.
Digital recording of the insects

Lac insect settlement within the slot was digitally photographed with the help of a Digital Single Lens Reflex (DSLR) camera fitted with 100 mm micro lens by settling it in manual mode with ISO 400 and shutter speed of 4.5 to 6. Several pictures of the slot was taken for clarity, finally the best click was selected and counted with the help of paint 3D program.

Frequency of lac insect count

Counting of lac insects within the slots was done at 65th, 70th, 95th, 125th, 155th and 185th day after BLI. On 70th day of BLI, the number of lac insects were adjusted as per treatments i.e., T1, T2, T3, T4, T5 and T7 with 80, 100, 40, 50, 60, no lac insect (control) and natural settlement respectively.

Emergence of male lac insects

The date of emergence of male lac insects as well as its duration was recorded.

Data analysis

Data was analyzed using parameters given in the Table 4.

The significance among different treatment means was judged by critical difference (C.D) at 5% level of significance for comparison among the treatments, for which the marginal means of each treatment was considered. The following formula was used for various estimations.

\[
\text{Standard error of mean } \text{SEm} \pm = \sqrt{\frac{\text{Ems}}{r}}
\]

Critical difference (C.D.) = \text{SEm} \pm x \sqrt{2} x t 0.05

where,

Ems = error mean sum of square

\[t = 't' \text{ value at 5 } \% \text{ level at error d.f.}

r = number of replications

\[\text{SEm} \pm = \text{standard error of any treatment mean}

\text{CD} = \text{Critical difference}

Results and Discussion

Live lac insects per 2.5cm\(^2\) on 65th day after BLI (07.01.2019)

The mean number of live lac insects settled per 2.5cm\(^2\) of the branches varied from 60.33 to 140.17 (Table 5) on 65th day after BLI (07.01.2019). C. cajan plants in all the treatments were inoculated with brood lac except treatment T6 which was kept free of lac insects. Counting of the settlement of lac insects in a unit space of 2.5cm\(^2\) (2.5cm long and 1.00cm width) space on the lac insect settled branches is considered as a standard protocol by earlier workers viz., Khobragade, (2010), Rathore, (2011), Patel, (2013), Bhalerao, (2013), Shah et al.,(2014), Sharma et al., (2015), Gurjar, (2016), Ghugal et al., (2016), Namdev et al., (2015), Kumar et al., (2017) and Shah et al., (2018).

However Mohanta et al., (2014), Kalahal et al., (2017), Sharma et al., (2018) and Hazarika et al., (2018) has reported lac insect count from 1cm\(^2\). Counting of larvae insects of size varying from 0.2 to 0.5mm with in a small space of 1 cm is extremely difficult in field condition, while from 2.5cm\(^2\) is quite comfortable.

Adjustment population density of live lac insects on 70th day after BLI (12.01.2019)

The density of live lac insects (no. per 2.5cm\(^2\)) was adjusted according to the treatments by
removing excess live lac insects. Finally, all the slots on the C. cajan of treatments T1, T2, T3, T4, T5 and T7 had 80, 100, 40, 50, 60 and 127.39 lac insects per 2.5 cm².

The treatment T7 had mean natural population density 127.39 per 2.5 cm² i.e., the naturally settled live lac insects that was left undisturbed and T6 had no lac insect (Table 5). There was a reduction in the mean live lac insect count per 2.5cm² on the branches after 70th day of BLI in all the treatments during the growth stages of the lac insects.

Initial settlement of lac insects per 2.5cm² space is reported to vary from 52.40 to 63.0 (K hobragade, 2010), 130.44 to 179.54 (Rathore, 2011), 61.40 to 102.60 (Patel, 2013), 37.95 to 58.24 (Sharma et al., 2015), 79.32 to 90.02 (Namdev, 2014), 42.88 to 46.44 (Gurjar, 2016), 49.95 to 51.11 (Ghugal et al., 2016), 44.95 to 50.28 (Kumar et al., 2017) and 84.01 to 88.54 (Shah et al., 2018). Thus, in view of the past studies in the present study the population densities per 2.5cm² were fixed to 0, 40, 50, 60, 80, 100 and natural settlement (127.39).

Live lac insects in different population densities on 125th day after BLI (07.03.2019)

The mean number of lac insects per 2.5cm² continued to reduce in comparison to that on 95th day after BLI. It was maximum 79.11 in the population density of 127.39 per 2.5 cm² while it was minimum 33.78 cm in that with population density of 60 insects per 2.5 cm² on 125th day after BLI.

The mean of live lac insects per 2.5cm² in the population density of 80, 100 and 127.39 per 2.5 cm² were significantly more over rest of the treatments.

However, the mean number of live lac insects in the population densities of 80 and 100 insects per 2.5 cm² were at par with each other, while that in population density of 127.39 per 2.5 cm² differed significantly.

Live lac insects in different population densities on 155th day after BLI (07.04.2019)

The mean number of live lac insects per 2.5cm² on 155th day after BLI continued to reduce from 70th day after BLI.

The mean number of mean live lac insects per 2.5cm² was maximum 72.44 in C. cajan with population density of 127.39 per 2.5cm² while it was minimum 32.39 in C. cajan with population density of 60 insects per 2.5cm² on 155th day after BLI.

The mean number of live lac insects per 2.5cm² in the population density of 80, 100 and 127.39 per 2.5cm² were significantly more over rest of the treatments with BLI.

However the mean number of live lac insects in population densities of 80, 100 and 127.39 per 2.5cm² were at par with each other.
Live lac insects in different population densities on 185th day after BLI (07.05.2019)

The mean number of live lac insects per 2.5cm² on 185th day after BLI varied from a minimum of 31.28 in the population density of 60 insects per 2.5cm² to 70.89 in the population density of 127.39 per 2.5cm². The mean numbers of live lac insects in the population densities of 80, 100 and 127.39 per 2.5cm² were significantly more over 40, 50 and 60 insects per 2.5 cm² with BLI. The mean number of live lac insects in the population densities of 80, 100 and 127.39 per 2.5cm² were at par with each other. Similarly it was at par with each other in population density 40, 50 and 60 insects per 2.5cm². The mean live lac insects in different treatment is reported to vary from 60 to 95.80 (Patel, 2013), 28.13 to 40.53 (Jhanghel, 2013), 51.35 to 64.08 (Namdev, 2014), 38.31 to 43.37 (Gurjar, 2016), 37.05 to 39.34 (Kumar et al., 2017) and 57.48 to 64.08 (Shah et al., 2018).

Survivability of Lac insects at different population densities

We have to understand that among many of the deciding factors for the Lac crop productivity, the percent survival of Lac insects from the BLI to harvest is one of the important factors, as lac is produced by Lac insect. Now, there are again two sub factors in the population density that can play a vital role in Lac production. The emergence and presence of male lac insects, in the lac ecosystem is one sub factor while another sub factor is the loss in the number of Lac insects before and after emergence of the male lac insects. This will matter though be discussed later but the data must be looked with that perspective.

The percent survival of Lac insects is reported in three phases of Lac insect growth after BLI. The duration between 70th to 125th day are usually larval growth and pupal period of the Rangeeni lac insects during summer crop (October to May-June). Male emergence and mating takes place between 125th to 155th day, while the major lac secretion phase is after mating of lac insect i.e., 150th day onwards in case of Baishakhi crop of Rangeeni lac.

Between 70th to 95th day after BLI, the maximum survival of Lac insects was 98.20 percent in the population density of 40 insects per 2.5cm² closely followed by that 94.45 percent in the case of 80 insects per 2.5cm². The lowest percent (73.70%) survival of Lac insect during this period was in the population density of 60 insects per 2.5cm². In comparison to the live lac insects during 70th to 95th day after BLI the maximum survival of lac insects during the 95th to 125th day period was 92.45 and 92.21 percent in the population densities of 50 and 40 insects per 2.5cm² respectively. The minimum percent (76.39%) survival of Lac insects during this period continued in the population density of 60 insects per 2.5cm². However during the 125th to 155th day period the percent survival of lac insects over that during 95th to 125th day period was very high in all the population densities as it varied from 91.57 to 96.50 percent. Similar, in survival percent of Lac insects during 155-185 days period over 125th to 155th day was still higher ranging from 94.84 to 97.86 percent.

The above was the survival percent of the Lac insects during its various growth phases focusing a comparison among the population
densities and with the mean number of live lac insect count of preceding growth phase. The survival percent of lac insects among the population densities when compared from 70th days to 185th day after BLI, it was maximum (81.53%) in the population density of 40 insects per 2.5cm². The survival was 65.70, 65.55 and 62.50 percent in the population densities of 80, 50 and 100 insects per 2.5cm² which were very close to each other. The lowest survival of 52.13 and 55.65 percent was observed in 60 and 127.39 insects per 2.5cm².

Survivability of lac insects from BLI to maturity of crop has been reported by many workers. Shah et al., (2014) reported it from 10.71 to 17.21 percent, while according to Gurjar, (2016) it was from 34.08 to 51.53 percent. Sharma et al., (2015) reported it to be from 33.53 to 41.77 percent in different treatments, while according to Kumar et al., (2017) it varied from 20.86 to 26.05 percent. Namdev et al., (2015) and Shah et al., (2018) also reported that it to varied from 19.63 to 20.58 percent and 20.47 to 23.52 percent respectively in case of Kusmi lac on Z. mauritiana.

Loss of Lac insects from 70th to 185th day after BLI

There occurred a loss in the mean number of Lac insects per 2.5cm² in all the population densities during the growth stages of the Lac insects. Loss of insects means death of insect due to various reasons. In order to simplify the complex information, the loss of Lac insects is reported in percent (Table 6).

During 70th to 95th day after BLI, the percent loss of Lac insect was lowest (1.8%) in the population density of 40 insects per 2.5cm². It was followed by 5.55, 18.0, 20.56, 23.63 and 26.30 percent respectively in population densities of 80, 100, 50, 60 and 127.39 insects per 2.5cm². This trend was not observed during 95th to 125th day period, where the minimum insect loss was of 7.56 percent in the population density of 50 insects per 2.5cm². It was closely followed by 7.78 percent in the population density of 40 insects per 2.5cm². The maximum loss of Lac insects (23.62%) during this period was observed in the population density of 60 insects per 2.5cm². The percent loss of Lac insects was more during 95th to 125th day period over 70th to 95th day. But there was a reduction in the percent loss of Lac insects in almost all the population densities during 125th to 155th day period in comparison to that during 95th to 125th day. The minimum loss of Lac insects was 3.50 and 4.11 percent population densities of 100 and 60 insects per 2.5cm², while the maximum loss of 8.43 and 8.23 percent was in 127.39 and 80 insects per 2.5cm² respectively.

The percent loss of Lac insects during 155th to 185th day period was just 2.14 and 2.77 percent in population densities of 127.39 and 100 insects per 2.5cm² while maximum loss of 5.16 percent was in the population density of 50 insects per 2.5cm².

Loss of lac insect during its growth stages is common and reported by previous worker viz., Khobragade, (2010), Patel, (2013), Jhanghel, (2013), Bhalerao, (2013), Namdev, (2014), Ghugal, (2015), Gurjar, (2016), Sahu, (2016) and Shah et al., (2018). The percent loss of lac insect from BLI to maturity or harvest varies and depends on the various conditions. The mean percent lac insect loss ranged from 7.62 to 16.83 percent (Khobragade, 2010), while according to Patel, (2013) it ranged from 69.14 to 74.52 percent. Bhalerao, (2013) reported it from 73.95 to 81.63 percent, while Jhanghel, (2013), Namdev, (2014), Ghugal et al., (2016) and Kumar et al., (2017) reported it to vary from 68.10 to 73.01, 79.42 to 80.37, 39.60 to 63.41 and 22.99 to 28.85 percent respectively.
Table 1: The details of the treatments and notations used are as below

<table>
<thead>
<tr>
<th>Treatments (Population density per 2.5 cm²)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_1$ = 80 lac insects</td>
<td></td>
</tr>
<tr>
<td>$T_2$ = 100 lac insects</td>
<td></td>
</tr>
<tr>
<td>$T_3$ = 40 lac insects</td>
<td></td>
</tr>
<tr>
<td>$T_4$ = 50 lac insects</td>
<td></td>
</tr>
<tr>
<td>$T_5$ = 60 lac insects</td>
<td></td>
</tr>
<tr>
<td>$T_6$ = 0 lac insect</td>
<td></td>
</tr>
<tr>
<td>$T_7$ = Natural population density 127.39</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Physico-chemical properties of the substrate (65kg) filled in Poly propylene bag (PPB)

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Value (g/65kg substrate)</th>
<th>Method used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Available N</td>
<td>136.15</td>
<td>Alkaline permanganate method (Subbiah and Asija, 1956)</td>
</tr>
<tr>
<td>Available P₂O₅</td>
<td>45</td>
<td>Calorimeter method (Olsen et al., 1954)</td>
</tr>
<tr>
<td>Available K₂O</td>
<td>304</td>
<td>Flame Photometer method (Chapman and Pratt, 1961)</td>
</tr>
</tbody>
</table>

Table 3: Spray schedule of pesticides

<table>
<thead>
<tr>
<th>Spray</th>
<th>Chemical</th>
<th>Dose</th>
<th>Day</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>Emamectin benzoate</td>
<td>1g/liter</td>
<td>30 DAT</td>
<td>To manage foliage feeders</td>
</tr>
<tr>
<td>Second</td>
<td>Cartap hydrochloride</td>
<td>1g/liter</td>
<td>30 days after BLI</td>
<td>To manage predators and parasites of lac insect</td>
</tr>
<tr>
<td>Third</td>
<td>Cartap + Diethane M-45</td>
<td>2g/liter</td>
<td>60 days after BLI</td>
<td>To manage predator and parasites of lac insect and sooty mold</td>
</tr>
</tbody>
</table>

* DAT = Days after transplanting, * BLI = Brood lac inoculation

Table 4: Skeleton of Analysis of Variance (ANOVA)

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>d.f.</th>
<th>S.S</th>
<th>M.S.S</th>
<th>F.cal</th>
<th>F. tab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>(r-1)</td>
<td>SSR</td>
<td>VR</td>
<td>VR/VE</td>
<td>-</td>
</tr>
<tr>
<td>Treatments</td>
<td>(t-1)</td>
<td>SST</td>
<td>VT</td>
<td>VT/VE</td>
<td>F at 5% (t-1), (r-1) (t-1)</td>
</tr>
<tr>
<td>Error</td>
<td>(r-1) (t-1)</td>
<td>SSE</td>
<td>VE</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>(rt – 1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

where,

r = number of replications

where,

r = number of replications

t = number of treatments

V = replication mean sum of square

VT = treatment mean sum of square

VE = error mean sum of square
Table 5 Mean number of live lac insects settled per 2.5 cm² on the *C. cajan* branches under different treatments

<table>
<thead>
<tr>
<th>Treatments (Pop density per 2.5 cm²)</th>
<th>Mean number of live lac insects settlement per 2.5 cm² at days after BLI</th>
<th>Mean survival (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>65th</td>
<td>70th</td>
</tr>
<tr>
<td><strong>T₁ = 80 lac insects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>130.83 (11.46)</td>
<td>80.00 (8.97)</td>
</tr>
<tr>
<td><strong>T₂ = 100 lac insects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>140.17 (11.3)</td>
<td>100.00 (10.02)</td>
</tr>
<tr>
<td><strong>T₃ = 40 lac insects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>79.06 (8.92)</td>
<td>40.00 (6.36)</td>
</tr>
<tr>
<td><strong>T₄ = 50 lac insects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>60.33 (7.46)</td>
<td>50.00 (7.11)</td>
</tr>
<tr>
<td><strong>T₅ = 60 lac insects</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>137.11 (11.69)</td>
<td>60.00 (7.78)</td>
</tr>
<tr>
<td><strong>T₆ = 0 lac insect</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.00 (0.71)</td>
<td>0.00 (0.71)</td>
</tr>
<tr>
<td>**T₇ = 127.39 ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>127.39 (11.26)</td>
<td>127.39 (11.26)</td>
</tr>
<tr>
<td>SE(m) ±</td>
<td>0.64</td>
<td>0.26</td>
</tr>
<tr>
<td>CD at 5%</td>
<td>1.98</td>
<td>0.82</td>
</tr>
</tbody>
</table>

*Figure in parenthesis are transformed values √(x + 0.05)
*mean natural population density

Table 6 Percent of loss in the mean number of lac insects per 2.5 cm²

<table>
<thead>
<tr>
<th>Treatments (Pop density per 2.5 cm²)</th>
<th>Percent of loss in the mean no. of lac insects per 2.5 cm² at different periods after BLI</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70th to 95th day</td>
<td>95th to 125th day</td>
</tr>
<tr>
<td><strong>T₁ = 80 lac insects</strong></td>
<td>5.55</td>
<td>21.40</td>
</tr>
<tr>
<td><strong>T₂ = 100 lac insects</strong></td>
<td>18</td>
<td>18.77</td>
</tr>
<tr>
<td><strong>T₃ = 40 lac insects</strong></td>
<td>1.8</td>
<td>7.78</td>
</tr>
<tr>
<td><strong>T₄ = 50 lac insects</strong></td>
<td>20.56</td>
<td>7.56</td>
</tr>
<tr>
<td><strong>T₅ = 60 lac insects</strong></td>
<td>26.3</td>
<td>23.62</td>
</tr>
<tr>
<td><strong>T₆ = 0 lac insect</strong></td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>**T₇ = 127.39 ***</td>
<td>23.03</td>
<td>19.32</td>
</tr>
</tbody>
</table>

* mean natural population density
Table 7 Sex ratio of lac insects on 155th day after BLI

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Number of Male lac insects</th>
<th>Female &amp; Male ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 = 80 lac insects</td>
<td>4.89</td>
<td>11.15 :1</td>
</tr>
<tr>
<td>T2 = 100 lac insects</td>
<td>2.35</td>
<td>27.55 :1</td>
</tr>
<tr>
<td>T3 = 40 lac insects</td>
<td>1.94</td>
<td>17.63 :1</td>
</tr>
<tr>
<td>T4 = 50 lac insects</td>
<td>2.22</td>
<td>15.53 :1</td>
</tr>
<tr>
<td>T5 = 60 lac insects</td>
<td>1.39</td>
<td>23.32 :1</td>
</tr>
<tr>
<td>T6 = 0 lac insect</td>
<td>0.00</td>
<td>0:00</td>
</tr>
<tr>
<td>T7 = 127.39 *</td>
<td>6.67</td>
<td>10.87 :1</td>
</tr>
</tbody>
</table>

* mean natural population density

In the present study, maximum loss of insect was during the immature stage of lac insects i.e., within 125th day after BLI. High mortality of during immature stages of insects is reported by Khobragade (2010), Patel (2013), Jhanghel (2013), Bhalerao (2013), Namdev (2014), Gugal et al., (2016), Gurjar (2016), Sahu (2016) and Shah et al., (2018). Thus higher percent loss within 125th day of BLI is a natural phenomenon.

Male emergence

Adult male emergence was first observed on 12.03.2019, i.e., on 129th day after the BLI. It was observed till 26.03.2019 i.e., on 143th day after BLI. The duration of presence of adult males in the lac ecosystem was 14 days. This duration provides sufficient opportunity for the agile male to mate with numerous sedentary female lac insects. Both winged as well as wingless adult males were observed. Adult male lac insects within its short life period of three to four days should mate with as many as adult female lac insects. Thus, this growth phase of Lac insect is very important biologically (for generation) and economically (as female produces Lac). In this context more female lac is very important for increasing lac production. Male emergence (Rangeeni lac) at 50th day after BLI in katki crop on Z. mauritiana. Namdev, (2014) reported male emergence in Aghani crop of kusmi lac on Z. mauritiana between 65th and 75th day after BLI, when winged male lac insect were seen, which were short lived.

Female to male ratio in lac insects

As mentioned earlier, the adult male lac insects were observed in between 129th and 143th day after BLI. In the present study, the growth, survival and lac production of Lac insects was studied after the initial maintenance of different population densities of 40, 50, 60, 80,100 and 127.39 (natural settlement) per 2.5 cm² on the branches on 70th day after BLI. Counting of minute agile adult males from the population within the fixed slot size of 2.5 cm² on the branches was very difficult, as any number of male insects from outside the slot can either enter or those in the slot can leave during the tedious counting process. In order to overcome this technical issue, the number of lac insects lost during the live insect count (125th to 155th day period) on 155th day is taken into consideration as male insects because (a) they (males) were observed in between 129th and 143th day after BLI and (b) the life of adult male is just 3 to 4 days. That means even if the last male that may have emerged on 143rd day is expected to live only till 147th day, while
The live insect count was done on the 155th day. Another supporting data to this concept can be drawn from the fact that the maximum percent of loss of Lac insects was during the period of 95th and 125th day. This period coincides with late larval and pupal stage of Lac insects, just 4 days after i.e., on 129th day after BLI adult males emerged.

Taking all the above facts into consideration, the mean number of lac insects lost between 125th and 155th day after BLI is estimated as mean number of 'male insects' in different population densities under the present study. Thus, the mean number of live lac insect count per 2.5cm² on the 155th day was the live female lac insects. Accordingly the mean number of adult male lac insects in the population densities of 40, 50, 60, 80, 100 and 127.39 insects per 2.5cm² was 1.94, 2.22, 1.39, 4.89, 2.35 and 6.67 respectively. Thus a reliable data of male and female lac insects is generated for calculating the female to male sex ratio in the field condition. On this basis, the female to male was highest 27.55:1 in the population density of 100 insects per 2.5cm² closely followed by that 23.32:1 in the population density of 60 insects per 2.5cm². The female to male was lowest 10.87:1 in the population density of 80 insects per 2.5cm² (Table 7) per 2.5cm².

Higher female lac insects in the lac production are a good signal for higher lac production, as female lac secretes lac (Rathore, 2011). Female to male sex ratio of lac insect is reported by many workers, but the variation in sex ratio of lac insects may be due to poor brood, improper brood lac inoculation, host tree management etc. Sex ratio reported by Rathore (2011) varied from 9.04:1 to 10.32: 1, while it was 2.46: 1 to 3.26: 1 reported by Bhalerao (2013).

The percent survival of lac insects is reported of four phases of lac insects growth i.e., between 70th-95th, 95th-125th, 125th-155th and 155th-185th day after BLI. The percent survival of lac insects was maximum (81.53) with population density of 40 insects per 2.5cm² and minimum (52.13) with population density of 60 insects per 2.5cm².

The loss period of lac insects is reported of four phases i.e., between 70th-95th, 95th-125th, 125th-155th and 155th-185th day after BLI. The maximum percent of loss of Lac insects was during the period of 95th-125th day is 23.62 in population density of 60 insects per 2.5cm² and minimum percent loss is 2.14 in population density of 127.39 insects per 2.5cm² on 155th-185th day. During 75th-95th day minimum loss percent of lac insects 1.8 with population density of 40 insects per 2.5cm² and maximum 26.30 in population density of 127.39 insects per 2.5cm². Similarly in 95th-125th day minimum loss percent of lac insects 7.56 with population density of 50 insects per 2.5cm² and maximum 23.62 in population density of 60 insects per 2.5cm². The percent loss of lac insects during 125th-155th day was minimum 3.50 with population density of 100 insects per 2.5cm² and maximum 8.43 in population density of 127.39 insects per 2.5cm². The percent loss of lac insects during 155th-185th day was just 2.14 percent in population density of 127.39 insects per 2.5cm², while maximum loss of 5.16 percent was in population density of 50 insects per 2.5cm².

Adult male lac insects were observed in between 129th-143th day after BLI. The mean number of male lac insects maximum (6.67) with population density of 127.39 insects per 2.5cm², while minimum 1.39 in the population density of 60 insects per 2.5cm². The mean number of female lac insects maximum 27.55 with population density of 100 insects per 2.5cm² while minimum 10.87 in the
population density of 127.39 insects per 2.5cm². The female to male ratio was highest (27.55:1) in the population density of 100 insects per 2.5cm² while the female to male ratio was lowest (10.87:1) in the population density of 127.39 insects per 2.5cm².

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