Original Research Article

Impact of biotic and abiotic stress on survival of lac insects (*Kerria lacca* (Kerr) on pigeon pea (*Cajanus cajan* (L.) Millsp)

Abstract

Cajanus cajan (*C. cajan*) is generally grown in rainfed conditions, and is also a good annual host plant of lac insect. *C. cajan* is widely reported to have biotic stress due to insect pests on it. Lac insect is phloem sap feeder and hence impart a biotic stress. The present field study was conducted to evaluate the survival of lac insects on *C. cajan* by adjusting different levels of biotic and abiotic stress on the host plant. The biotic stress due to insect pests on *C. cajan* was minimised with a periodic spray of contact insecticides. The varying level of biotic stress i.e., No, Low, Medium, and High levels was maintained on *C. cajan* plants with lac insects on it. The three abiotic stresses in this experiment were soil moisture stress. It was managed the irrigation per plant through drips, which was believed that create different levels of moisture stress in soil that will impact the host plant. The abiotic stress was of three levels i.e., Low, Medium, and High. The result reveals that survival percent of Lac insect from brood lac inoculation to the harvest of lac crop was highest 37.52% on *C. cajan* with one primary branch and its secondary branches with lac insect (L_1- Low biotic stress) and 32.13% (W_3- Low soil moisture stress). The study indicates that biotic and abiotic stress play a major role in the growth of the host plants and survival of *Kerria lacca* (*K. lacca*).

Keywords – Biotic, Abiotic, Survival, Lac insect, Pigeonpea.

Introduction

Pigeon pea (*Cajanus cajan* (L.) Millsp) is a significant deep-rooted pulse crop that is mostly grown in rainfed regions by small and marginal farmers in South Africa and India [1]. Interestingly, this group of farmers is undernourished and has a low socioeconomic status. It is an effective lac insect host plant. [2]. The lac insect, *Kerria lacca* (Kerr), is a scale insect that is a member of the superfamilies Lacciferidae, Coccoidea, order Hemiptera and suborder Homoptera. The world's largest producer of lac is India; other significant producers are Indonesia, Thailand, China, Burma, and Sri Lanka. [3]. Abiotic and biotic variables, including weather (rain, heat, and temperature), soil conditions (water, pH, and nutrients),

insect populations, disease incidence, and management techniques (cultivar, irrigation, fertilization, and rotation), all have an impact on crop development and output [4,5]. The process of producing lac requires growing *K. lacca* on its host plants. As a result, in addition to environmental stress, K. lacca's sap feeding causes stress to the host plant. In addition, even the lac insect faces biotic and abiotic stress in a particular ecosystem, which has an impact on lac crop productivity. Lac production causes stress to the host plants, as seen by the 10.9–25.3% decrease in *Z. jujube* yield [6]. Lac insect mortality is a common observation in India and is caused by soil moisture stress and pest burden on the host, particularly during the summer [7- 11], which have reported the effect of abiotic stress on organisms. The ongoing raising of Lac insects on their host trees puts the plants under stress, which causes the trees to weaken and produce fewer coppices in the following years. The biotic stressors in lac production are predators [12]. Three primary predators of *K. lacca* include *Psuedohypatopa pulverea* Meyr (Lepidoptera: Blastobesidae), *Eublemma amabilis* Moore (Lepidoptera: Noctuidae), *Chrysopa lacciperda* Kimmins, and *C. madestes* Banks. (Chrysopidae; Neuroptera) [13-18]. In this context, the present field study was conducted to evaluate survival of lac insects on *C. cajan* by adjusting different levels of biotic and abiotic stress on the host plant.

Materials and methods

The field trial under Ph.D. thesis programme was conducted at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P during the year *kharif – Rabi* season in 2020-21. The field experiment in a Factorial Randomized Completely Blocked Design (RCBD) with three replications comprising of two factors viz., settlement of lac insect on a varying number of branches and varied level of irrigation on pigeon pea crop. The experiment consisted of twenty-one treatment combinations with seven level of lac insects' settlement (L_1 to L_7) and three levels of irrigation (W_1 to W_3).

Treatment details:

Factor A: Biotic stress

Settlement of lac insect on

L_1 - Any one primary branch and its secondary branches with lac

L_2 - Any two primary branches and their secondary branches with lac insects

Low biotic stress

L_3 - Any three primary branches and their secondary branches with lac

Medium

insects	biotic stress
L_4 - Any four primary branches and their secondary branches with lac insects	
L_5 - Any five primary branches and their secondary branches with lac insects	High biotic stress
L_6 – All the primary branches and their secondary branches with lac insects	
L_7 – Control (Plant with no lac insects)	No biotic stress

Factor B: Abiotic stress

W_1 - @ 2-litres h^{-1} (high soil moisture stress)

W_2 - @ 4-litres h^{-1} (medium soil moisture stress)

W_3 - @ 8-litres h^{-1} (low soil moisture stress)

Schedule of operations

The schedule of field operations during the experiment was

i) Nursery raising of *C. cajan* - Nursery of *C. cajan* was raised on the substrate (Kapu + FYM in equal ratio) filled polythene bag of size 18 x 16 cm, by sowing seeds treated with *Trichoderma viridae*, Rhizobium and phosphorus solubilizing bacteria (PSB). Perforated polythene bags with seedlings were irrigated at weekly intervals. The perforated wall of polythene bags drained excess irrigation water. Seedlings were sprayed Insecticides to avoid insect pest infestation. The seedling's growth tips were nipped at 15 days intervals till its transplantation.

ii) Layout of the main field - The experimental layout in the main field was planned in a plot size of 62 feet x 42 feet to accommodate 63 *C. cajan* plants. Plant to plant and row to row spacing was maintained at six feet while, it was ten feet between the replications. Transplantation of *C. cajan* seedlings was done in the evening hours of 16.08.2020, in polypropylene bags (PPB) filled with forty-five kilograms of substrate [19].

iii) Poly propylene bag (PPB) - The PPB weighed 125 g and had a dimension of 93 cm x 61 cm when empty. On filling the PPB with 45 kg substrate filled PPB attained [20] a dimension of 30 cm height and 125 cm circumference. The substrate was filled in the PPB on the designated spot in the layout of the experiment, such that it is not disturbed in the future. Thirty days old seedlings were transplanted in the PPB.

iv) Substrate - *C. cajan* seedlings were transplanted in polypropylene bags (PPB). The substrate was a combination of well-rotted farmyard manure (FYM) and river bed basin soil (Kapu). The substrate consisted of 30 kg of soil and 15 kg of FYM. The soil and FYM were

filled in the PPB in layers i.e., soil followed by FYM. A *tasala* was used to fill the substrate in the PPB. After each filling the PPB was vigorously shaked for compactness.

v) Irrigation - Each PPB with a *C. cajan* plant was irrigated using a drip irrigation system as per the treatment schedule. There was no irrigation from July to September 2020 owing to rain. The irrigation interval was at 7 days from October 2020 to May 2021.

vi) Brood lac inoculation (BLI)- *Rangeeni* brood lac purchased from Adarsh Lac Samiti, Jamankhari village, Tehsil Barghat, district Seoni, M.P. on 30.10.2020, was segregated for quality and predator-free brood before its inoculation on *C. cajan*. Each *C. cajan* in the PPB was inoculated with a 15 g brood lac stick with the help of a twine as per the treatments.

vii) *Phunki* removal - Removal of left-over brood lac twigs from *C. cajan* after complete emergence of lac nymphs from female cells is *Phunki* removal operation. It was carefully removed from *C. cajan* plant 21 days after BLI without damaging the freshly settled lac insect on the branches [1], [21].

viii) Marking of slot - Usually by 30 days after brood lac inoculation (BLI), majority nymphs of *K. lacca* leaves the brood lac cells to settle on the branches of host plant. After settlement the crawlers become sedentary by inserting their stylets into the phloem tissues, to become sedentary. Thirty days after BLI, branches with good lac insect settlement were selected for marking of slot. A 1cm width and 2.5cm length slot was marked on the branch bearing good settlement of lac insects. Three slots S_1, S_2 and S_3 were made on a single branch each of 2.5cm^2. These slots were tagged with the help of woolen threads of different colours for different slots. Stretching a thread between the index fingers of both hands, the insect settlement adjacent to the boundaries of the slot was carefully removed to differentiate the slot from the rest of the lac settlement on the branch [19].

ix) Digital recording - Lac insect settlement within the slot was digitally photographed with the help of a Digital Single Lens Reflex (DSLR) camera fitted with 100mm micro lens by setting it in manual mode with ISO 400 and shutter speed of 4.5-6. Several pictures of the slot were taken for clarity. Finally, the best frame was selected [19].

x) Digital counting - The digital images from the DSLR camera were transferred to the laptop by inserting memory card in the port. The images were opened in the Paint 3D programme of the MS-Windows 10. After enlarging the image on the laptop screen, the brush tool on the tool bar of the Paint 3D programme was selected. Selection of the thickness point of calligraphy pen was selected from 1x to 18x with a contrast colour of the brush tool. This was followed by placing the cursor on the individual lac insect in the image within the slot displayed on the computer screen, on a left click of the mouse, a dot of the selected thickness

and colour appears on the insect. The process was repeated till all the lac insects in the slot of the image had a dot on it. At the end all the dots were counted and recorded as live lac this was followed by saving the image in a designated folder after renaming it for retrieval in future (Patent application no. (201921007852A) [19].

xi) Frequency of lac insect count - Counting of live lac insects within the slots was done on 30 th, 60 th, 90 th, 120 th, 150 th and 180 th day after BLI during the year 2020-21.

Result and discussion

Mean number of live lac insects per 2.5 cm^2 of branches (MNL) on *C. cajan* (host plant)

As mentioned in xi, The MNL were recorded on 30th (28.11.2020), 60th (28.12.2020), 90th (27.01.2021), 120th (26.02. 2021), 150th (27.03.2021) and 180th (26.04.2021) day after BLI.

On 30th day after BLI

(Biotic stress)

On 28.11.2020 i.e., 30 days after BLI, the settlement of lac insects was remarkably good in all the treatments. The MNL varied from 166.26 (L_3) to 209.33 (L_6). Among the two low biotic stresses, The MNL was 186.30 (L_1) and 177.52 (L_2). Among in the medium biotic stress, it was 166.26) (L_3) and 183.63 (L_4), while that in high biotic stress levels were 184.30 (L_5) and 209.33 (L_6). The MNL was significantly higher in (L_6) over L_3 (166.26).

Abiotic stress

The MNL on *C. cajan* at different levels of irrigation (soil moisture stress) varied from 154.73 (W_2 – medium abiotic stress), 156.90 (W_1 – high abiotic stress) to 162.94 (W_3- low abiotic stress), but had no significant difference among the treatments. The irrigation was initiated on 6.10.2020, as the rain was till 25.09.2020. During this period maximum and minimum mean temperature was 29.6ºC and 11.6ºC respectively. Rainfall was just 6.6mm.

The MNL due to the interaction effects of settlement of lac insect on varying number of branches (biotic) and irrigation levels (abiotic) varied from 150.78 (L_3W_1) to 235.44 (L_6W_1). The MNL was significantly higher in L_2W_1 (197.33) L_1W_2 (209), L_1W_3 (191.56), L_4W_3 (207.44), L_5W_3 (200.22), L_6W_3 (223.89) and L_6W_1 (235.44) over L_3W_1 (150.78). However, the former seven interactions were at par with each other.

On 60th day after BLI

(Biotic stress)

In comparison to 30th day BLI, on 60th day a reduction in the MNL due to biotic stress 14.99 (L_1- low biotic stress to 26.65 percent (L_6- high biotic stress) was observed. On 28.12.2020 i.e., 60 days after BLI, the MNL was varied from 128.61 (L_3- medium biotic stress) to 158.37

(L_1- low biotic stress). The MNL was significantly higher in L_6 (153.54) and L_1 (158.37) over L_3 (128.61). However, the former two were at par with each other.

Abiotic stress

The MNL on *C. cajan* at different levels of irrigation though varied from 118 (W_2- medium abiotic stress) 123.84 (W_1- high abiotic stress) to 125.24 (W_3- low abiotic stress) but had no significant difference in the MNL among all the level of irrigation. Between 30 to 60 days after BLI the percent loss in the MNL due to abiotic stress varied from 21.07 (W_1) to 23.74 (W_3). Between 30 and 60 days after BLI, the amount of water per plant was 16 litre (W_1), 32 litres (W_2) and 64 litres (W_3). During this period maximum and minimum mean temperature was 26.2ºC and 8.9ºC respectively. The winter rain during this period was 2.3mm. The MNL due to the interaction effects of settlement of lac insect on varying number of branches (biotic) and irrigation levels (abiotic) varied from 116.22 (L_3W_1) to 182.33 (L_1W_3). The MNL was significantly higher in L_2W_1 (153.44), L_6W_1 (174.22), L_1W_2 (158.66), and L_1W_3 (182.33) over L_3W_1 (116.22). However, the MNL in all the former four interactions was at par with each other. Between 30 to 60 days after BLI the percent loss in MNL varied from 4.81 (L_1W_3) to 36.55 (L_6W_3).

On 90th day after BLI

(Biotic stress)

On 27.01.2021 i.e., 90 days after BLI, the MNL was varied from 107.64 (L_2- low biotic stress) to 126.15 (L_1- low biotic stress). The MNL was significantly higher in L_5 (122), L_6 (120.68), and L_1 (126.15) over L_2 (107.64). The MNL of all the former three treatments were at par with each other. Between 60 to 90 days after BLI the percent loss in MNL varied from 13.43 (L_3) to 21.40 (L_6).

Abiotic stress

The MNL on *C. cajan* at different levels of irrigation though varied from 99.22 (W_1- high abiotic stress) 100.63 (W_2- medium abiotic stress) to 103.26 (W_3- low abiotic stress) but had no significant difference in the MNL among all the levels of irrigation. Between 60 to 90 days after BLI the percent loss in MNL due to abiotic varied from 14.72 (W_2) to 19.88 (W_1). The total water supply per plant varied from 36 liters (W_1), 72 litres (W_2) to 144 litres (W_3) between 30 to 90 days after BLI. The MNL due to the interaction effects of settlement of lac insect on varying number of branches (biotic) and irrigation levels (abiotic) varied from 99.56 (L_3W_1) to 135.11 (L_1W_2). The MNL was significantly higher in L_2W_1 (121.11), L_6W_1 (127.32), L_1W_2 (135.11), L_4W_3 (127.22), L_5W_3 (130.44) and L_6W_3 (122.58) over L_3W_1 (99.56). The MNL of all the former six interactions were at par with each other. Between 60

to 90 days after BLI, the percent loss in MNL varied from 6.97 (L_3W_2) to 27.30 (L_1W_3). During this period maximum and minimum mean temperature was 25.3ºC and 10.1ºC respectively, where the rainfall was just 0.9mm. In the first three observations, the weather was favorable (November to January) and the lac insects were still in their immature stage, therefore both biotic and abiotic factors were almost the same. During 120 to 180 days after BLI (February to April) which had extreme weather with a temperature range of 26.7ºC to 37.7 ºC, the lac insects were in the adult stage drawing more phloem sap from the host plant adding biotic stress. Thus, both type of stress was more during this period.

On 120th day after BLI

(Biotic stress)

The MNL was varied from 85.96 (L_3- medium biotic stress) to 106.91 (L_1- low biotic stress). The MNL was significantly higher in L_5 (96.96), L_6 (93.85) and L_1 (106.91) over L_3 (85.96). The MNL of all the former three treatments were at par with each other. Between 90 to 120 days after BLI, the percent loss in MNL varied from 15.25 (L_1) to 23.56 (L_6). There was 10.09 to 13.55 percent more MNL loss as compared to 60 to 90 BLI due to increased biotic stress.

Abiotic stress

The MNL on *C. cajan* at different levels of irrigation varied from 77.38 (W_1- high abiotic stress) 81.52 (W_2- medium abiotic stress) to 82.66 (W_3- low abiotic stress). The MNL was significantly higher in (W_3) over W_2 and W_1. Between 90 to 120 days after BLI the percent loss in MNL varied from 18.99 (W_2) to 22.01 (W_1). There was 10.71 to 29 percent more loss in MNL as compared to 60-90 BLI due to increase abiotic stress temperature and wind speed 1.4 ºC and 0.03 km/h respectively. The total water supply per plant varied from 52 litres (W_1), 104 litres (W_2) to 208 litres (W_3) between 30 to 120 days after BLI. During this period the maximum and minimum mean temperatures were 26.7ºC and 9.3ºC respectively. There was winter rain and it was 12.6mm. The total rainy days was two. The MNL due to the interaction effects of settlement of lac insects on varying number of branches (biotic) and irrigation levels (abiotic) varied from 78.22 (L_3W_1) to 124.11 (L_1W_2). The MNL was significantly higher in L_1W_1 (90.78), L_2W_1 (95.78), L_5W_1 (92.89), L_6W_1 (98.78), L_1W_2 (124.11), L_2W_2 (91.74), L_3W_2 (97.11), L_5W_2 (90.56), L_1W_3 (105.85), L_3W_3 (82.56), L_4W_3 (103.78), L_5W_3 (107.44) and L_6W_3 (100.56) over L_3W_1 (78.22). However, all the former thirteen interactions were at par with each other. Between 90 to 120 days after BLI, the percent loss in MNL varied from 8.14 (L_1W_2) to 28.05 (L_4W_1).

On 150th day after BLI

(Biotic stress)

The MNL was varied from 61.11 (L_3- medium biotic stress) to 80.03 (L_1- low biotic stress). The MNL was significantly higher in L_4 (64.33), L_5 (67.93) and L_1 (80.03) over L_3 (61.11), however, the former three were at par with each other. Between 120 to 150 days after BLI the percent loss in MNL varied from 25.14 (L_1) to 33.19 (L_6). There was 40.87 to 64.85 percent more MNL loss as compared to 90 to 120 BLI due to increased biotic stress and male emergence.

Male emergence and mating take place between 120th and 150th day of BLI while the major Lac secretion phase is after mating of female Lac insect i.e., 150th day onwards in case of Baishakhi crop of *Rangeeni* Lac. Adult female lac insects play a major role in lac production. In comparison to male lac insects, female insects have longer life i.e., emergence from egg to the harvest of lac crop at maturity. Adult male insect on the contrary has a very short life span of 3 to 5 days, when it aggressively mates with its adult females.

Abiotic stress

The MNL on *C. cajan* at different levels of irrigation varied from 53.25 (W_1- high abiotic stress) 58.41 (W_2- medium abiotic stress) to 59.38 (W_3- low abiotic stress). The MNL was significantly higher in (W_3) and ($W_{2)}$ over ($W_{1)}$. However, the former two were at par with each other. Between 120 to 150 days after BLI, the percent loss in MNL varied from 28.16 (W_3) to 33.18 (W_1). There was 48.28 to 50.74 percent more MNL loss as compared to 90 to 120 BLI due to abiotic stress increased temperature and wind speed 6.8ºC and o.4 km/h respectively. The total water supplied per plant varied from 68 litres (W_1), 136 litres (W_2) to 272 litres (W_3) between 30 to 150 days after BLI. The maximum and minimum mean temperature during this period was 33.5ºC and 14.3ºC respectively. Rainfall was 6.2mm. The MNL due to the interaction effects of settlement of lac insects on varying number of branches (biotic) and irrigation levels (abiotic) varied from 51.22 (L_6W_2) to 90.78 (L_1W_2). The MNL was significantly higher in all the interactions except L_3W_1 (7.40) and L_6W_2 (7.19). However, rest of the treatments were at par with each other. Between 120 to 150 days after BLI, the percent loss in MNL varied from 21.38 (L_1W_3) to 37.69 (L_6W_2).

On 180th day after BLI

(Biotic stress)

The MNL was varied from 52.19 (L_{3-} medium biotic stress) to 69.89 (L_{1-} low biotic stress). The MNL was significantly higher in L_5 (58.85) and L_1 (69.89) over L_3 (52.19), however, the former two were at par with each other. Between 150 to 180 days after BLI the percent loss in MNL varied from 12.68 (L_1) to 17.50 (L_4). There was 89.65 to 98.26 percent more female adult was

survive as compared to 120-150 BLI.

Abiotic stress

The MNL on *C. cajan* at different levels of irrigation varied from 43.62 (W_1- high abiotic stress), 49.65 (W_2- medium abiotic stress) to 52.35 (W_3- low abiotic stress). The latter (W_3) was significantly higher than (W_1) but was at par with (W_2). Between 150 to 180 days after BLI the percent loss in MNL varied from 11.84 (W_3) to 18.09 (W_1). The total water per plant varied from 84 litres (W_1), 168 litres (W_2) to 336 litres (W_3) between 30 to 180 days after BLI. During these period maximum and minimum mean temperature was 37.7ºC and 17.4ºC respectively. The rain during the period was 0.6mm. The MNL due to the interaction effects of settlement of lac insects on varying number of branches (biotic) and irrigation levels (abiotic) varied from 41.22 (L_6W_2) to 79.89 (L_1W_2). The MNL was significantly higher in all the interactions except and L_6W_2 (6.46). However, rest of the interactions were at par with each other. Between 150 to 180 days after BLI, the percent loss in MNL varied from 7.61 (L_1W_3) to
20.82 (L_6W_1).

Mean survival percent

The percent survival of Lac insects is reported here is in three phases of Lac insect growth after BLI. The duration between 30th and 120th day of BLI is usually larval growth and pupal period of the Baishakhi crop of *Rangeeni* Lac insects. The overall mean percent survival of lac insects from 30 days after BLI to 180 days after BLI was highest 37.52% in (L_1- low biotic stress) followed by 31.93% (L_5- high biotic stress), 31.39% (L_3- medium biotic stress), 29.88% (L_2- low biotic stress) and 28.90% (L_4- medium biotic stress), while it was lowest 25.19% in (L_6- high biotic stress). The percent survival in (L_1- low biotic stress) was 48.94 % more as compared to (L_6- high biotic stress).

The overall mean percent survival of lac insects at different levels of irrigation (soil moisture stress) varied from 27.80 percent (W_1- high abiotic stress), to 32.13 percent (W_3- low abiotic stress). The latter was closely followed by 32.09 percent (W_2- medium abiotic stress). The percent survival in (W_3) was 15.57 % more as compared to (W_1), while in (W_2) it was 15.43 %. The percent survival in (W_3) was 0.12 % more as compared to (W_2) and it takes 168 litres more water as compared to (W_2). The total water per plant varied from 84 litres (W_1), 168 litres (W_2) to 336 litres (W_3) between 30 to 180 days after BLI.

Discussion

Mean live lac insects (MNL) per 2.5cm^2 on *C. cajan*

Survival and growth of insects especially phloem feeders depend on the quantity and quality of

Table 1: Mean number of live lac insect (MNL) count per 2.5. cm^2 on the branches after BLI

Treatments	30th	60th	90th	120th	150th	180th	Mean Survival (%)
Factor A (Biotic stress)							
L_1	186.30 (13.62)	158.37 (12.58)	126.15 (11.24)	106.91 (10.34)	80.03 (8.95)	69.89 (8.35)	37.52
L_2	177.52 (13.29)	136.77 (11.69)	107.64 (10.39)	88.65 (9.43)	63.00 (7.96)	53.04 (7.31)	29.88
L_3	166.26 (12.89)	128.61 (11.34)	111.33 (10.56)	85.96 (9.29)	61.11 (7.84)	52.19 (7.25)	31.39
L_4	183.63 (13.53)	140.37 (11.87)	119.44 (10.95)	91.30 (9.57)	64.33 (8.04)	53.07 (7.31)	28.90
L_5	184.30 (13.55)	138.86 (11.80)	122.00 (11.06)	96.96 (9.86)	67.93 (8.26)	58.85 (7.69)	31.93
L_6	209.33 (14.44)	153.54 (12.39)	120.68 (11.00)	93.85 (9.70)	62.70 (7.93)	52.74 (7.27)	25.19
L_7	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	-
SEm(±)	0.31	0.32	0.19	0.11	0.05	0.05	
CD(5%)	0.88	0.91	0.56	0.31	0.15	0.15	
Factor B (Abiotic stress)							
W_1	156.90 (11.67)	123.84 (10.40)	99.22 (9.34)	77.38 (8.26)	53.25 (6.88)	43.62 (6.24)	27.80
W_2	154.73 (11.60)	118.00 (10.16)	100.63 (9.40)	81.52 (8.46)	58.41 (7.18)	49.65 (6.62)	32.09
W_3	162.94 (11.89)	125.24 (10.45)	103.26 (9.51)	82.66 (8.52)	59.38 (7.24)	52.36 (6.81)	32.13
SEm(±)	0.20	0.21	0.13	0.07	0.03	0.03	
CD (5%)	0.58	0.59	0.36	0.20	0.10	0.10	
Interaction							
L_1W_1	158.33 (12.60)	134.11 (11.60)	110.78 (10.55)	90.78 (9.55)	66.11 (8.16)	52.89 (7.30)	33.40
L_2W_1	197.33 (14.05)	153.44 (12.41)	121.11 (11.02)	95.78 (9.51)	65.56 (8.13)	53.11 (7.32)	26.91
L_3W_1	150.78 (12.29)	116.22 (10.80)	99.56 (10.00)	78.22 (8.87)	54.22 (7.40)	47.56 (6.93)	31.54
L_4W_1	175.67 (13.27)	146.11 (12.11)	118.44 (10.91)	85.22 (9.26)	58.89 (7.71)	47.56 (6.93)	27.07
L_5W_1	180.78 (13.41)	142.78 (11.97)	117.33 (10.85)	92.89 (9.66)	60.22 (7.79)	50.56 (7.14)	27.97
L_6W_1	235.44 (15.35)	174.22 (13.22)	127.32 (11.30)	98.78((9.96)	67.78 (8.26)	53.66 (7.36)	22.79
L_7W_1	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	-
L_1W_2	209.00 (14.42)	158.66 (12.62)	135.11 (11.64)	124.11 (11.16)	90.78 (9.55)	79.89 (8.97)	38.22

L_2W_2	183.00 (13.50)	120.67 (11.01)	101.70 (10.11)	91.74 (9.60)	68.34 (8.30)	57.11 (7.59)	31.21
L_3W_2	182.78 (13.53)	133.89 (11.59)	124.56 (11.18)	97.11 (9.88)	70.89 (8.45)	57.33 (7.60)	31.37
L_4W_2	167.78 (12.97)	137.33 (11.74)	112.67 (10.64)	84.89 (9.24)	61.22 (7.86)	52.22 (7.26)	31.13
L_5W_2	171.89 (13.08)	131.15 (11.46)	118.22 (10.90)	90.56 (9.54)	66.44 (8.18)	59.78 (7.76)	34.78
L_6W_2	168.67 (13.00)	144.33 (12.03)	112.16 (10.61)	82.21 (9.09)	51.22 (7.19)	41.22 (6.46)	24.44
L_7W_2	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	-
L_1W_3	191.56 (13.85)	182.33 (13.52)	132.56 (11.53)	105.85 (10.31)	83.22 (9.15)	76.89 (8.79)	40.14
L_2W_3	152.22 (12.34)	136.20 (11.66)	100.11 (10.03)	78.44 (8.88)	55.11 (7.45)	48.89 (7.02)	32.12
L_3W_3	165.22 (12.84)	135.73 (11.63)	109.89 (10.51)	82.56 (9.11)	58.22 (7.66)	51.67 (7.22)	31.27
L_4W_3	207.44 (14.35)	137.67 (11.75)	127.22 (11.30)	103.78 (10.21)	72.89 (8.57)	59.44 (7.74)	28.66
L_5W_3	200.22 (14.16)	142.67 (11.96)	130.44 (11.44)	107.44 (10.39)	77.11 (8.81)	66.23 (8.17)	33.08
L_6W_3	223.89 (14.98)	142.06 (11.93)	122.58 (11.09)	100.56 (10.05)	69.11 (8.34)	63.33 (7.98)	28.29
L_7W_3	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	-
SEm(±)	0.54	0.25	0.14	0.11	0.09	0.09	
CD(5%)	1.53	0.72	0.40	0.32	0.25	0.26	

Figures in parenthesis are √X+0.5 value. Dash represents no brood lac inoculation.

sap access to it [22- 23], as well as protection from its natural enemies [24- 25]. Survival of any insect on a crop or variety indicates its compatibility [26] and preference [27- 28]. There was a loss in lac insects from the first count to the last count at the lac crop maturity i.e., there was a reduction in survival of lac insects. The decline in the MNL is reported earlier by [19], [29- 36] and [37]. The mean percent Lac insect loss ranged from 7.62 to 16.83 percent [29], while according to [30] it ranged from 69.14 to 74.52 percent. [32] reported it from 73.95 to 81.63 percent, while [31], [33], [34] and [38] 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. The survival percent of lac insects from BLI to the harvest of the lac crop was highest (37.52) in (L_{1-} low biotic stress) followed by (31.93) (L_{5-} high biotic stress), 31.39 (L_{3-} medium biotic stress), 29.88 (L_{2-} low biotic stress), 28.90 (L_{4-} medium biotic stress) and 25.19 (L_{6-} high biotic stress). 32.13 (W_{3-} low abiotic stress), 32.09 (W_{2-} medium abiotic stress), and 27.80 (W_{1-} high abiotic stress). The result reveals that less lac insects on branches survival were higher. That means plants with less biotic stress helped in

survival of lac insects. It may be due to less competition for food. A plant with more branches free of lac insects produced enough food for the plant itself and the phloem feeder on it. This reveals that biotic stress on the host plant impacts the survival of lac insects. The survival percent of lac on *C. cajan* reported by earlier workers varied from 24.91 to 38.13 [37]. 48.00 to 61.54 [39] at harvest. 21 to 25 percent [19] from BLI to maturity of lac crop. In the present study, it was observed that the MNL in L_1 was significantly higher throughout the observation period. In *C. cajan* plants of the treatment L_1 refers to the presence of lac insects in only one primary branch and its secondary branches in the whole plant. It means the load of lac insects in the plant was comparatively very less, while the plant was producing enough food for itself and the phloem feeders on it. This means that the host plant could tolerate the pest on it and in the abundant food availability (phloem sap) the insect on it could grow with minimum mortality. In the initial three observations i.e., at 30^{th}, 60^{th} and 90^{th} day after BLI, there was no significant difference in MNL among the different levels of irrigation (abiotic stress). The soil moisture stress during the early three observations may not be much because of the weather factor (immediate day after rains) and less demand for phloem sap by the immature lac insects [21]. However, the MNL was significantly higher in the *C. cajan* plant with less abiotic stress (soil moisture stress) i.e., in plants with high irrigation level. This means the demand of the plant for water was sufficient to meet its growth and reproductive demand as well as the phloem sap drown by the growing lac insects. In the plant with less water supply, there must have been soil moisture stress [40], which may have affected the food supply (phloem sap) to the lac insects. Constraint in food availability may have affected the survival of lac insects in W_1.

This study holds significant scientific relevance. Firstly, it contributes to our understanding of ecological interactions in agricultural ecosystems. By investigating how both biotic (predators) and abiotic (like climate conditions) stressors affect lac insect survival, the study can offer insights into the complex dynamics of these systems [41]. Understanding the ecological factors influencing lac insect populations can lead to better pest management practices and ultimately improve pigeon pea cultivation, an important food and cash crop in many regions [42]. Moreover, it can shed light on potential ecosystem services provided by lac insects, such as natural pest control [43, 44].

From a social perspective, this research carries substantial importance as well. Pigeon pea is a

vital source of nutrition and income for numerous communities, especially in developing countries like those in Latin America. By investigating the factors that impact lac insect survival on pigeonpea, the study may contribute to the development of more sustainable and resilient agricultural practices [45]. This, in turn, can lead to increased crop yields [46], economic stability [47], and improved food security [48]. Furthermore, this research can be linked to broader discussions on sustainable agriculture and the preservation of biodiversity, as it highlights the importance of considering both biotic and abiotic factors in crop management strategies [49].

When compared to studies of environmental factors on pests and diseases in agricultural areas of Latin America, the research on lac insects and pigeon pea presents a unique ecological perspective. While many studies in the region tend to focus on the direct effects of environmental conditions on crops, this research expands the scope to include intricate insect-plant interactions. This holistic approach can provide a valuable complement to existing research, as it adds depth to our knowledge of the complex relationships within agricultural ecosystems [40, 51, 52]. Consequently, this study may serve as a model for how to address similar issues in Latin American agriculture, offering innovative solutions that consider both ecological and environmental factors [53, 54, 55].

Conclusion

The study indicates that biotic and abiotic stress play a major role in the growth of the host plants and survival of *K. lacca*. The result reveals that survival percent of Lac insect from brood lac inoculation to the harvest of lac crop was highest 37.52% on *C. cajan* with one primary branch and its secondary branches with lac insect (L_{1}- Low biotic stress) and 32.13% (W_{3}- Low soil moisture stress).

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