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Impact of Biotic and Abiotic Stress on Survival of Lac Insects *Kerria lacca* Kerr. on Pigeonpea (*Cajanus cajan* (L.) Millsp)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Cajanus cajan is generally grown in rainfed condition. The crop 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 imparts biotic stress. The present field study was conducted to evaluate the percent 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 periodic spray of contact insecticides. The varying level of biotic stress i.e., No, Low, Medium, and High level was maintained on *C. cajan* plants with lac insects on it. The three levels of abiotic stress in this experiment were considered in terms of soil moisture stress. It was managed through irrigation per plant through drip system, it was considered that creating different levels of moisture stress in soil 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 percent on *C. cajan* with one primary branch and its secondary branches with lac insect (L_{1-} Low biotic stress). It was 32.13 percent (W_{3-} Low soil moisture stress). The study indicates that biotic and abiotic stress play a major role in the survival of *K. lacca*.

Keywords: Biotic; abiotic; survival; lac insect; pigeonpea.

1. INTRODUCTION

Pigeonpea (*Cajanus cajan* (L.) Millsp) is a 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 socio - economic status [1]. The crop proved to be an effective lac insect host plant. [2]. The lac insect, *Kerria lacca* (Kerr), is a scale insect that is a member of the superfamily Lacciferidae, Coccoidea, order Hemiptera, and suborder Homoptera. India is the world's largest producer of lac; the other leading producers are Indonesia, Thailand, China, Burma, and Sri Lanka. [3]. Abioticfactors viz., weather (rain, heat, and temperature), soil conditions (water, pH, and nutrients), and biotic factors viz., insect populations, disease incidence, and management techniques (cultivar, irrigation, fertilization, and rotation), all have an impact on crop development and output [4].

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 itself faces biotic and abiotic stress in a particular eco system, which also impacts lac crop productivity. Lac production induces stress on the host plants, as it reduces the yield of *Z. jujube* by10.9–25.3 percent [5]. Lac insect mortality is a common observation in India [4] and is caused by soil moisture stress and pest burden on the host, particularly during the summer [6-10], are the abiotic stress on lac insects. 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 [4].

The biotic stressors in lac production are predators [11]. 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) [12-17]. 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.

2. MATERIALS AND METHODS

The field trial under Ph.D. Thesis programme was conducted at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P in the *kharif* – *Rabi* season 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 varying number of branches and varied level of irrigation on pigeonpea 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).

3. SCHEDULE OF OPERATIONS

i) Nursery raising of *C. cajan*

Nursery of *C. cajan* was raised in polythene bag of size 18 x 16 cm substrate filled with (Kapu + FYM) in equal ratio. The seeds treated with *Trichoderma viridae*, *Rhizobium* and PSB were sown in substrate filled polythene bag with perforation. Perforated polythene bags with seedlings were irrigated at weekly intervals. Excess irrigation water was drained through the perforation. The polythene bags were kept in the shade. Insecticides were sprayed on the seedlings to avoid insect pest infestation. The seedlings growth tips were nipped at 15 days intervals till transplantation.

ii) Layout of the main field

The experimental layout in the main field was planned in 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 were done in the evening hours of 16.08.2020, in polypropylene bags (PPB) filled with forty-five kg of homogeneous substrate [18].

iii) Poly propylene bag (PPB)

The PPB had a dimension of 93 cm x 61 cm and weighed 125 g when empty. The PPB was filled with 45 kg substrate. The substrate packed PPB now had a dimension of 30 cm height and 125 cm diameter [19]. In order to prevent future disturbance, the substrate was filled in the PPB at the precise location indicated in the experiment arrangement. Seedlings were transplanted on 30 day after sowing (DAS) in the PPB.

iv) Substrate

The Substrate consisted of a combination of 30 kg light soil (Kapu) and 15 kg well-rotted farmyard manure (FYM). The PPB was filled with alternate layers of soil and FYM i.e., soil layer followed by FYM then soil. The substrate was filled in the PPB with the help of *tasala.* The PPB was shaked after filling of each layer 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 was at 7 days interval from October 2020 to May 2021.

vi) Brood lac inoculation (BLI)

Quality *Rangeeni* brood lac that was purchased on 30.10.2020, from Adarsh Lac Samiti, Jamankhari village, Tehsil Barghat, District Seoni, M.P. This Samiti is a reputed brood lac supplier in M.P. Each *C. cajan* in the PPB was inoculated with 15 g brood lac stick with the help of a twine as per the treatments.

vii) *Phunki* removal

Removal of the 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 insects on the branches [1], [20].

viii) Marking of slot

Usually by 30 days after BLI, majority nymphs of *K. lacca* leaves the brood lac cells to settle on the branches of host plant. After settlement the crawlers becomes sedentary by inserting its stylets into the phloem tissues. Thirty days after BLI, branches with good lac insect settlement were selected for marking of slot. A slot of 1cm width and 2.5cm length 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 colour for different slots. Stretching a thread between the index fingers of both the hands, the insect settlement adjacent to the boundaries of the slot was carefully removed to make the slot clearly differentiated from the rest of the lac settlement on the branch [18].

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 [18].

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) [18].

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.

3.1 Treatment Details

There were two major factors in the treatment, one was biotic stress factor which consisted on lac insect load on varying number of branches of *C. cajan*. The biotic stress factor was categorised into four levels i.e., Low, Medium, High and No biotic stress. The details are mention as below

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

The Second factor was abiotic stress factor, this was maintained by managing the soil moisture at different levels. It was achieved by managing the discharge of drip irrigation at different rates per hour at weekly interrvals as mentioned below

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)

4. RESULTS AND DISCUSSION

4.1 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.

4.2 On 30th Day After BLI (Biotic Stress)

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 stress, the MNL was 186.30 (L_1) and 177.52 (L_2), while that in the medium biotic stress, it was 166.26) (L_3) and 183.63 (L_4), and in high biotic stress levels were 184.30 (L_5) and 209.33 (L_6). The MNL was significantly higher in (High biotic stress - L_6) over (L_3 - Medium biotic stress). Rest of the treatments were at par with each other.

4.3 Abiotic Stress

The MNL on *C. cajan* at different levels of irrigation (soil moisture stress) though 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 last rainfall during *kharif* season was on 25.09.2020. During this period mean maximum and minimum temperature was 29.6ºC and 11.6ºC respectively.

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.

4.4 On 60th Day After BLI (Biotic Stress)

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 - high biotic stress (153.54) and L_1 (158.37) over L_3 (128.61). However, the former two were at par with each other. There was a decline in the MNL on the 60th day in comparison to that in the 30th day after BLI, the decrease in the MNL varied from 14.99 percent (L_1- low biotic stress) to 26.65 percent (L_6- high biotic stress) was observed.

4.5 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 among all the levels of irrigation. Between 30th to 60th day after BLI the percent loss in the MNL due to abiotic stress varied from 21.07 (W_1) to 23.74 (W_3). Between 30th and 60th day after BLI, the quantity of water per plant during this period was 16 litre (W_1), 32 litres (W_2) and 64 litres (W_3). During this period mean maximum and minimum 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 were 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).

4.6 On 90th Day After BLI (Biotic Stress)

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). At this time the lac insects were still in its immature stage.

4.7 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 60th to 90th day 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 litres (W_1), 72 litres (W_2) to 144 litres (W_3) between 30th to90th day after BLI. There weather was cool and favourable.

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 in 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 mean maximum and minimum temperature was 25.3ºC and 10.1ºC respectively, while the rainfall was just 0.9mm.

During the first three observations (November to January) the weather was favourable and the lac insects were still in its immature stage, therefore both biotic and abiotic factors in all the treatments remained almost the same.

4.8 On 120th Day After BLI (Biotic Stress)

Between 120th to 180th day after BLI (February to April) the weather conditions were extreme with temperature range of 26.7ºC to 37.7 ºC. The lac insects were in adult stage drawing more phloem sap from the host plant adding biotic stress, during this stage the plant was flowering and pod maturity stage. Thus, both type of stress was more during this period.

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 in all the former three treatments were at par with each other. Between 90th to 120th day 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 in comparison to 60th to 90th day after BLI. Even during this period, the lac insects continued in its immature stage.

4.9 Abiotic Stress

The MNL on *C. cajan* in 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 that during 60th to 90th day after BLI. During the observation period the temperature increased by 1.4 ºC over that at 90th day after BLI. The wind speed was 0.03 km/h. 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 mean maximum and minimum temperatures were 26.7ºC and 9.3ºC respectively. There was winter rain occurred for two days with a precipitation of 12.6mm.

The MNL due to the interaction effects of settlement of lac insects on varying number of branches (biotic) and irrigation levels (abiotic) varied from 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 90th to 120th day after BLI, the percent loss in MNL varied from 8.14 (L_1W_2) to 28.05 (L_4W_1).

4.10 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). The former three treatments were at par with each other. Between 120th to 150th day 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 that during 90th to 120th BLI. Male emergence in the present case occurred between 125th and 133th day of BLI. The estimated number of male insect varied from 11.44 to 15.33. The male to female sex ratio varied from 1:5.12 to 1:7.47.

The major Lac secretion phase by female Lac insect is after her 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. 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.

4.11 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 90th to 120th BLI the increase in the temperature and wind speed 6.8ºC and o.4 km/h respectively. The total water supplied per plant between 30th to 150th day after

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	142.78	117.33	92.89	60.22	50.56	27.97

Treatments	30th	60th	90th	120th	150th	180th	Mean Survival (%)
	(13.41)	(11.97)	(10.85)	(9.66)	(7.79)	(7.14)	
L_6W_1	235.44	174.22	127.32	98.78(	67.78	53.66	22.79
	(15.35)	(13.22)	(11.30)	(9.96)	(8.26)	(7.36)	
L_7W_1	0.00	0.00	0.00	0.00	0.00	0.00	-
	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	
L_1W_2	209.00	158.66	135.11	124.11	90.78	79.89	38.22
	(14.42)	(12.62)	(11.64)	(11.16)	(9.55)	(8.97)	
L_2W_2	183.00	120.67	101.70	91.74	68.34	57.11	31.21
	(13.50)	(11.01)	(10.11)	(9.60)	(8.30)	(7.59)	
L_3W_2	182.78	133.89	124.56	97.11	70.89	57.33	31.37
	(13.53)	(11.59)	(11.18)	(9.88)	(8.45)	(7.60)	
L_4W_2	167.78	137.33	112.67	84.89	61.22	52.22	31.13
	(12.97)	(11.74)	(10.64)	(9.24)	(7.86)	(7.26)	
L_5W_2	171.89	131.15	118.22	90.56	66.44	59.78	34.78
	(13.08)	(11.46)	(10.90)	(9.54)	(8.18)	(7.76)	
L_6W_2	168.67	144.33	112.16	82.21	51.22	41.22	24.44
	(13.00)	(12.03)	(10.61)	(9.09)	(7.19)	(6.46)	
L_7W_2	0.00	0.00	0.00	0.00	0.00	0.00	-
	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	
L_1W_3	191.56	182.33	132.56	105.85	83.22	76.89	40.14
	(13.85)	(13.52)	(11.53)	(10.31)	(9.15)	(8.79)	
L_2W_3	152.22	136.20	100.11	78.44	55.11	48.89	32.12
	(12.34)	(11.66)	(10.03)	(8.88)	(7.45)	(7.02)	
L_3W_3	165.22	135.73	109.89	82.56	58.22	51.67	31.27
	(12.84)	(11.63)	(10.51)	(9.11)	(7.66)	(7.22)	
L_4W_3	207.44	137.67	127.22	103.78	72.89	59.44	28.66
	(14.35)	(11.75)	(11.30)	(10.21)	(8.57)	(7.74)	
L_5W_3	200.22	142.67	130.44	107.44	77.11	66.23	33.08
	(14.16)	(11.96)	(11.44)	(10.39)	(8.81)	(8.17)	
L_6W_3	223.89	142.06	122.58	100.56	69.11	63.33	28.29
	(14.98)	(11.93)	(11.09)	(10.05)	(8.34)	(7.98)	
L_7W_3	0.00	0.00	0.00	0.00	0.00	0.00	-
	(0.71)	(0.71)	(0.71)	(0.71)	(0.71)	(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 $\sqrt{X+0.5}$ value. Dash represents no brood lac inoculation

BLI varied from 68 litres (W_1), 136 litres (W_2) to 272 litres (W_3). 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 120th to 150th day after BLI, the percent loss in MNL varied from 21.38 (L_1W_3) to 37.69 (L_6W_2).

4.12 On 180th Day After BLI (Biotic Stress)

The MNL varied from 52.19 ($L_{3\text{-}}$ medium biotic stress) to 69.89 ($L_{1\text{-}}$ 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 150th to 180th day 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 live female adults as compared to that between120th to150th day after BLI.

4.13 Abiotic Stress

The MNL on *C. cajan* at different levels of irrigation varied from 43.62 ($W_{1\text{-}}$ high abiotic stress), 49.65 ($W_{2\text{-}}$ medium abiotic stress) to 52.35 ($W_{3\text{-}}$ low abiotic stress). The latter (W_3) had significantly higher MNL than (W_1) but was at par with (W_2). Between 150th to 180th day after BLI the percent loss in MNL varied from 11.84 (W_3) to 18.09 (W_1). The total water per plant between 30th and 180th day after BLI varied from 84 litres (W_1), 168 litres (W_2) to 336 litres (W_3). During this 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 150th to 180th day after BLI, the percent loss in MNL varied from 7.61 (L_1W_3) to 20.82 (L_6W_1).

4.14 Mean Survival Percent

The percent survival of Lac insects is reported here is in three phases immature stage 30-120 BLI, adult male emergence 125-133 BLI, and adult female 180 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 30th day after BLI to 180th day after BLI was highest 37.52% in ($L_{1\text{-}}$ low biotic stress) followed by 31.93% ($L_{5\text{-}}$ high biotic stress), 31.39% ($L_{3\text{-}}$ medium biotic stress), 29.88% ($L_{2\text{-}}$ low biotic stress) and 28.90% ($L_{4\text{-}}$ medium biotic stress), while it was lowest 25.19% in (L_6- high biotic stress). The percent survival in ($L_{1\text{-}}$ 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 ($W_{2\text{-}}$ medium abiotic stress). The percent survival of lac insects in W_3 was 15.57 percent more as compared to W_1, while in W_2 it was 15.43 percent. The percent survival in W_3 was 0.12 percent 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.

5. DISCUSSION AND CONCLUSION

5.1 Mean Live Lac Insects (MNL) Per 2.5cm^2 on *C. cajan*

The MNL declined from 30th day to 180th day of BLI in all the treatments. However, there was variation. Decline in the population of lac insects is reported by numerous earlier workers like [18], [21- 28] and [29]. Loss of the number of insects in a population from its immature stage to the adult stage is also reported by [18]. This loss is due to various factors like predators, parasites, high population density, food availability (biotic factors) and weather, shelter, soil type, moisture (abiotic factors). In the present case, when the weather was conducive (30th – 90th day of BLI) and the lac insects were in its immature stage (30th -120th day) though there were loss of lac insects but there was no significant difference in the MNL among the treatments.

The MNL in the present study on 30th day after BLI varied from 150.78 (L_3W_1 - Medium biotic and high abiotic stress) to 235.44 (L_6W_1 - High biotic and high abiotic stress). This was a good population settlement of lac insects on *C. cajan*. The MNL on 30th BLI on *C. cajan* reported [30] to varied from 91.77 to 98.39.

On 60th day the MNL varied from 116.22 (L_3W_1 – Medium biotic and high abiotic stress) to 182.33 (L_1W_3 – Low biotic and abiotic stress). The variation in the MNL at 60th day is reported [31] was from 153.75 to 168.04. On 90th day the MNL varied from 99.56 (L_3W_1 – Medium biotic and high abiotic stress) to 135.11 (L_1W_2 – Low biotic and medium abiotic stress). The variation in the MNL at 90th day is reported [31-32] was from 129.25 to 152.08. On 120th day the MNL varied from 78.22 (L_3W_1 – Medium biotic and high abiotic stress) to 124.11 (L_1W_2 – Low biotic and medium abiotic stress). The variation in the MNL at 120th day is reported [31] was from 112.88 to 129.75On 150th day the MNL varied from 51.22 (L_6W_2 – High biotic and medium abiotic stress) to 90.78 (L_1W_2 – Low biotic and medium abiotic stress). The variation in the MNL at 150th day is reported [31,32] was from 72.54 to 97.29. On 180th day the MNL varied from 41.22 (L_6W_2 - High biotic and medium abiotic stress) to 79.89 (L_1W_2 - Low biotic and medium abiotic stress). The variation in the MNL at 180th day is reported [31] was from 55.29 to 76.31. The percent survival of lac insects in case of Low biotic stress was highest from 120th to 180th day after BLI. In the present study the biotic stress due to (predator and parasite) was minimized by spraying of contact insecticides from 30th day after BLI to 60th day after BLI. By 30th day after BLI the lac insects secretes resinous protective covering over its soft body thus remains safe from the effect of contact insecticides [33]. Here the biotic stress relates to the load of lac insects on number of branches per *C. cajan*. More number of branches per plant with lac insects increases the biotic stress not only on the host plant but also on the lac insects. The stress on the host plant is due to more drawl of phloem sap from the plant due to more lac insects. This leads to diversion of plant food meant to its growth centre and sink [34]. Phloem sap is nutrient rich and is crucial for plant growth and development [34]. It is equally important for phloem feeding insects. Plant can survive and produce more if the number of phloem feeders are less [35]. i.e., less biotic pressure, but its growth may be stunted or produce less if the load of phloem feeders are more. Similarly, if the sucking insect population is less on the plant there will less competition for food and more space. Thus, the survival and development of sap feeders will be more [35]. On the contrary, if the density and population of phloem feeders are more in the plants the phloem feeders population may decline due to competition for space and food [36]. Soil moisture is an important factor for the growth of the plant. It helps to improve the microbial activity in the rhizosphere [37]. Reduction in soil moisture is replenished with irrigation to overcome abiotic stress [37]. When the soil moisture stress increases it adversely affect the plant growth and also the insect pests feeding on it. Soil moisture stress has direct impact on the phloem feeders survival.

In present study, it was observed that when the abiotic stress (soil moisture) was less, the survival percent of the lac insects was more. Survival of phloem feeders in irrigated field was more over less irrigated field is reported by [38].

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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