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Production of Lac and Seed of *Cajanus cajan* under Varying Stresses

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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

Production pulse and lac from the same plant of *Cajanus cajan* simultaneously provides two cash crops from the same plant is important for pigeonpea growers of both continents - Africa and Asia. The highest raw lac production per plant was 171.17 g while the highest seed yield was 1383.33 g per plant. *C. cajan* plant with least stress i.e., less lac insects had highest 100 lac cell weight 1.57 g (Low biotic stress) while it was 1.41 g in plants with (Medium biotic stress). The seed yield per plant was highest (1137.78 g) in plants under high biotic stress. It was least (872.22 g) in plants with Low biotic stress.

Keywords: Stress; Lac; cajanus cajan.

1. INTRODUCTION

Interaction of insect – plant and weather factors are intrinsically related to the growth and survival of both the living organism [1]. Agroclimatic zones and local weather factors play an important role in the growth of plants [2]. Apart from weather factors, nutrient and moisture status of the soil [3] are also crucial for plant development. Insect – plant relationship is one among the widely studied subject [4] are behaviour changes and varying interactions between the two. Plant attract phytophagus insects. Host plants are important in the food web of phytophagus insects. Thus, phytophagus insects exert biotic stress on its host [5]. This stress invariably impacts the growth and development of the host plant. Interestingly, no organisms are free from abiotic and biotic stress [5].

Pigeonpea (*C. cajan*) is one among the most popular pulse crop in the world. Its split seeds known as daal in India is widely consumed [6]. This leguminous crop is grown as rainfed crop through the country [7], in an area of 4,550 thousand hectares [6]. The crop is attacked by insect pests which reduces its yield by 15 to 25 percent [8]. *C. cajan* is a good host plant of lac insects [9-10]. The lac has economic importance. Lac is an export commodity [11]. India is the largest producer of lac in the world [12-13]. Lac is also a cash crop [14-16] and therefore plays an important role in the socio – economy of small and marginal farmers. Thus, both pigeonpea and lac are important crops obtained from the same crop simultaneously [7]. The present study was to explore the performance of *C. cajan* with different load of lac insects and soil moisture for yield of lac and grain. In this context the present field study was conducted.

2. MATERIALS AND METHODS

C. cajan is generally grown in rainfed condition, is also a good annual host plant of lac insect. There is a possibility of production of both seed and lac yield on *C. cajan* [7]. *C. cajan* is widely reported to have biotic stress due to insect pest on it [8,17]. Lac insect is phloem sap feeder [7] and hence imparts biotic stress. The present field study was conducted to evaluate the yield of both lac and seed of *C. cajan* by adjusting different level of biotic and abiotic stress on the host plant. The biotic stress due to insect pest on *C. cajan* was minimised with periodic spray of contact insecticides [18]. 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.

2.1 Experimental Details

The field trial was conducted at Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P during the year *kharif-Rabi* season in 2020-21. The field experiment was 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). The data on different yield parameters viz., lac and seed yield of *C. cajan* were statistically analysed.

2.2 Treatment Details

A. Biotic stress

Low biotic stress

a. *C. cajan* with one primary branch and its secondary branches with lac insects (L_1)
b. *C. cajan* with two primary branches and its secondary branches with lac insects (L_2)

Medium biotic stress

a. *C. cajan* with three primary branches and its secondary branches with lac insects(L_3)
b. *C. cajan* with four primary branches and its secondary branches with lac insects (L_4)

High biotic stress

a. *C. cajan* with five primary branches and its secondary branches with lac insects (L_5)
b. All the primary branches and its secondary branches with lac insects (L_6)

No biotic stress

C. cajan with no lac insects and no insect pest (L_7)

There were three abiotic stresses in this experiment was soil moisture stress. It is believed that managing the irrigation per plant through drips, will create different level of moisture stress in soil that will impact the host plant. The abiotic stresses were of three levels

B. Abiotic stress

Low abiotic stress

It was maintained by adjusting the drip irrigation with 8 litres per hour per plant at seven days interval.

Medium abiotic stress

The irrigation was 4 litres per plant per hour at seven days interval

High abiotic stress

The irrigation was 2 litres per plant per hour at seven days interval

2.3 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 [9].

2.4 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 drained out from the perforation. The polythene bags were stored 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.

2.4.1 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.

2.4.2 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. Irrigation from October 2020 to May 2021 was 7-day interval.

2.4.3 Brood lac inoculation

On October 30, 2020, *Rangeeni* brood lac inoculation (BLI) was done on the *C. cajan*. The brood was purchsed from Adarsh Lac Samiti in Jamankhari village, Tehsil Barghat, District Seoni, M.P. The quality brood lac brought from Seoni to the experiment was predator-free brood. Brood lac stick at the rate of 15g per *C. cajan* was tied to the plant with the help of a jute twine.

2.4.4 Phunki removal

Phunki removal procedure involves removing the brood lac sticks after 21 days of its BLI from *C. cajan* without harming the newly settled lac brood on the branches. This process was followed as per the protocol suggested by Patidar et al. [7], Khichi et al.19].

2.4.5 Marking of slot

Usually by 30th day after BLI, majority nymphs of *K. lacca* leaves the brood lac cells to settle on the 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. The slot making was followed as suggested by Vajpayee et al. [9]. 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 single branch each of 2.5cm^2, 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

2.4.6 Harvest of pods

Harvesting was done by hand picking of mature pods separately. There were two hand pickings. Harvesting was on the maturity of 80 percent pods. The first and second pickings done on last week of December 2020 and first week of April 2021 respectively. The harvested pods were counted, dried weighed, threshed for grain yield during successive pickings and maintained a record.

2.4.7 Harvest of lac crop

C. cajan with lac crop was harvested on 27.05.2021 by cutting the plant from its base. The harvested *C. cajan* plant with lac crop was shade dried for four days and all the branches with lac encrustation were kept and tagged. The lac was scrapped from the plant after placing it on a clean plastic sheet. The lac obtained was dried and weighed to record the data.

3. RESULTS AND DISCUSSION

Mean weight of seed in 1st and 2nd picking.The mean weight of seed (MWS) in first picking revealed significant difference among the factor A, factor B and their interactions. *C. cajan* plant with Lac insects on five primary branches and its secondary branches (L_5 - High biotic stress) was found to be associated with the highest seed yield (608.89 g). Lowest seed yield was in L_3 – Medium biotic stress (477.78 g). During the 1st picking the weather was favourable (December), During this period lac insects on the host was 56 days old from BLI and was in its immature stage, at this stage the phloem sap intake by immature lac insects may have been less, resulting in less biotic stress, Favourable weather also had minimum abiotic stress. This may be the reasons for non-significant difference among the treatments (Table 1).

Among the irrigation level, highest seed yield (599.52 g) was recorded in *C. cajan* plant with (W_3 - Low abiotic stress). The seed yield in W_2 - Medium abiotic stress (555.71 g) was found at par with W_1 - High abiotic stress (450.95 g). The total irrigation water per plant given from 6.10.2020 to 1st picking (31.12.2020) was 52 litres (W_1), 104 litres (W_2) and 208 litres (W_3).

The yield attributes viz., number of pods per plant, weight of pods per plant and seed yield per plant were improved significantly with three irrigations as compared to two irrigations and rainfed treatment earlier reports also indicated similar trends [20-22].

Among interactions of the treatment combination L_5W_2 (783.33 g) had significantly highest seed yield. The seed yield in the combination L_6W_3 (666.67 g) and L_2W_3 (730 g) was found at par with L_5W_2. Rest of the treatments were at par with each other. In the 2nd picking, the MWS varied from 366.67g (L_1 - Low biotic stress) to 547.78g (L_4 – Medium biotic stress). The MWS was significantly highest in L_4 (547.78g) followed by L_5 (528.89g) and L_6 (541.67g). Rest of the treatments were at par with each other.

Highest seed yield was recorded in 560.48 g (W_3 - Low abiotic stress). Lowest seed yield was recorded in W_1 - High abiotic stress (398.33 g). W_2 - Medium abiotic stress (508.10g) was at par with W_3. There was a reduction in MWS in 2nd picking. It may be due to the increased biotic stress imposed by lac insects as compare to the 1st picking. Podding and rapidly growing lac insects may have exerted extra biotic stress on the plant [19]. During the second picking the flowering to podding stage was from January to April which had extreme weather with temperature. The maximum and minimum mean temperature was 38.1ºC and 17.1ºC respectively. Rainfall was just 0.6mm, the lac insects were in adult stage drawing more phloem sap from the host plant adding biotic stress. Thus, both type of stress was more during second picking. Among interactions treatment combination L_6W_3 (673.33 g) showed significantly highest seed yield. The total seed yield per plant of both the pickings was highest (1137.78 g) in L_5. It was lowest (872.22 g) in L_1. Application of irrigation W_3 (@ 8lph) was found to be associated with highest seed yield (1160 g). It was lowest (849.29 g) in W_1. However, in W_2 (1063.81g) was found at par with W_3 (1160 g). The total additional water was given from 6.10.2020 to 11.05.2021 was 132 litres (W_1), 264 litres (W_2), and 528 litres (W_3). Among interactions treatment combination L_5W_2 (1383.33 g) showed significantly highest seed yield, while it was lowest (570 g) in L_1W_1 (666.67 g).

Table 1. Mean seed yield per plant during different pickings

Treatments	Mean seed yield per plant (g) 2020-21		
	1st Picking	2nd Picking	Total
Factor A (Biotic stress)			
L_1	505.56	366.67	872.22
L_2	592.22	480.00	1072.22
L_3	477.78	486.67	964.44
L_4	532.22	547.78	1080.00
L_5	608.89	528.89	1137.78
L_6	524.44	541.67	1066.11
L_7	506.67	471.11	977.78
SEm(±)	61.93	47.13	
CD (5%)	177.01	134.71	
Factor B (Abiotic stress)			
W_1	450.95	398.33	849.29
W_2	555.71	508.10	1063.81
W_3	599.52	560.48	1160.00
SEm(±)	40.54	30.85	
CD (5%)	115.88	88.19	
Interaction (AxB)			
L_1W_1	350.00	220.00	570.00
L_2W_1	573.33	516.67	1090.00
L_3W_1	346.67	336.67	683.33
L_4W_1	526.67	446.67	973.33
L_5W_1	476.67	520.00	996.67
L_6W_1	460.00	441.67	901.67
L_7W_1	423.33	306.67	730.00
L_1W_2	546.67	426.67	973.33
L_2W_2	473.33	476.67	950.00
L_3W_2	510.00	466.67	976.67
L_4W_2	603.33	576.67	1180.00
L_5W_2	783.33	600.00	1383.33
L_6W_2	446.67	510.00	956.67
L_7W_2	526.67	500.00	1026.67
L_1W_3	620.00	453.33	1073.33
L_2W_3	730.00	446.67	1176.67
L_3W_3	576.67	656.67	1233.33
L_4W_3	466.67	620.00	1086.67
L_5W_3	566.67	466.67	1033.33
L_6W_3	666.67	673.33	1340.00
L_7W_3	570.00	606.67	1176.67
SEm(±)	107.27	81.63	
CD (5%)	306.60	233.32	

3.1 Raw Lac Yield Per Plant

C. cajan plant were harvested on 27.05.2021 for lac yield by cutting the plants from its base. The sticklac was scrapped to obtain raw lac. Raw lac is the marketable produce. The mean lac yield per plant of *C. cajan* in settlement of lac insects on varying number of branches varied from 23.96 g in L_1 (Low biotic stress) to 152.72 g in L_6 (High biotic stress). The latter (L_6) was significantly higher than all the treatments (Table 2).

The mean lac yield per plant of *C. cajan* in different levels of irrigation (Soil moisture stress) varied from 49.17 g (W_{1}- High abiotic stress) to 58.76 g (W_3 - Low abiotic stress). The latter W_3 was significantly higher than W_1 but was at par with (W_2 – Medium abiotic stress). The total volume of water per plant was 132 litres (W_1), 264 litres (W_2) and 528 litres (W_3).

The mean lac yield per plant of *C. cajan* due to the interactions of Lac insect settlement and levels of irrigation varied from 20.83 g (L_1W_1) to 171.17 g (L_6W_1). The latter (L_6W_1) was significantly higher than all the interactions. The productivity of lac also depends on the variety [23] reported 350g of lac from *C. cajan*. Earlier workers have reported the per plant yield of lac 3.74 g to 29.45 g [24], 332.33 g to 446 g [9] in *C. cajan.* Thus, when compared to wild lac host trees like *B. monosperma* it was 0.58 kg to 2.10 kg [25], 2.03 kg to 4.01 kg [26] and *Z. mauritiana* 3.83 to 5.08 kg [15].

3.2 Mean Length of Sticklac on the *C. cajan*

The total length of branches on the host plant with lac insects from which raw lac is scrapped is the sticklac.The mean length of sticklac per plant of *C. cajan* in settlement of lac insect on varying number of branches varied from 104.89 cm (L_1 – Low biotic stress) to 450.83 cm (L_6 -High biotic stress). The latter (L_6) was significantly higher than all the treatments. The mean length of sticklac per plant of *C. cajan* in different levels of irrigation varied from 190.62 cm (W_1 - High abiotic stress) to 193.75 cm (W_3 - Low abiotic stress). There was no significant difference among the treatments. The total volume of water per plant was 132 litres (W_1), 264 litres (W_2) and 528 litres (W_3). The mean length of sticklac per plant of *C. cajan* in varying number of branches with Lac insect and levels of irrigation varied from 99.67 cm (L_1W_1) to 468.83 cm (L_6W_1). The latter (L_6W_1) was significantly higher than all the interactions. Mean length of stick lac and lac yield per plant has to be less in (L_1 – Low biotic stress) because of only lac insects on a primary branch and its secondary branches, while it was on all primary branches and their secondary branches per plant in (L_6 – High biotic stress).

3.3 Mean Weight of 100 Dry Lac Cell (MWHL)

The mean weight of 100 lac cells on *C. cajan* with lac insects on varying number of branches varied from 1.41 g in L_3 (Medium biotic stress) to 1.57 g in L_1 (Low biotic stress). The latter L_1 was significantly higher than (L_3) but was at par with L_4 (1.50 g), L_2 (1.48g) and L_6 (1.48g).

The mean weight of 100 lac cell of *C. cajan* in different levels of irrigation varied from 1.24 g (W_1 - High abiotic stress)) to 1.28 g (W_3 - Low abiotic stress)). The latter (W_3) was significantly higher than (W_1) but was at par with (W_2 - Medium abiotic stress)). The total volume of water per plant was 132 litres (W_1), 264 litres (W_2) and 528 litres (W_3).

Dash represents no brood lac inoculation. The mean weight of 100 lac cells on *C. cajan* due to the interactions of Lac insects on varying number of branches and levels of irrigation varied from 1.38g (L_1W_1) to 1.65 g (L_2W_1). The latter (L_2W_1) was significantly higher than all the interactions. However, the mean 100 lac cell weight in L_1W_1 and L_4W_2 was same (1.51 g) and was at par with L_6W_1 (1.53g), L_2W_2(1.59), L_1W_3(1.55g), L_4W_3 (1.52g) and L_5W_3 (1.57g). The weight of each lac cell has a direct relationship to the quality and quantity of phloem sap that was access to the female lac insect [26]. The secretion of lac decreased gradually in the mid late adult stage of female lac insect [27]. This means *C. cajan* with one primary branch and its secondary branches (L_1) and irrigation level (W_3) provides better quality and quantity of phloem sap, which may have promoted lac insect to secrete more resin. However, the mean weight of 100 lac cell was significantly higher in L_1. This is evident as less insects with abundant availability of food reduces the competition in the population. This helps the insects to grow better and produce more lac by the insects. The mean weight of 100 lac cell reported by earlier workers was 13.16 to 38.33 mg [28], 2.02g to 2.12g [29], 2.24g to 2.54g [30], 1.79g to 3.42g [31], 5.54g to 6.90g [16], 5.18g to 6.30g [32], 3.82g to 5.18g [33], 3.03g to 3.68g [25], 4.66g to 6.33g [34], 4.95g to 8.21g [26], 3.03 to 3.12 [9].

Table 2. Lac yield per plant

Treatments	Mean stick lac length (cm)	Mean weight (g)		
		Lac yield per plant	100 lac cells	Lac per 2.5 cm^2 slot
Factor A (Biotic stress)				
L_1	104.89	23.96	1.57	0.72
L_2	143.39	34.28	1.48	0.62
L_3	177.41	44.22	1.41	0.56
L_4	212.05	55.06	1.50	0.60
L_5	257.08	68.44	1.46	0.57
L_6	450.83	152.72	1.48	0.64
L_7	-	-	-	-
SEm(±)	3.34	0.85	0.02	0.02
CD (5%)	9.56	2.44	0.06	0.04
Factor B (Abiotic stress)				
W_1	190.62	49.17	1.24	0.50
W_2	192.34	54.37	1.29	0.53
W_3	193.75	58.76	1.28	0.56
SEm(±)	2.19	0.56	0.01	0.01
CD (5%)	6.26	1.60	0.04	0.03
Interaction (AxB)				
L_1W_1	99.67	20.33	1.51	0.78
L_2W_1	140.16	28.67	1.38	0.61
L_3W_1	171.67	39.83	1.41	0.49
L_4W_1	210.33	51.67	1.46	0.54
L_5W_1	243.67	64.33	1.42	0.45
L_6W_1	468.83	139.33	1.53	0.65
L_7W_1	-	-	-	-
L_1W_2	109.67	24.89	1.65	0.67
L_2W_2	146.33	35.83	1.59	0.62
L_3W_2	178.67	44.67	1.43	0.54
L_4W_2	208.50	56.17	1.51	0.66
L_5W_2	251.89	71.33	1.39	0.63
L_6W_2	451.33	147.67	1.45	0.58
L_7W_2	-	-	-	-
L_1W_3	105.33	26.67	1.55	0.72
L_2W_3	143.67	38.33	1.46	0.63
L_3W_3	181.89	48.17	1.40	0.65
L_4W_3	217.33	57.33	1.52	0.59
L_5W_3	275.67	69.67	1.57	0.62
L_6W_3	432.33	171.17	1.47	0.68
L_7W_3	-	-	-	-
SEm(±)	5.79	1.48	0.04	0.03
CD(5%)	16.55	4.23	0.10	0.08

3.4 Mean Weight of Lac Per 2.5cm^2 Slot

The mean weight of lac per 2.5cm^2 of *C. cajan* in settlement of lac insect on varying number of branches varied from 0.56 g (L_3 Medium biotic stress) to 0.72g (L_1 – Low biotic stress). The latter L_1 was significantly higher than (L_3) but was at par with L_2 (0.62 g), and L_6 (0.64 g).

The mean weight of lac per 2.5cm^2 of *C. cajan* in different levels of irrigation varied from 0.50 g (W_1 - High abiotic stress) to 0.56 g (W_3 - Low abiotic stress). The latter (W_3) was significantly higher than all the levels of irrigation. However, (W_1) was at par with (W_2 - Medium abiotic stress).

The mean weight of lac per 2.5cm^2 of *C. cajan* due to the interactions of Lac insect settlement and levels of irrigation varied from 0.45 g (L_5W_1) to 0.78 g (L_1W_1). The latter (L_1W_1) was significantly higher than all the interactions but was at par with L_6W_3 (0.68 g). However, the interaction L_3W_1 (0.49 g) was at par with L_4W_1 and L_3W_2 (0.54 g).

The mean weight of lac per 2.5 cm^2 slot was significantly higher in L_1 this means plants with less lac insects have more photosynthate as its disposal than those *C. cajan* plants with more branches loaden with lac insects. Thus, *C. cajan* with less abiotic and biotic stress had higher mean weight of lac per 2.5 cm^2 slot. The mean weight of lac per 2.5 cm^2 reported by earlier worker it was 0.25 g to 0.97 g [9].

4. CONCLUSION

The study explores the performance of *C. cajan* with different load of lac insects and soil moisture for yield of lac and grain. In this context the present field study was conducted. This is evident that as less insects with abundant availability of food reduces the competition in the population. This helps the insects to grow better and produce more lac by the insects.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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