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Field screening of *Cajanus cajan (L.) Millsp.* varieties for production of lac and seed

Shobha Pardhi[1], Rita Bhandari[2], Moni Thomas[3]
[1] Researcher, Department of Biotechnology and Zoology, Govt. Model Science (Auto.) College, Jabalpur, Madhya Pradesh, India
[2] Govt. Science College, Khamariya, Jabalpur, Madhya Pradesh, India
[3] Department of Entomology, JNKVV Jabalpur, Madhya Pradesh, India

Abstract
A two year field trial was conduct with 12 varieties of *C. cajan*. The two year pooled data on the mean weight of total pods and seed yield of *C. cajan* with lac insects was significantly highest 3307g and 2023g in MA-3 over all the 12 varieties evaluated. The mean weight of 100 seeds *C. cajan* varieties with lac insect on it varied from 5.85g (Bahar) to 18.10g (Azad).The mean weight of raw dry lac yield per plant from 291.33g (NDA-1) to 519.17 g (MA-3).

Keywords: brood lac, raw lac, seed weight

Introduction
Subsistence agriculture is commonly practiced in India and particularly in Madhya Pradesh (Bhanwarlal Osari *et al*., 2020) [5]. Subsistence agriculture means, growing for crops to meet the household needs of the farm family. In recent years, this practices is neither sustainable (Bhanwarlal Osari *et al*., 2020) [5] nor profitable (Cotula *et al;* 2009) [7] migration from villages (Shenggen Fan *et al.*, 2013) [57] and selling agricultural lands (Cotula *et al;* 2009) [7] occurs among small and marginal farmers (Shenggen Fan *et al.*, 2013) [57].
In Madhya Pradesh the small and marginal farmers constitute 51percent of the farming community *(S. Mahendra Dev 2014*). Agriculture among majority of the farmers are traditionally for (Fan and Chan-Kang, 2003), subsistence. Rainfed agriculture, changing climate, increase in input (Asha latha K. V. *et al;* 2012) fluctuating market price (Kibrom T. Sibhatu, 2017) and un_availability of labour (Bryceson DF *et al;* 2000) during critical field operations are a few of the major constraints Shrinking agriculture land (Cotula *et al;* 2009) [7] and natural resource (Shenggen Fan *et al;* 2013) [57] are other worrying factors.
Governments both at central and state level are working on ways and policies improve farm productivity and farmers profitability. However in a diverse agro climatic conditions in Madhya Pradesh, the production system as well as crops cultivated are too diverse, to have a common program. Development managers and policy makers are looking for option and opportunities to double income across the country.
Farmer's income can be improved, if they grow cash crop along with their traditional crops. In Madhya Pradesh, the forest area is around 30 percent (FSI, 2019) of its geographical area. Forest and agriculture are the two major land use patterns in M.P. (Singh *et al*., 2012). Minor forest produce and agriculture both can contribute significantly to improve farmer's income (ISFR, 2019) [18]. Among minor forest produce, lac is an important commonly produced in M.P. Lac production in the state approximately vary 60,000q to from 100000q annually (Yogi *et al.*, 2017). M.P. is the 3rd largest produced of lac in India (Jaiswal *et al., 2013*) [24]. The enterprise was in revived in M. P. in 1997 (India: Madhya Pradesh Public Resource Management Program, 2007).
Lac is a resinous secretion of minute lac insect *Kerria lacca* Kerr. It belongs to family Tachardiidae (Kerriidae), and order Hemiptera, there are two strains of lac insect viz. *Kusmi* and *Rangeeni*. *Kusmi* lac is grown on *Schleichera oleosa*, *Zizyphus mauritiana and Flemingia semialata* (Kumar *et al*., 2013*). Rangeeni* lac is grown on commercially *B. monospera*, and *Z. mauritiana* (Jaiswal and Singh 2015) [25]. There are over 400 host plants of lac insect (Saha *et al*, 2014), one among them is *Cajanus cajan* (L.) Millisp.
C. cajan is cultivated on about 3.9 m ha in India (FAO, 2018) and 0.32 m ha in Madhya Pradesh. *C. cajan* is one of the most popular pulse grown in the state. The annual production is 0.23 m tones and its productivity is 441kg/ha (Anon, 2019) in Madhya Pradesh. *C. cajan* is grown by most of the small and marginal farmers in the Madhya Pradesh (Bijalwan *et al.*, 2019) [3]. *C. cajan* beside been a good source of protein (Saxena *et al.*, 2010), also provides fuel wood to the farmers (Kwesiga *et al.*, 2003) [26]. MP is the 3rd largest producer of *C. cajan* in India (Sarvade, *et al*. 2018), and 3rd largest producer of lac in the country (Shah *et al.*, 2015). *C. cajan* is also a good host of *K. lacca.* Thus, the state stands a good opportunity to improve the small and marginal's income of lac production is promoted on *C. cajan*. There are numerous local, improved as well as long duration *C. cajan* varieties available in the country (Lohot *et al.*, 2018) [35]. But the need is to find a suitable *C. cajan* for lac production which can be profitable to the farmers, with compromising the yield of their pulse crop.

In this context, the two year field evaluation of 12 *C. cajan* varieties for lac production was carried out in Balaghat. Balaghat is a prominent tribal district of MP, where migration of farmers and youth to neighboring districts as well as Maharashtra, Andhra Pradesh and other state is very common.

Material and Methods

The materials and methods followed the two year farmer's participatory field trial was conducted in Balaghat district MP for screening of *C. cajan* varieties for production of lac and seed lac is as below.

Balaghat

Balaghat is a predominant tribal district of MP. Geographically, it is located between 21°19' to 22°24' north latitude and 79°31' to 81°3' east longitude. The total area of the district is 9,245 km². There are 1400 villages spread in ten development blocks of the districts viz: Balaghat, Baihar, Birsa, Paraswada, Katangi, Waraseoni, Lalbarra, Khairlanji, Lanji, and Kirnapur. Balaghat district with a population of 1,701,156, (2011 census) roughly ranks 288th (out of 640 districts) in India. The population density is 184 inhabitants per km^2, while the population growth rate over the decade 2001–2011 was 13.56 percent. There were 1021 females for every 1000 males. The literacy rate of 78.29 percent. The forest (3, 92, 243ha) is more than the cultivated area (3,34,838ha). Among the four major soil types in the district, deep soil is predominant (36.53%) followed by mixed red and black (18.30%), alluvial (7.57%) and shallow light medium black (6.91%). Rice is the predominant crop (2, 65, 000 ha) grown the district followed by black gram (70,000ha), wheat (58,000ha), maize (12,000ha), pigeon pea (4,500ha), and sugarcane (2,363ha). Canals, dug wells, tube wells and ponds irrigate 20 percent of the total cultivated area in the district.

A. Experimental location

The field trial on 12 varieties of *C. cajan* was conducted in the farmer's field located in village Bamhani, Block Kirnapur, District Balaghat, Madhya Pradesh during the year 2015-16 and 2016-17.

B. Selection of *C. cajan* varieties

Rangeeni lac production was evaluated on the 11 *C. cajan* varieties (Bahar, Azad, MA-3,MA-6, PUSO-9, MAL-13, T-7, DA-11, NDA-2, NDA-1 and Amar). I obtained from Indian Institute of Pulses Research (IIPR) Kanpur, and a local variety of a farmer in Bamhani village, in Balaghat district.

C. Field Operations

a. Nursery raising of *C. cajan*

1. Filling of polythene bag with substrate

Black polythene bag of size 10x14 inch and 38 guage were used for the raising of *C. cajan* in nursery. In order to drain excess irrigation water, all the polythene bags were perforated with 10-12 holes before filling the substrate (medium for growth of the seedling).

2. Preparation of substrate

Substrate was prepared by mixing equal quantity of light soil and well rotten FYM (Farmyard manure) in a ratio of 1:1, in the first week of May. The FYM was treated with *Trichoderma viride* at the rate of 5g per kg of FYM and kept under shade. The treated FYM was mixed thoroughly at weekly intervals for one month for the growth of *T. viride* prior to filling the polythene bag.

3. Filling of substrate

The perforated polythene bags were filled with substrate upto three quarter of its volume, and arranged in 4 rows under shade.

4. Sowing of *C. cajan*

C. cajan seeds were treated with *T. viride*, *Rhizobium* and Phosphorous solubulizing bacteria (PSB) culture, before sowing. The treated seeds were spread on a polythene sheet and 3-4 seeds were sown in a substrate filled perforated Polythene bags, during the last week of May. They were then arranged in separate rows of each for the 12 *C. cajan* varieties and properly labelled. Watering was done at weekly intervals, till its transplantation in the main field.

5. Germination and weeding

Polythene bags were irrigated regular intervals. Weeds were removed as and when required. Re-sowing was done where ever there was no germination.

6. Nipping

The growing tip of the seedlings was nipped with fingers, when it attained a height of 6-7 inches. Nipping was carried at 10 days interval in the nursery. Nipping induced branching. Nipping of growing tip continued till the transplantation of the seedlings in the main field.

b. Main field

1. Digging of pits

Field preparation was done with two ploughing operation by tractor drawn cultivator. It was followed by disc operation for breaking the soil clots. The layout of the experiment in field was prepared. Pits were digged of size 1x1x1 foot with the help of a pickaxe and spade in the month Jun. The spacing was maintained at a distance of 2

metres (plant to plant) and 1.5 metres (among treatments).The soil dug from the pit was kept on eithe side of the pits for natural sterilization.

2. Nutrient management

Well rotten FYM, Diammonium phosphate (DAP), Zinc and Murate of Potash (MoP) as well as *T. viride*, *Rhizobium* and PSB were added to all the pits and mixed well with the soil before the transplantation of *C. cajan* seedling.

3. Transplantation of *C. cajan* seedlings

All the seedlings of *C. cajan* were transplanted in the field during the first week of July, during both. The years of the experiment, as per the experimental layout in RBD format.

4. Nipping

After transplantation, the plants were again nipped at 10 days interval till 1st week of October during both the years.

c. Broodlac inoculation

1. Broodlac

Healthy broodlac with minimum signs of predator and parasite infestation were selected for its inoculation of the *C. cajan* plants. Broodlac weighing 10-20g was inoculated per *C. cajan* plant depending on the size of the plant (Thomas *et al*, 2015). Broodlac stick was tied with a twine on the main stem about one foot about the ground.

2. Shifting

Broodlac was shifted carefully to different branches on the same plant after six days of inoculation. The purpose of shifting was to ensure uniform distribution of crawling larvae of K. lacca the brood on those branches which had no or less larval settlement. (Shah *et al*, 2015) of lac insects.

3. *Phunki* removal

The larvae of *K. lacca* leave Broodlac to settle on branches within 21 days, and the Broodlac on the plant without lac larvae is called *Phunki*. It is infact sticklac. The *Phunki* was removed after 21 days of Broodlac inoculation and scrapped to recover raw lac and in this process the predators of any in the phunki are removed (Janghel, 2013).

d. Spraying of pesticides

The pesticides solution (Cartap hydrochloride + Mancozeb) were sprayed on the *C. cajan* plants inoculated with *K. lacca* settlement, with the help of a Foot sprayer for management of predators and parasites of lac insect.

1. Preparation of pesticide solution

The solution of pesticide was prepared by adding Cartap hydrochloride (@1g/litre of water and Mancozeb @ lg/litre of water) in small separate containers followed by brisk stirring with a piece of stick (Rathore, 2011). Both the solutions were then poured in the tank of the sprayer followed by adding of 13 litres of clean water in to it. The solution in the tank of the sprayer was again stirred with the help of a stick to ensure proper mixing of the pesticides.

2. Spraying schedule

The first spray was done after 25-30 days of Broodlac inoculation (Engla, 2011). The second spray was carried out in the month of December.

e. Harvesting

Harvesting by hands picking of pods, when about 80percent of the pods on the plant at carried maturity.

C. cajan

Harvesting were done on 12.01.2016 and 28.04.2016 during first year while on 28.12.2016 and 25.04.2017 during second year of the experimental trial. The pods were sun dried and weight was recorded. The pods were threshed and grain yield per plant was recorded in each treatment. The mean weight of 100 seeds of weight of each treatment was also recorded.

Lac

Lac yield per plant was recorded by scrapping the lac on the branches of *C. cajan* after the harvest. The branches with lac encrustation were shade dried and scrapped with a knife, while keeping a plastic sheet below. The raw lac yield was weighed to record lac production per plant. The 100 lac cell weight of each treatment were also recorded by weighing of 100 healthy lac cell after scraping it from the stick lac.

Result and Discussion

Seed yield of *C. cajan* with lac insect

Lac production on *C. cajan* exerts biotic stress, as lac insects inoculated are phloem sap feeder. Thus, it can influence on the crop in terms of number of pod, dry pod weight and dry seed weight per plant as well as 100 seed weight, is a general perception.

The mean weight of total pods per *C. cajan* with lac insects

During the year 2015-16 the mean weight of total pods per *C. cajan* varied from 2794.30 g. (NDA-1) to 3404.70g (MA-3). It was significantly highest in MA-3 overall the varieties except Azad (3284 g) which was at par. The mean weight of total pods per plant in rest of the varieties were at par with each other.

In the year 2016-17, the mean weight of total pods per *C. cjan* varied from 2172.3g (Amar) to 3210g (MA-3). It was significantly highest in MA-3 over all the varieties.

The two year pooled data on the mean weight of total pods per plant revealed that MA-3 (3307g) was significantly highest among all the varieties of *C. cajan.* The next highest (2920g) was in Azad, which though significantly differed from MA-3 but was at par with almost all the varieties.

Lac production on *C. cajan* in MP was first reported in 2003 by Thomas (2003a). Its possibility as a viable option was reported by Thomas(2003b), Pardhi (2015) [46], 3307g to 2543g, Daheriya *et al* (2015) [46], Patidar (2019), 4316.34 to 3701.00 and Vajpayee *et al*., (2019) reported that the mean weight of pods per plant during 3rd picking was minimum (1391.67g) in *C. cajan* with no lac insects while it was maximum (1692.33g) on those *C. cajan* plants with population density of 80 insects per 2.5cm2 on 27.03.2019 *i.e.* on 115th day after BLI.

Mean weight of total seeds per *C. cajan* with lac insects

During the year 2015-16, the mean weight of total seeds per *C. cajan* varied from 1535.3 g (DA-11) to 2208.70g (MA-3). It was significantly highest in MA-3 overall the varieties of *C. cajan* evaluated. Rests of the varieties were at par with each other.

In the year 2016-17, the mean weight of total seeds per *C. cajan* varied from 1246.7g (NDA-1) to 1836.70g (MA-3). It was significantly highest in MA-3 overall the varieties except MAL-13 (1773.7g) with which it was at par. Remaining varieties were at par with each other themselves.

The two year pool analysis of the data on the mean weight of the total seeds per plant revealed that MA-3 (2023g) was significantly highest overall the varieties of *C. cajan* evaluated with lac insects.

Kant *et al*. (2016) reported that application of *Rhizobium* and PSB along with 75 kg $ha^{-1}P_2O_5$ gave the maximum grain yield (9.28 q ha^{-1}) which was 47.06% more over control. Ghosh *et al*., (2014) reported that reduction in seed yield per plant (12.1%) due to lac insect cultivation on pigeon pea germplasm. Ghosh *et al*., reported (2018) after a field evaluation *C. cajan* varieties for lac production reported 7.27q (Assam local-1) to 19.88q seed (KA 9-2) from lac inoculated pigeon pea, control 8.58q (Assam local-1) to 21.67q (KA 9-2) seed yield per ha.

Vajpayee *et al.,* (2019), reported mean seed yield per plant of TJT-501 of *C. cajan* varied from 160.08% to 61.94% of indifferent treatments.

Mean weight of 100 seeds of *C. cajan* varieties with lac insect

On hundred healthy seeds of each varieties of *C. cajan* per plant with lac insect were randomly selected and weight after each hand pecking of the pods.

During the 2015-16, the mean weight of 100 seeds of *C. cajan* varieties varied from 5.80g (Bahar) to 17.98g (Azad). It was significantly highest in Azad over rest of the *C. cajan* varieties evaluated with lac insects on them. The next variety with highest mean weight of 100 seed was NDA-1 (15.25g) which was at par with local variety 14.20g. Rest were at par with each other.

In the year 2016-17, mean weight of 100 seeds of *C. cajan* varieties varied from 5.90g (Bahar) to 18.23g (Azad). It was significantly highest in Azad overall the varieties of *C. cajan* with lac insect on them. The next highest was local variety (14.11g) which was at par with PUSO-9 (13.73g) and NDA-2 (13.85g).

The two year pooled data analysis of the mean weight of 100 seeds *C. cajan* varieties with lac insect on it varied from 5.85g (Bahar) to 18.10g (Azad). The latter was significantly highest among rest of the *C. cajan* varieties. The next highest (14.15g) was in the local variety which was at par with that of NDA-1 (13.52g).

The mean weight of 100 seeds of *C. cajan* with lac was 9.10g-11.70g (Kumar *et al*. (2014),
13.03g and 12.08g (Ghosh *et al.* 2014), 9.07g to 11.7g (Ghosh *et al.* 2018) and 9.1g to 11.7g (Lohot *et al*., 2018), 9.67g to 11.26g (Vajpayee *et al*., 2019).

Mean weight of raw dry lac yield per plant

All the plants of *C. cajan* varieties with lac crop was harvested on 29th April 2016. The plants were cut from the base and shade dried followed by scrapping of the raw lac from the plant. During the year 2015-16, the mean dry raw lac yield per *C. cajan* varied from 239.67g in NDA-1 to 486.67g in MA-3. The mean dry raw lac yield per *C. cajan* was significantly higher in MA-3(486.67g) over MA-6(325.33g), DA-11(353.33g), T-7(297.67g), MAL-13(268.33g) and NDA-1(239.67g**)**. However it was at par among MA-3(486.67g), Azad(467g), Amar(427.33), NDA-2(421g), PUSO-9(416g), Local(395g) and Bahar(366.67g).

During the year 2016-17, all the *C. cajan* with lac was harvested on 29 April 2017.The mean dry raw lac yield per *C. cajan* varied from 253.33g (Amar) to 551.67g (MA-3). It was significantly higher in MA-3(551.67g) over all the varieties. The mean dry raw lac yield per *C. cajan* of MA-6(481g) was significantly higher over PUSO-9(410.33g), Azad(403.33g), T-7(386.00g), Local(376.67g), MAL-13(370g), DA-11(363.67g), Bahar(350g), NDA-2(348.33g), NDA-1(343.00g) and Amar(253.33g).

The analysis of the two year pooled data revealed the mean dry raw lac per *C. cajan* varied from 291.33g (NDA-1) to 519.17 g (MA-3). It was significantly higher in MA-3(519.17g) over all the varieties. The mean dry weight of raw lac per *C. cajan* on rest of the varieties were at par with each other.

Table 1: Mean dry weight (g) of lac, pods per plant, grain yield and 100 seed weight (g) per plant

Varieties of *C. cajan*	Lac yield (g)			Seed yield per plant								
	Lac yield /plant			Pods / plant			Grain yield			100 seed weight		
	2015-16	2016-17	Pooled data	2015-16	2016-17	Pooled data	2015-16	2016-17	Pooled data	2015-16	2016-17	Pooled data
Local	395.00	376.67	385.83	3165.0	2613.7	2889	1769.7	1590.0	1680	14.20	14.11	14.15
Bahar	366.67	350.00	358.33	2996.7	2404.7	2701	1930.0	1571.7	1751	5.80	5.90	5.85
Azad	467.00	403.33	435.17	3284.0	2556.7	2920	1758.7	1487.0	1623	17.98	18.23	18.10
MA-3	486.67	551.67	519.17	3404.7	3210.0	3307	2208.7	1836.7	2023	10.48	10.76	10.62
MA-6	325.33	481.00	403.17	3069.0	2416.0	2743	2066.7	1528.3	1798	9.36	8.58	8.97
PUSO-9	416.00	410.33	413.17	3034.3	2418.0	2726	1974.0	1547.0	1761	9.82	13.73	11.78
MAL-13	268.33	370.00	319.17	2885.7	2625.7	2756	1594.7	1773.7	1684	10.20	9.76	9.98
T-7	297.67	386.00	341.87	2931.0	2528.3	2730	1711.3	1390.0	1551	11.88	10.68	11.28
DA-11	353.33	363.67	358.50	3057.3	2567.3	2812	1535.3	1666.3	1601	12.08	12.35	12.21
NDA-2	421.00	348.33	384.67	3126.3	2354.7	2741	1793.7	1476.7	1635	11.07	13.85	12.46
NDA-1	239.67	343.00	291.33	2794.3	2291.0	2543	1621.0	1246.7	1434	15.25	11.79	13.52
Amar	427.33	253.33	340.33	2987.3	2172.3	2580	1886.3	1302.0	1594	13.68	10.90	12.29
SEm	43.58	17.77	23.50	89.58	125.97	125.97	127.33	32.57	32.57	0.37	0.22	0.22
CD	127.84	52.11	68.93	262.75	369.48	369.48	373.48	95.54	95.54	1.07	0.64	0.64

The mean dry raw lac yield per plant depends on the host, its nutrient status, season and strain of lac insects. *Rangeeni* lac yield per *B. monosperma* was 4.58kg to 7.08kg (Khobragade, 2010),4.96kg to 6.72kg (Jhanghel, 2013), 0.58kg to 2.10kg (Sharma *et al*. 2015), 2.03kg to 4.01kg (Ghugal *et al*. 2015), 0.95kg to 1.95kg (Gurjar, 2016) and 2.80kg to 4.59kg (Sahu, 2016), while on *Z. mauritiana* it was, 5.08kg to 8.22kg (Rathore, 2011), 4.03kg to 5.89kg (Engla, 2011), 3.20kg to 5.70kg (Patel, 2014), 6.32kg to 10.75kg (Bhalerao, 2013), 3.83 to 5.33kg (Namdev *et al*. 2015).

The mean lac yield per *C. cajan* was 8.9g to 23.7g (Ghosh *et al.* 2014), 3.74g to 29.45g (Kalahal *et al*. 2017). Vajpayee *et al.,* 2019 reported per plant production of *Rangeeni* lac on TJT-501 variety of *C. cajan* to varing from 332.33g to 446g, depending on the different population densities of lac insects on it. Patidar (2019), also reported mean raw lac per *C. cajan* plant to vary from 327.47 to 386.2g. The present higher production of lac per plant is due to better plant management practices.

The lac production depends on host plant (Patel *et al.,* 2014, Sharma and Thomas., 2016, Ghugal *et al* 2016, Shah and Thomas 2017, 2018,Vajpayee *et al.*,2019), nutrient management (Namdev *et al.*, 2014,2015, 2018, Kumar *et al.*, 2017 a, b, Ghughal *et al.*, 2015,2016, Sharma *et al.*, 2015), pest management (Patel *et al.*, 2015,Janghel *et al*., 2014 a, b, 2015, 2016, Shah *et al*.,2014, Khobragade *et al*., 2012.

Conclusion

Thus the two year field screening of the 12 varieties of *C. cajan* for lac production reveals that.

Lac production can be successful proofed on *C. cajan* growing areas, provided farmers can irrigated the crop.

Lac production can be adopted on *C. cajan* without compromising its yield. Protein and cash the two major constraints of small and marginal, it can be address by promoting lac production of *C. cajan*. In Madhya Pradesh, *C. cajan* variety MA-3 is best suited for lac production, as it gives higher yield of both lac and *C. cajan* from the same plant simultaneously.

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