Study on the performance of *Rangeeni* lac insect (*Kerria lacca* Kerr.) on tall and long duration genotypes of *Cajanus cajan* (L.) Millsp.

THESIS

Submitted to

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur

In partial fulfillment of the requirements for the Degree of

MASTER OF SCIENCE

In

AGRICULTURE
(ENTOMOLOGY)

By

Ankit Khichi

180119002

Department of Entomology
College Of Agriculture, Jabalpur 482004
Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P.

2020

CERTIFICATE - I

This is to certify that the thesis entitled **"Study on the performance of *Rangeeni* lac insect (*Kerria lacca* Kerr.) on tall and long duration genotypes of *Cajanus cajan* (L.) Millsp."** *submitted in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE*** *in* ***AGRICULTURE (Entomology)*** *of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by* ***Mr. Ankit Khichi*** *under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instructions.*

All the assistance and help received during the course of the investigation has been acknowledged by him.

Place: Jabalpur

Date: / / 2020 **Dr. Moni Thomas**

Chairman of the Advisory Committee

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Committee	Name	Signature
Chairman	**Dr. Moni Thomas**	....
Member	**Dr. A.K. Saxena**	....
Member	**Dr. Anubha Upadhyay**	....
Member	**Dr. H. L. Sharma**	....

CERTIFICATE – II

This is to certify that the thesis entitled **"Study on the performance of *Rangeeni* lac insect (*Kerria lacca* Kerr.) on tall and long duration genotypes of *Cajanus cajan* (L.) Millsp."** *submitted by* ***Mr. Ankit Khichi*** *to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur in partial fulfillment of the requirements for the degree of* ***Master of Science*** *in* ***Agriculture*** *in the Department of* ***Entomology*** *has been, after evaluation, approved by the External Examiner and by Student's Advisory Committee after an oral examination on the same.*

Place: Jabalpur

Date: / / 2020

Dr. Moni Thomas

Chairman of the Advisory Committee

MEMBER OF THE ADVISORY COMMITTEE

Committee	Name	Signature
Chairman	**Dr. Moni Thomas**	....
Member	**Dr. A.K. Saxena**	....
Member	**Dr. Anubha Upadhyay**	....
Member	**Dr. H.L. Sharma**	....
Head of the Department	**Dr. A. K. Bhowmick**	....
Director of Instructions	**Dr. A.K. Shukla**	....

Declaration and Undertaking by the Candidate

I, **Ankit Khichi** S/o **Mr. Umashankar Khichi** certify the work embodied in the thesis entitled ***"*Study on the performance of *Rangeeni* lac insect (*Kerria lacca* Kerr.) on tall and long duration genotypes of *Cajanus cajan* (L.) Millsp*."*** is my own first time bonafide work carried out by me under the guidance of **Dr. Moni Thomas** at **Department of Entomology, College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 2019-2020.**

The matter embodied in the thesis has not been submitted for the award of any other degree/diploma. Due credit has been made to all the assistance and help.

I, undertake the complete responsibility that any act of misinterpretation, mistakes, and errors of fact are entirely of my own.

I, also abide myself with the decision taken by my advisor for the publication of material extracted from the thesis work and subsequent improvement, on mutually beneficial basis, provided the due credit is given, thereof.

Place: Jabalpur **Ankit Khichi**

Date: / / 2020

Copyright Transfer Certificate

Title of the Thesis: "Study on the performance of *Rangeeni* lac insect (*Kerria lacca* Kerr.) on tall and long duration genotypes of *Cajanus cajan* (L.) Millsp."

Name of the candidate	:	Ankit Khichi
Subject	:	Entomology
Department	:	Agricultural Entomology
College	:	College of Agriculture, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur
Year of the Thesis submission	:	2020

Copyright transfer

The undersigned **Ankit Khichi** as signs to the Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, all rights under Copyright Act, they may exists in and for the thesis entitled "**Study on the performance of *Rangeeni* lac insect (*Kerria lacca* Kerr.) on tall and long duration genotypes of *Cajanus cajan* (L.) Millsp.**" submitted for the award of M. Sc. (Ag.) degree.

Date: / / 2020

Place: Jabalpur

Dr. Moni Thomas | **Ankit Khichi**

(Major advisor) | **(Student)**

ACKNOWLEDGEMENT

It is my proud privilege to express my venerable regards and profound sense of gratitude to my guide Dr. Moni Thomas, Principal Scientist, Directorate of Research Services, JNKVV, Jabalpur for his precious, able guidance, convincing suggestions and constant encouragement during the tenure of investigation and preparation of the manuscript as chairman of my advisory committee.

I am extremely grateful to all the respected members of my advisory committee, Dr. A.K. Saxena, Associate Professor, Department of Entomology, JNKVV, Jabalpur, Dr. Anubha Upadhyay, Professor, Department of Food Science and Technology, JNKVV, Jabalpur, Dr. H.L. Sharma, Professor & Head, Department of Mathematics and Agricultural Statistics, College of Agricultural Engineering, JNKVV, Jabalpur for their valuable suggestions during the study and preparation of the manuscript.

I am also very thankful to the Head of the Department of Entomology, Dr. A. K. Bhowmick for encouraging me to proceed my work properly.

I express my gratitude to Prof. P.K. Bisen, Hon'ble Vice Chancellor, JNKVV, Jabalpur, Director of Instruction, Dr. D. Khare, Dr. P.K. Mishra, Director Research Services, Dr. A.K. Shukla, Dean faculty of Agriculture, JNKVV, Dr. R. M. Sahu, Dean, College of Agriculture, Jabalpur for providing necessary facilities for this research work.

I am also thankful to all the Professors, Associate Professors and Assistant Professor of the Department and other staff members for their co-operation and help in completion of this investigation.

I express my sincere gratitude to Dr. Niraj Tripathi, Research Associate, Dr. Sanjay Singh, Dr. R.K. Samaiya, Dr. A. K. Sharma, Dr. Yashpal Sharma, Dr. B.S. Diwadi my senior Sumit Kakde, Dhaneshwar B. Patil and friends Vishal Raut, Manoj, Sudeep, Rotish, Suryaprakash, Nageshwar, Jagriti, Madhuri, Shruti, Jitendra, Sudarshan uncle, Rameshwar uncle, Magan, Ashish for their cooperation and immense support.

Words are not enough to express my gratitude and regards to my beloved parents Shri. Umashankar Khichi and Smt. Lokmani Khichi for their blessing and good wishes without which I could not fulfill this study. I thanks my sister Deepika, Yashvanti, Bhavna and brother Mohit and as well as members for their everlasting inspiration, abundant love, encouragement, blessing and valuable support during the period of study.

Finally, I am thankful to the Almighty God for his heavenly blessings which has enabled me to achieve this seemingly invincible.

Place: Jabalpur **Ankit Khichi**

Date:

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF SYMBOLS

Symbol	**Stand for**
@	At the rate of
>	More than
<	Less than
±	Plus or minus
%	Percentage
°C	Degree Celsius
Abbreviation	
CD	Critical difference
cm	Centimetre
ha	hectare
hr	hour
kg	Kilogram
L	Litre
M	Meter
G	Gram
Max	Maximum
Min	Minimum
NS	Non significant
RH	Relative humidity
SEm ±	Standard error of mean
SMW	Standard Metrological Week
Temp	Temperature
G	Granules
EC	Emulsifiable concentration
et al.	(And other or co-worker)
Fig.	Figure
VAM	Vesicular – Arbuscular Mycorrhiza
PSB	Phosphate Solubilizing bacteria
BLI	Brood lac inoculation
DAT	Days after transplanting

INTRODUCTION

Insects are of ecological importance (Biere and Bennett, 2013). They are of economic importance like lac insect (Jaiswal *et al*., 2006), honey bee (Shrestha, 2008) and silkworm (Nagaraju and Goldsmith, 2002; Babu *et al*., 2009), while some are of biological importance like parasites (Williams *et al*., 1992; Blackburn and Ewen, 2017), parasitoids (Pizzol *et al*., 2012) and predators (Straub and Snyder, 2006; Grez *et al.,* 2014) of insect pest of crops. Insect pest of crops are also referred as herbivorous (Gassmann and Onstad, 2009) as they feed on the plants.

Host plants offer resistance to the insect pests feeding on it, in different ways (Palaniswamy, 1994) is well known. This is an interesting subject and referred as insect – plant interaction (Beck and Reese, 1976). In agriculture, understanding of insect-plant interaction is the key to for development resistance or tolerant crop varieties (Tabashnik *et al*., 2012).

Lac, is the only natural resin of insect origin of wide commercial and economical importance (Siddiqui, 2004; Thomas *et al*., 2018) across the world. Lac is secreted from the 3 pairs of the highly specialized lac glands (Colton, 1984) of minute lac insect *Kerria lacca* Kerr. It belongs to the order Hemiptera, Suborder Homoptera, Super family Coccoidea and Family Kerriidae. *K. lacca* also has highly specialized piercing and sucking mouthparts (Ahmad *et al*., 2014; Sharma, 2017). It feed exclusively on the phloem sap (Vashishtha *et al*., 2011; Lohot and Ghosh, 2018) of its 400 host plants (Sharma *et al.,* 2006; Kaushik *et al*., 2012; Sharma, 2016). Among these, not all the host plants are good for commercial production of lac. As lac is a cash crop (Sharma *et al*., 1999; Ramani *et al*., 2007; Singh *et al*., 2009), it is valuable to the forest dependants (Ogle and Thomas, 2006) as well as resource poor small and marginal farmers (Jaiswal *et al*., 2006; Pal, 2011) in India. Growth and development of phloem feeders are also reported to depend on quality and quantity of the phloem sap of its host plants (Shah *et al*., 2014).

Host plant management, is thus an important part in lac production (Shah *et al.* 2014; Shrivastava *et al.,* 2019). Many workers have earlier worked to improve the health of host plants for better growth, survival and lac production by *K. lacca.* Namdev *et al*. (2014); Shah *et al.* (2015) and Patidar (2019) found that basal application of nutrients to the host plant also improved the lac production. Sharma *et al.* (2015); Ghugal *et al*. (2015); Gurjar (2016) and Kumar *et al*. (2017) have reported that foliar application of nutrients on host plants were helped in increase the lac production. These works prove the existence of lac insect plant (host) interaction.

Pigeonpea [*C. cajan* (L.) Millsp.] is an important pulse crop cultivated in 3.90 mha (FAO, 2018) in India and 0.64 mha (Anon, 2017-18) in Madhya Pradesh. India is the largest producer, consumer and importer of pigeonpea in the world. M.P. is the second largest producer of pigeonpea in India (Anon, 2017-18). It is mostly cultivated in rainfed condition (Singh *et al.,* 2007; Kumar and Paslawar, 2017) and by small as well as marginal farmers (Sharma *et al*., 2009) in M.P. Pigeonpea fixes 200 kg N/ha atmospheric nitrogen in the soil (Anon, 2010), phosphorous provides a valuable pulse crop (Saxena, 2006) and fuel wood (Saxena *et al*., 2010; Snapp, 2014) to the farmers. The crop is widely cultivated in all 11 agro-climatic zones in M.P (Anon, 2017).

M.P. is the third largest producer of lac in India (Sharma and Jaiswal, 2011; Thomas *et al*. 2011; Shah *et al*., 2018), with an annual production between 0.60 to 1 lakh quintal per annum (Pal, 2011). Lac serves as a valuable cash crop to the resource poor farmers and forest dependents in M.P (Ogle *et al*., 2006).

Government of India and Madhya Pradesh is focusing on doubling of farmers' income by 2022 (Anon, 2017). According to a survey, the annual household income of small and marginal farmers in India is Rs 77,112 (NSSO, 2016). These farmers seldom fail to invest more in agriculture to raise their farm output and adopt recent technologies. In this context lac production on *C. cajan* can be a viable low input option to help pigeonpea farmers to increase their income (Vajpayee *et al*., 2019). Tall and long duration pigeonpea genotypes are required for lac production. At present, majority of pigeonpea varieties developed are short duration and dwarf (Sharma *et al*., 2020). This calls for a need of evaluation of tall and long duration local genotypes of pigeonpea available with farmers for lac production.

Thus, the present study entitled **"Study on the performance of *Rangeeni* lac insect (*Kerria lacca* Kerr.) on tall and long duration genotypes of *Cajanus cajan* (L.) Millsp.**" conducted with the following objectives

1. To study the performance of *Kerria lacca* Kerr. on *C. cajan* genotypes.
2. Assessment of seed and lac yield on *C. cajan* genotypes.

REVIEW OF LITERATURE

The scientific literature related to the present research has been reviewed under following subheads.

Pigeonpea varieties

Jensen *et al.* (2007), performed a comprehensive comparative study on the performance of six pigeonpea varieties in a maize-based cropping system in Eastern and Southern Africa. The study revealed that the newly introduced ICEAP 00040 outperformed all the other tested varieties (ICP 9145; ICEAP 00020, ICEAP 00053, ICEAP 00068, and a local variety called "Babati White") under farmer managed conditions. Wide range of environmental conditions and yearly rainfall variations with mean grain yields ranging from 36 to 890 kg DM ha^{-1} in Ntonda the third season vs. the first season. The grain yields differed between years (P = 0.0001), sites (P = 0.0001) and varieties (P = 0.001). The mean grain yields dropped from 740 kg/ha in the first season to 230 kg/ha in the second season and further to 172 kg/ha in the third season. Across the seasons, the grain yields (kg/ha) ranking was Babati (489), Ntonda (442), Nyambi (330) and Gairo (216). Babati and Ntonda had better yield performance ($P<0.05$) than Nyambi and Gairo.

Egbe and Vange (2008) concluded after their three years of experimentation that the short duration genotypes achieved 50% flowering earlier than the medium, which in turn flowered earlier than the long duration types. Though classified as late maturity (>180 days), ICP 7193 flowered in 124.00, 121.00 and 119.00 days in the year 2002, 2003 and 2004 respectively, which were not statistically different from the means for the medium duration (151 – 180 days) genotypes which flowered in 120.71, 123.25 and 124.46 days for the same period. Similarly, the short duration (< 150 days) genotypes reached maturity earlier (X = 149.95 days) than medium (X = 175.00 days) and the medium matured significantly earlier than the long duration (X = 209.08 days). Although grouped as short duration ICP 6971 matured in 165.00 days (2002), 163.00 days (2003 and 2004), which were not significantly different from those of other genotypes as ICP 7992 and ICP 7338, which have been designated as medium duration. The local check reached maturity in 210.00 days (2002), 199.00 days (2003) and 205.00 days (2004). However, when the farmers' preference for early-maturing and high-yielding genotypes are considered, ICP 6971 and ICP 88039 may be chosen, as these varieties gave mean yields of 1.54 t/ha, which is even higher than the farmers' average of 1.25 t/ha.

Kumar *et al.* (2014) evaluated fourteen, *C. cajan* (L.) Millsp. genotypes for their yield performance at two locations during Kharif season of 2009-10 and 2010-11. A significant genotypic difference for yield character was observed. The stability analysis showed significance of linear component of variation for grain yield. The genotypes TJT-501 (1728.667 kg/ha) and GRG-2009-3 (1570.00 kg/ha) exhibited low mean performance along with regression value nearer to unity (bi=1) and non significant deviation from regression (S2 di=0) indicating, the high stability and wider adaptability across the different environments.

According to IIPR (2015), Pigeonpea [*C. cajan* (L.) Millsp.] is the fifth prominent pulse crop in the world and in India after chickpea. It is one of the most important Kharif pulse suitable for rainfed situation with an area of 4.06mha (15.5%), production 3.2mt (18.6%) and productivity 902kg/ha.

According to another report (AGRICOOP, 2015), India is having the largest share of about 25 per cent production, about 33 per cent acreage and about 27 per cent consumption of total pulses of the world. The acreage increased from 20.35 (2000-01) to 25.21mha (2014-15) while the production during the period from 11.08 to 19.78 mt. The productivity increased from 544 kg/ha (2000-01) to 785 kg/ha (2014-15). The major pulses producing states are Madhya Pradesh (25%), Uttar Pradesh (13%), Maharashtra (12%), Rajasthan (11%), Andhra Pradesh (9%) and other states together (30%) during 2014-15.

Hluyako (2017) evaluated the six pigeonpea landraces collected from Hluhluwe in KwaZulu-Natal, South Africa and characterized in cream white, dark brown, white with black, cream white with brown, light brown with brown and light brown landrace. Results showed significant differences at ($P < 0.05$) and the highest germination per cent was achieved by light brown with brown with 100 per cent germination. There were also significant differences among the landraces with respect to leaf area index in Makhathini research Station, days to 50 per cent flowering and days to 75 per cent physiological maturity. Significant differences were also observed among landraces in terms of yield and yield components which included 100 seed weight and seeds per pod. There were no much differences in morphological characters of the crop such as leaf colour, stem colour, flower colour, streak pattern, pod colour, growth habit and flowering pattern. Cream white took maximum days to 50 % flowering in Makhathini which was 165 days, and 208 days to reach 75 % physiological maturity while the same landrace took 201 days to 50 % flowering in Newlands which was also the maximum days to reach flowering. Grain yield in tons per ha was also significant positive correlated with pod mass (0.84) and harvest index (0.76). Correlation results also revealed that biomass was the major influence to fixed nitrogen at maturity (0.86). Negative correlations also existed between germination per cent and seeds per pod (-0.52), seed emergence and harvest index (-0.50). Significant negative correlation also existed between harvest index and biomass (-0.76).

Saxena *et al.* (2018) reported traditional pigeonpea cultivars are of long duration and mature in 170–275 days under different eco-systems. Pigeonpea is used to fetch its green pods (for vegetable purpose)/dry pods (grain purpose) and stems for the much- needed domestic fuel. Intercropping of pigeonpea (1 row) and soybean (3 rows), the control cultivar produced 648 kg/ha grains, while the hybrid under this system yielded 1250 kg/ha with 93 per cent superiority over the inbred. These are very important yield contributing traits and their breeding is rather easy due to high heritability and easy identification of desirable sergeants. In pigeonpea germplasm, there is a vast range of variability for both pod size (2–9 seeds/pod) and seed size (4–26 g/100 seeds). In general, pod and seed size are positively correlated with each other, but their relationship with yield is not linear; and this needs a compromise among seed size, pod size and yield.

According to the report (Anon, 2019) of the domestic production of pigeonpea in 2018-19 was 3.68 million mt. Total production in India was 4250.00 thousand ton in 2018-19 total production was 16.84 per cent. During the period India's exported 8.20 thousand ton pigeonpea.

Pigeonpea yield

Gwata and Shimelis (2013) after a study found in South Africa that an average yield of 0.5 and 1 t ha^{-1} obtained for different landraces is still very low when compared with genotypes cultivated in Malawi, with an average yield ranging from 2.7 to 3 t ha^{-1}.

Khakhi (2014) reported that average yield potential of pigeonpea was between 1.5 and 2.5 t ha^{-1} in India and up to 3 t ha^{-1} in Malawi. Pigeonpea yields in other African countries are very low, ranging from 0.40 (Kenya) to 0.70 (Nigeria) t ha^{-1}.

Nndwambi *et al.* (2016) reported that variable P fertilizer rates exerted significant effect on pigeonpea grain yield in both seasons. Highest grains yields of 922 and 1141.7 kg/ha under sole and intercrops plots, respectively, were achieved was 45 kg P ha-1 during first and second seasons, respectively. However, the predicted optimum grain yield of 734 and 1034 kg/ha based on the response model was achieved at 52.67 kg P ha-1 and 42.84 kg P ha-1, in the respective seasons. Intercropping achieved a significantly higher pigeonpea grain yield (+37%) during second year than sole cropping following P addition; with over 21 per cent mean grain yield advantage across the two planting seasons. Hence, depending on the inherent soil-P level, application of 42-53 kg P ha-1 under Pigeonpea/maize intercrop represents the range at which P is optimum for increasing maximum 166% pigeonpea grain yield. Among the P rates evaluated, the 45 kg P ha-1 was more productive and profitable under both maize and pigeonpea and sole pigeonpea.

Shrivastava *et al.* (2018) reported raised bed sowing of pigeonpea TJT-501 in the vertisols of Narsinghpur district in Central Narmada Valley Agro-climatic Zone of Madhya Pradesh during the years 2014-15 and 2015-16. Under the flat bed sowing the crop yield was just 9.75 q/ha which improved to 15.23 q/ha under the raise bed sowing. The flat bed sown Pigeonpea fetched at gross return of Rs. 56,800/- whereas the raised bed sown crop fetched a gross return of Rs. 88,480/-

.

Effect of abiotic factors on pigeonpea

Sallette and Courbois (1968) reported that pigeonpea is a drought tolerant plant, and its seeds and forage have over 20 per cent protein. Experience in several Asian and other African countries have shown the importance of pigeonpea in sustaining rain-fed and semi-arid cropping systems. In South Africa, only 10 per cent of the total arable area receives an annual precipitation of more than 750 mm. Under these circumstances pigeonpea could find a place to enhance sustainability and profitability of the drought-prone cropping systems and to alleviate rural poverty. For vegetable purposes, the pods are picked when the seed has reached physiological maturity. A yield of around 15 tonnes per hectare (35% dry matter) has been reported.

Willey *et al.* (1981) reported that pigeonpea is a drought tolerance partly emanates from its ability to produce grain using residual soil water at the end of the rainy season. Being a legume, pigeonpea can also make a valuable contribution to the nitrogen economy of pigeonpea based cropping systems.

Sardana *et al.* (2010) observed that pigeonpea crop is mostly planted in areas receiving a mean annual rainfall of between 600 to 1400 mm in India; the temperature required for cultivation of pigeonpea in India is 26–30 °C during the rainy season between June and October and 17–22 °C during the November–March.

Mathews (2010) proposed that indigenous crops can broadly be defined as crops that have originated in Africa. These include bambara groundnut (*Vigna subterranea* L.), cowpea (*Vigna unguiculata* L.), cassava (*Manihotes culenta* Crantz), and pigeonpea (*Cajanus cajan.*) Indigenous crops with their relatively higher tolerance to drought and adaptability to marginal areas have great potential in sustaining productivity and profitability of dry land farming and ensuring food security, in addition to their role in improving soil fertility.

Effect of biotic factors on pigeonpea

Bhatnagar and Davies (1978) observed that the losses due to pod borer (*Helicoverpa armigera*) in pigeonpea significantly reduced when it was intercropped with sorghum.

Minja (1997) reported that a single seed locule contained more than 2 larvae/pupa of *Moellenkampi chalcosoma* (up to 40 larvae/pupa were observed per pod of five seeds in Kenya) compared to 1 or 2 for *M. obtusa* in India. Pod fly accounted for up to 4 per cent, 7 per cent, 13 per cent, and 46 per cent of seed losses in Malawi, Tanzania, Uganda, and Kenya, respectively.

Shanowr *et al.* (1998) reported that *Melanagromyza obtusa* Malloch, restricted to Asia. Pod fly damage has been reported from several countries. Extensive studies have been conducted on *M. obtusa* in Asia (Intercropping did not affect pod borers, but reduced pod-sucking bugs. Early planting increased pod borer damage but reduced damage by pod suckers. Therefore to be able to utilize cultural practices in pest management, it is important to establish which group of pests causes most damage.

Meena *et al*. (2010) reported that tur pod fly (*Melanagromyza obtusa*) is the major insect pest of long duration pigeonpea, especially in north and central India.

Singh and Nath, (2011) reported that Tur pod bug *Clavigralla gibbosa* (Spinola), a potential pest and occasionally cause significant grain yield losses in long duration pigeonpea. The damage in grain yield due to pod bug generally ranges between 25 to 40 per cent.

Sharma *et al.* (2014) suggested that chlorpyriphos 20 EC the best treatment to control *Helicoverpa armigera*. They recommended the use of combination of insecticide with neem formulations. The use of insecticide in half the quantity with half quantity of neem products was very effective if compared with chemical insecticide alone to control pod borer *Helicoverpa armigera*, the key pest of pigeonpea.

Pigeonpea Uses

Fu *et al*. (2007) reported that pigeonpea possesses various medicinal uses, mainly as anti-inflammatory, anti-bacterial and abirritative properties.

Igene *et al.* (2012) found that the substitution of up to 50 per cent of the soybean cake in chicken feed with pigeonpea has no negative effect on the chicken's growth, despite having an adverse impact on haematological indicators, such as the level of haemoglobin and leukocytes.

Kumar and Joshi (2014) observed that pigeonpea is the widely consumed pulse in India by a narrow margin over chickpea. Its relative importance in the composition of pulse demand has not changed that much in the recent past. Between 1988 and 2009, its share in total pulse consumption declined marginally from 26.8 to 25.4 per cent.

Fuel wood and fodder

Yude *et al.* (1993) reported that pigeonpea dry stems are important household fuel woods in many countries. A normal pigeonpea crop produces about 10-12 t ha-1 of dry fuel wood. The quality of pigeonpea fuel wood has been estimated to be excellent, yielding energy @ 4350K-cal kg^{-1}.

Zhenghong and Fuji (1997) reported that pigeonpea has strong woody stems that grow up to 4m tall and branch freely, its spindly stalks are extensively used as a cooking fuel in energy short villages of several African countries and in India, Nepal and Sri Lanka. Moreover, in the low mountain range of China, the farmers cultivate pigeonpea on wastelands and field bunds providing relief from the energy shortage and likewise help in arresting deforestation.

Matthews and Saxena (2000) observed that dry stems of pigeonpea are an important source of fuel in rural India and produces about 10 to 12 tons per ha of dry woods.

Egbe and Kalu, (2006) reported that pigeonpea is a multipurpose leguminous crop that can provide food, fuel wood and fodder for the small-scale farmer in subsistence agriculture and is widely cultivated in Nigeria.

Snapp (2014) observed that ratooned pigeonpea plants are expected to have larger root systems, which can reduce the risk of erosion, especially early in the season. In addition to producing grains for food, perennial grains can also provide fodder for livestock and stover as fuel for cooking. Among the potential benefits derived from pigeonpea is that about 15-20 tons/ha of fuel wood from pigeonpea crop can provide energy @ 4,000 kcal/kg (ICRISAT, 2013).

Wasteland management

Sherchan *et al.* (1997) reported that alley cropping with pigeonpea was also found useful to reduce soil erosion. Pigeonpea is outstanding in the depth and lateral spread of its root systems, which enables it to tolerate drought. The deep (3 m) root system allows optimum utilization of moisture. Leaf-fall not only adds to the organic matter to the soil, but also provides additional nitrogen. Studies carried out in the hilly areas of Nepal showed that the organic matter content, infiltration and improvement of water retention were the highest in plots under pigeonpea.

According to Saxena (2000), in China pigeonpea is grown in about 60, 000 ha of hilly wastelands for soil conservation, which helps in arresting deforestation.

Small and Marginal farmer

Makoka (2009) reported that women dominate smallholder pigeonpea production in Malawi, and they play an important role in informal food distribution and processing.

Mussa *et al.* (2012) indicated that smallholder pigeonpea producers were experiencing increasing returns to scale, suggesting that the output of pigeonpea could respond positively and with higher proportion for a given simultaneous per cent change in the quantity of seed, manure and labor. Therefore, support for human capital development of farmers and increased access to improved pigeonpea seed varieties could be important intervention areas to increase pigeonpea productivity. Production analysis for the smallholder pigeonpea production in Northern Tanzania, results showed that inputs including plot size, labor, interaction between plot size and quantity of seed, and the interaction between seed use and time positively and significantly affected pigeonpea productivity.

Pal *et al.* (2016) reported that average land holding size of pigeonpea seed farmers was higher in comparison to grain farmers and the district average. The study illustrates ratio of 32:68 towards fixed and variable costs in pigeonpea certified seed production with a total cost of Rs 39,436 and the gross and net returns were Rs 73,300 and Rs 33,864 per hectare, respectively. The total cost of cultivation, gross return, and net return in pigeonpea seed production were higher by around 23, 32, and 44 per cent than grain production, respectively.

Lac production on Pigeonpea

Yunzheng *et al.* (1980) compared different pigeonpea population densities by using spacing 0.5 × 2 m (19,980 plants ha^{-1}), 1 × 1.5 m (13,320 plants ha^{-1}), and 1 × 2 m (9,990 plants ha^{-1}) for the total branch length available for lac production. The results showed positive relationship between plant population and number and total length of useful branches. At the population of 19,980 plants ha^{-1}, 79,920 suitable branches were produced with a total branch useful length of 80,719 m ha^{-1}. It was interesting to note that a plant population of 9,990 plant ha^{-1} produced more number (49,950) of usable branches with more (46,153 m) total branch length than higher plant population (13,320), which yielded only 39,960 branches and 35,165m branch length in one hectare.

Zhenghong *et al.* (2001) reported pigeonpea (*C. cajan*) as a new host of lac insect. They stated that pigeonpea was identified as a favourite host for lac insect long back in 1950's, but on-farm lac production with pigeonpea has recently emerged as a result of increasing demand of lac from various parts of world.

Thomas (2003) reported lac production on pigeonpea in Madhya Pradesh for the first time, since then research and development in the state is in progress.

Ghosh *et al.* (2014) conducted experiment to study the impact of pigeonpea-lac insect interaction for the production of raw lac /scrapped lac as well as grain yield and protein quality in seeds. Five genotypes of pigeonpea viz., IPA 8-2, Bahar, Assam local, Acc. no. 591139 and RCMP 5 were identified promising for lac production. Rearing of lac insect on pigeonpea reduced 100 seed weight (13.03%) and grain yield per plant (12.08%) significantly but no significant reduction was observed on crude protein content in seeds (1.02%).

Lohot *et al.* (2018) found significant difference in 100 seed weight and seed yield among selected germplasm of pigeonpea. With lac insect hundred seed weight ranged from 9.1 g to 11.7 g in lac inoculated germplasm lines and 9.8 g to 12.9 g in control. The average seed yield in lac inoculated condition was 12.2 q/ ha as compared to 13.5 q/ ha in control. On an average, lac culture on pigeonpea reduced 100 seed weight and seed yield by 5.4 and 10.5 per cent, respectively. KA 9-2 (11.7g & 12.9g) and Assam Local 2 (11.2g & 12.1g) maintained high 100 seed weight as compared to check Bahar (9.9g & 10.5g), on the other hand KA9-2 (19.9 q/ha & 21.7 q/ha) and MAL 13 (18.7 q/ha&19.5 q/ha) had relatively higher seed yield in both condition as compared to check Bahar (10.7 q/ha&12.4 q/ha).

Vajpayee *et al.* (2019) conducted a field trial on *Baisakhi* lac production of *Cajanus cajan* with different population densities of lac insect during May 2018 to May 2019. Population density of 40 lac insects per 2.5cm^2 if maintained at the time of broodlac inoculation resulted in lesser intra specific competition for space to grow and food to produce lac. Thus the mean weight of 100 lac cell was highest (3.12 g). The mean total length of sticklac was highest (654 cm) on the *C. cajan* with natural settlement of lac insects 127.39 per 2.5 cm^2 while it was minimum (506.33 cm) on that with population density of 60 insects per 2.5cm^2. The mean weight of raw lac per 2.5 cm^2 was 0.97, 0.96 and 0.93 g on *C. cajan* with population densities of 100,127.39 and 80 insects per 2.5cm^2 while it was least 0.25 g on *C. cajan* with population density of 40 insects per 2.5cm^2 closely followed by 0.30 and 0.32g on *C. cajan* with population densities of 50 and 60 insects per 2.5 cm^2 respectively. The mean estimated yield of lac per plant was highest (446.0 g) on *C. cajan* with population density of 40 insects per 2.5cm^2 while it was lowest (332.33 g) on *C. cajan* with population density of 80 insects per 2.5 cm^2.

General information of lac

Ramani *et al.* (2007) reported that lac is cultivated as a cash crop in different countries of south, southeast and East Asian countries including India and China.

Ahmad *et al*. (2014) reported that the mouthparts of *K. lacca* are hypognathous. The salient features are the clypeolabral shield, labium and the stylet fascicle. The two segmented membranous labium is with a longitudinal groove on its anterior surface, and with sensilla in symmetrical configurations on either side of the groove. The stylet fascicle remains coiled inside a membranous pouch „crumena within the body comprising of two inner maxillary stylets and partially surrounded by the slightly shorter, outer mandibular stylets.

According to Jaiswal and Singh (2014), in India lac is mainly produced by two strain of lac insect, *Kerria lacca* Kerr. ("*Rangeeni"* and "*Kusumi*"). *Rangeeni* lac has summer (*Baisakhi*) and rainy (*Katki*) season crops, of 8 and 4 months duration respectively. Two crops of *Kusmi* lac are the summer (*Jethwi*) and winter (*Aghani*), each is of around six months duration.

Socio-economic impotence of lac in rural livelihood

Kumar *et al.* (2002) reported price of sticklac varied from ₹ 10- 40/kg in different years. According to the informants, through lac culture, they could earn INR (₹) 20000-25000 (₹ 71.33= US $1) annually which was estimated to be 25-30 per cent of their total household income as also was the case with more than 3 million people belonging to socio-economically weaker sections of the society in other parts the country.

Jaiswal *et al*. (2006) reported that a survey of Ranchi district revealed that 28 per cent of the total agriculture income is contributed by lac in this region.

Singh *et al.* (2015) studied the impact of lac cultivation on economic strengthening of tribal women of Jharkhand. Agriculture is the main occupation, but it provides employment only for 3-4 months and creates problem of seasonal unemployment. Male member of the family migrate for daily wage labour work, and women and children are forced for collection of forest produces for livelihood security. Lac cultivation provides a great scope for socio-economic upliftment of women. There is tremendous natural resource in the form of lac host trees in this region.

In a field survey Ghugal *et al.* (2015) found the middle aged lac growers' more predominant (46.15%) followed by young lac growers' (38.46%) and old lac growers' (15.38%). The study revealed that among the respondents only 61.53 per cent used quality brood lac for inoculation. Only 15.38 per cent purchased brood lac, while the rest either managed or produced their own brood lac. Use of excess brood lac per tree was a predominant practice, as 50 per cent of the respondents used more than one kg brood lac per tree. On the other hand (42.30%) respondents used one kg brood lac per tree. Only 7.69 per cent respondent used brood in lesser quantity i.e. from 500- 700g. Shifting of brood lac after one week of inoculation is not a practice in the village. Removal of phunki was practiced by 80.76% lac growers' however none of them applied pesticides for predator management. The lac production on *Zizyphus mauritiana* varied from 1kg to 10kg per plant.

Saryam *et al.* (2017) reported after a field survey among lac growers revealed that a maximum number of lac growers (60%) were found young age, level of education (40%) was illiterate and middle school, (40%) marginal land holders, (60%) medium training attended lac growers, (50%) highest information seeking behavior among the respondents. After the adoption of Lac production, the contribution of lac growers to their annual household income varied from Rs. 75,000 to Rs. 1, 23,000. The study also found that age and occupation had a positive relationship, whereas landholding, number of trainings attended, information seeking behaviour, extensive participation and economic motivation had been significant to an annual income of women lack growers.

Sarvade *et al.* (2018) reported that lac cultivation generated an employment for 16-160 man days. Lac cultivation produces maximum gross return (Rs. 9,77,600) from 100 Kusum host plants, and the highest Benefit-Cost (6.80) ratio was recorded for Ber-*Kusumi* (*Zizyphus mauritiana-Schleichera oleosa*) crop in Ranchi, Jharkhand.

Nutrient management of lac insect

Sharma *et al.* (2015) evaluated *Rangeeni* lac produced on *B. monosperma* with six treatments viz., Zinc (T1), Boron (T2), Humic acid (T3), Zinc + Humic acid (T4), Boron + Humic acid (T5) along with Control i.e. Water spray (T6) each with three foliar applications at 30, 45 and 60 days after Broodlac inoculation (BLI). Foliar application of nutrient had a significant impact in the mean lac yield per plant over the control. The increase was highest over control in T1 (262.06%) followed by T4 (186.2%), T2 (163.7%), T5 (153.4%) and T3 (150%). The mean weight of raw lac per plant has highest T1 (2.10kg), followed by (1.53kg), (1.45kg), (1.66kg), (1.47kg) and (0.58 kg) among the Treatments, T2, T3, T4, T5 and T6 respectively.

Shah *et al.* (2015) revealed that the production cost of *Kusmi* lac per *Zizyphus mauritiana* tree was highest in the basal application of NPK (INR 338.25) followed by NP (INR 319.51), N (INR 317.11) and control (INR 270.68) treatments. The net return per tree was highest in treatment NPK (INR 1059.75) followed by N (INR 1019.14), NP (INR 922.99) and control (INR 687.82) treatments. It is concluded that the basal application of NPK in *Z. mauritiana* is economically suitable for *Kusmi* lac production. The mean operational cost per *Z. mauritiana* tree in *Kusmi* lac production was highest in treatment NPK (INR 149.34) followed by N (INR 144.4), NP (INR 136.9) and the control (INR 104.18). Similarly, the input cost per tree was also highest in treatment NPK (INR 188.91). It was followed by NP (INR 182.61), N (INR 172.71) and the control (INR 166.5). The gross return per tree was highest in treatment NPK (INR 1398) followed by treatment N (INR 1336.25), NP (INR 1242.5) and it was lowest in the control (INR 958.5).

Ghugal *et al.* (2016) studied the impact of foliar application on *B. Monosperma* for lac production and reported that the mean number of lac insect settled per 2.5 sq. cm varied from 49.95 to 51.11 at 30 day after broodlac inoculation on *B. monosperma*. It was highest in Zinc (51.11) followed by PGR (51.05), Boron (50.73), Control (50.31), Micro-nutrients (49.98) and Humic acid (49.95). There was no significant difference among the treatments at 30 day after BLI. The mean live lac cell count per 2.5 sq. cm at harvest was highest in on *B. monosperma* treated with PGR (30.09) followed by Zinc (28.55), Boron (27.42), Micro-nutrients (23.33), Humic acid (21.19) and Control (19.08). There was significant difference in all the treatments over the control. The per cent survival of insect over that at BLI was highest in PGR (58.95) followed by Zinc (55.86), Boron (54.06), Micro-nutrients (46.68), Humic acid (42.43) and Control (37.93).

Population density of lac insects

Mohanta *et al.* (2014) reported that the initial density of larva of lac insect ranged between 92.58-126.74 per sq.cm and 93.12-109.62 per sq.cm on Kusum and Ber plants respectively.

Sharma *et al.* (2015) conducted a field trial with six treatments viz., [Zinc (T1), Boron (T2), Humic acid (T3), Zinc + Humic acid (T4), Boron + Humic acid (T5) along with Control i.e. Water spray (T6)} and three foliar applications at 30, 45 and 60 days after Broodlac inoculation (BLI). The mean number of live lac insects settled per 2.5 sq cm differed among the six treatments at 30 days after BLI. The density was highest in T1 (58.24) followed by T6 (55.06), T5 (51.47), T4 (47.94), T3 (42.91) and T2 (37.95).

Kumar *et al.* (2017) reported the mean population density of *K. lacca* per 2.5 cm^2 varied from 44.95 to 50.28 in different foliar application of nutrients. There was significant difference in the mean population density of Lac insect in T3, T5 and T8 over T6. The former three were at par with each other. It was highest (50.28) in T3 Multiplex and lowest (44.95) in T6 Humic acid + Bolt acid + Bolt. At 62 days after BLI, the mean population density of lac insect varied from 37.05 to 39.34 per 2.5 cm^2 in different treatments but was at par among the treatments. It was highest (39.34) in T3 -Multiplex and lowest (37.05) in T2-Auskelp super.

Kalahal *et al.* (2017) revealed that the initial density of settlement of first instar crawlers on a host plant varied in different parts of plant which ranged from 20 to 121 crawlers per sq.cm and with a mean initial density of settlement of 92.60, 84.10, 60.00; 86.70, 91.60, 71.00 and 67.40, 64.70, 61.00 crawlers per sq.cm at lower, middle and upper parts of plants in three plots respectively. The mean final density of settlement first instars crawlers ranged from 17 to 114 crawlers per sq.cm with mean of 85.50, 78.20, 53.10; 80.20, 85.90, 65.00 and 61.90, 57.30, 54.60 crawlers sq.cm on lower, middle and upper portion of plant in three plots respectively.

Hazarika *et al.* (2018) observed initial settlement density of the crawlers of lac insect, *K. lacca* Kerr. (Hemiptera: Tachardidae) in different cardinal directions of the host plant branches was examined for two consecutive crops of *Kusmi* strain, summer and winter crop, during 2016-17.

For the summer crop, initial settlement density towards west (31.2/sq. cm) and south (34.6/sq. cm) was significantly low as compared to that towards north (97.0/sq. cm) and east (89.2/sq. cm). For winter crop, highest settlement density was observed towards north (91.8/sq. cm) which differed significantly from that in the west direction (57.2/sq. cm). In case of horizontal branches, initial settlement density in the lower side of the branch was much higher (92.6/sq. cm and 77.2/sq. cm) than the upper side (26.8/sq. cm and 25.6/sq. cm) for both summer and winter crops, respectively. Most possibly crawlers of lac insect prefer shade and escape from direct exposure to sunlight. Generally, towards north and east as well as the lower side of the branch, shade is more which might be the reason for the highest settlement density.

Meena *et al.* (2019) collected lac insect collections from Hisar, Bhiwani, Umreth-Anand, Barauda, Bijolia-Bhilwara, Aburoad-Sirohi, Chittorgarh, Udaipur were evaluated on *Flemingia* macrophylla to study productivity parameters during *Katki* crop. The mean initial density for all locations during 2016 and 2017 was non-significant. Maximum mean density was in Chittorgarh (111.33 crawlers/cm^2) as against Umreth (70.67 crawlers/cm^2) during 2016. During 2017, 116.00 crawlers in Aburoad as compared to minimum in Hisar (78.67).

Survival of lac insect on host

Shah *et al.* (2014) after a field study on *K. lacca* inoculated on nutrient management *Z. mauritiana* (Lamb.) conducted during 2013-14, revealed that there was an increase in both the survivability of *K. lacca* as well as resin production by it. The mean percentage survivability of *K. lacca* at maturity of the lac crop was highest (17.21%) in NPK treated *Z. mauritiana* over the control. It was followed by N (12%) and NP (10.71%) treatments.

Vajpayee *et al.* (2019) reported the effect of population density of lac insect *K. lacca* Kerr. on its growth and survival. Experiment was conducted on *Cajanus cajan*, with seven treatments replicated thrice, during the year 2018-19. Lac insect population density of 40, 50, 60, 80, 100, natural population per 2.5cm^2 as well as no insect were the seven treatments. The highest survival of lac insect from brood lac inoculation to harvest was 81.53 per cent in the population density of 40 insects per 2.5cm^2.

Predators and parasites management in lac crop

Sharma *et al.* (1997) reported that fourteen species of parasitoids under 13 genera representing ten families associated with *K. lacca*, but *A purpureus* and *T tachardiae* constituted 55.82 and 28.37 per cent respectively of the total population of parasitoids.

Sharma and Ramani (2001) reported that though there was no significant difference in size of healthy and parasitized lac cells, quantity of the resin produced declined by 17.92 and 17.44 per cent while fecundity decreased by 32.55 and 34.71 per cent for *Kusmi* and *Rangeeni* strains, respectively.

Sharma *et al*. (2007) studied super parasitism in *K. lacca* and its implications on fecundity and resin producing efficiency of its two strains. The parasitoids of lac insect cause severe damage to the crop affecting adversely the resin yield and the fecundity of the insects, particularly during rainy seasons. The average reduction in resin produced by a single female due to parasitism varied between 17.25 to 39.80 per cent in *Rangeeni* and 25.24 to 37.91 per cent in *Kusmi* strain. On the other hand the reduction in fecundity of lac insects ranged between 22.44 to 96.82 and 25.29 to 90.39 per cent in *Rangeeni* and *Kusmi* strains respectively.

Janghel *et al.* (2014) reported the bio efficacy of insecticides for predator management of *K. lacca* on the natural stand of *B. monosperma* trees of 10 women lac growers of village Malhara Seoni district Madhya Pradesh during the July- October 2012. A combination of Cartap hydrochloride + Mancozeb (T1), Emamectin benzoate + Dithane M-45 (T2) and Control (T3) was evaluated against the predators of the lac insect. Pesticides application significantly reduced the incidence of major predators- *E. amabilis* and *P. pulverea*. In comparison to T3 there was a reduction in the population of *E amabilis* by 90 and 87 per cent respectively with (T2) and (T1). In case of *P. pulvera* reduction in the population was 90 and 86.18 per cent with T1 and T2 respectively over the control (T3).

Virendra *et al.* (2017) reported that mean monthly storage loss of lac was highest (31.87%) in stored lac samples collected in Nov. 2015 from *Kuchcha* storage structures. It was lowest (8.26%) in the stored lac samples collected in Dec. 2015 from *Pucca* storage structure. Among the lac traders the mean monthly storage loss was highest (19.12%) among Small lac traders in stored lac samples of August 2015, while it was lowest (10.97%) in Big traders in lac samples of December 2015. Larval stages of lac insects feeding on the stored lac spinned a loose web. A single larval predator is capable of destroying 45-60 mature lac cells.

Effect of abiotic factors on lac insect

Patel *et al.* (1997) reported unfavourable weather conditions such as heavy rains, very high or low temperatures, strong winds and hail storms also posed pronounced threats to lac culture and can affect it at any stage. In the villages under the study, about 11 per cent of the farmers reported failure of their lac culture due to heavy rains and hail stones during infestation period in the year 2012.

According to Das *et al.* (2020) the study on life cycle duration of lac insect revealed a minimum duration of 149 days during summer 2016 and the highest of 199 days during winter 2017. Variation of life span was more in *K. lacca* 149-199 days but in the case of *K. chinensis*, life span varied from 155-194 days. The correlation analysis of weather parameters with life cycle duration of lac insect showed a highly significant positive correlation (r = 0.85**) with morning relative humidity and significant negative correlation (r = -0.68*) with total rainfall. The multiple linear regression analysis showed that total rainfall, maximum temperature, bright sunshine hours, morning and evening relative humidity were the major weather parameters which affected the life cycle duration of *Kerria* spp. and these five weather parameters exhibited the highest Adjusted Coefficient of Determination of 86.37 per cent and explained 93.94 per cent of the total variation occurring in the crop growth period.

Weight of 100 lac cells

Mishra *et al.* (1999) reported that in *F. semialata,* the live cell weight and *Phunki* (dry) cell weight varied from 13.16 to 38.33 mg and 8.00 to 19.00 mg respectively, whereas on *F. macrophylla* it varied from 16.83 to 31.67 mg and 9.33 to 18.83 mg.

Patel (2013) reported that the mean fresh weight (g) of 100 mature lac cells was 4.88g in *Kusmi* lac and 3.38g in *Rangeeni* lac while the dry weight of 100 cell was 4.66g in case of *Kusmi* lac and 2.63g in case of *Rangeeni* lac.

Namdev (2014) reported that the mean fresh weight (g) of 100 mature lac cells was varied from 5.27 to 8.91g in various treatments. The mean dry weight of 100 cells was 4.25g to 7.84g.

Ghugal *et al.* (2015) revealed that the mean dry weight (g) of 100 cells of lac insect varied from 3.82g to 5.18g. The mean dry weight of 100 lac cells was highest in T4 (5.18) followed by T2 (5.14g), T3 (5.02g), T1 (4.59g), T5 (3.86) and T6 (3.82g). The mean dry weight (g) of raw lac per 30 cm stick varied from 07.53 to 21.57g and it was highest in T4 (21.57), followed by T2 (16.88), T3 (15.14), T1 (13.00), T5 (10.41) and T6 (07.53).

Namdev *et al.* (2015) conducted a field trial consisting of forty eight *Z. mauritiana* plants with four treatments (basal application of Urea- T1, Urea and SSP-T2, Urea, SSP and MoP- T3, and control- T4) and six replications. Mean fresh weight of 100 cell of Kusmi lac insect was highest (8.02) in T3 followed by T1 (7.20 g), T2 (6.89 g) and T4 (6.14).

Sharma *et al.* (2015) after a field trial consisting six treatments viz., Zinc (T1), Boron (T2), Humic acid (T3), Zinc + Humic acid (T4), Boron + Humic acid (T5) along with Control i.e. Water spray (T6), reported that the mean dry weight of 100 cells of lac insect was highest in T1, (3.68g) followed by T2 (3.49g) T5 (3.43g), T4 (3.41g), T6 (3.21g) and T3 (3.03g). There was a significant increase the dry weight of 100 lac cell of *Rangeeni* lac, It was highest (14.64%) in T1 followed by T2 (8.77%) over the control.

Kumar *et al.* (2017) conducted a trial from July 2015 to November 2015 to see the effect nutrient treated host of nutrition on lac cell production and transmission losses. The mean fresh weight of 100 mature healthy lac cells obtained from the sticklac at harvest varied from 6.36g (T8-Control) to 11.14g (T7). There was a significantly difference in the mean weight of 100 fresh cell weight in T7, T2 and T3 over the control; however T7 and T2 were at par with each other. The mean dry weight of 100 healthy cells of lac insect obtained seven days after shady drying varied from 4.95 g (T8 – control) to 8.21g (T7 – Humic acid + Auskelp). There was a significant difference in the mean dry weight in 100 lac cell of T7, T2 and T3 over the Control (T8), however but the former two were at par. The dry cell weight contributed significantly in the lac yield.

Wang *et al.* (2019) reported that female is able to secret vast amounts of lac in the adult stage, whereas the male do not secret lac anymore both in the pupal and adult stages. The lac secretion of *K. chinensis* in the whole summer generation was about 24.9 mg/female. Determination of individual gum secretion rate in each stage revealed that the secretion rate was slower in the larval stage which increased gradually in the adult stage. In the early adult stage (A1), the individual fastest secretion rate was 4.82×10^{-1} mg/d, and the secretion decreased gradually in the mid–late adult stage.

Sticklac and Lac yield

According to a report (FAO, 1995) the average yield of sticklac on an individual tree of *Schleichera oleosa*, *Zizyphus mauritiana* and *Butea monosperma* varied from 6 to 10 kg, 1.5 to 6 kg and 1 to 4 kg respectively.

Ferdousee *et al.* (2010) reported the sticklac yield per plant varied from 8 kg (*Acacia nilotica*), 10 kg (*B. monosperma)*, 12 kg (*Acacia catechu)*, 20 kg (*Z. mauritiana*), and 80 kg (*Samanea saman*) in Rajshahi division, Bangladesh.

Shah *et al.* (2017) revealed that the mean weight per foot of stick lac increased significantly in nutrient treated *Z. mauritiana* plants over those on the *Z. mauritiana* without nutrient management. The mean weight per foot of stick lac was highest in *Z. mauritiana* with treatment NPK (48.10g) followed by that treated with N (42.63g), NP (41.66g) and control (37.63g).

Meshram *et al.* (2018) found maximum number crop (237.91 stick per plant) of Aghani lac in *S. oleosa* with mean length of 52.14 cm per stick lac which was low. The highest fresh weight of stick lac 47.68 g per 30 cm stick, maximum weight of scraped lac 23.96 g per 30 cm stick, highest total stick lac 54.94 kg per plant.

Borah and Garkoti (2019) reported *F. religiosa* and *F. bengalensis* tree could produce about 120-200 kg of sticklac in a season. The average annual household production of sticklac ranged from 679 to 776 kg in the studied villages and contributed to about 25- 30% of annual household income. Similarly, yield of sticklac was reported as 50-80 kg/tree for *A.*

lucidior, 30–50 kg/tree for *T. orientalis*, 20-25 kg/tree for *Z. mauritiana* and 5-7 kg/tree for *Grewia S*.

Vajpayee *et al.* (2019) reported the mean total length of sticklac was highest (654cm) on the *C. cajan* with natural settlement of lac insects 127.39 per 2.5 cm^2 while it was minimum (506.33cm) on *C. cajan* with population density of 60 insects per 2.5 cm^2.

Insect diversity in lac crop

Sharma *et al*. (2006) reported that the lac insect infesting economically important plants viz. litchi (*L. chinensis*), mango (*M. indica*), Ber (*Z. mauritiana*), sandal (*S. album*), etc. are the direct targets of pest management leading to erosion of biodiversity of lac insects and associated fauna. Significant quantitative and qualitative variation in various biological attributes of the lac insect, viz. yield of resin, fecundity, sex ratio and body colour have also been reported. The pigment present in the lac insect haemolymph (laccaic acid or lac dye) is non toxic and finds numerous applications in textile, pharmaceutical and food industry.

Kumar *et al*. (2007) reported that in Rajasthan, 13 host plants of lac insect in southern Rajasthan among which Ber and Palash trees were dominant in numbers. Seven host plants viz. *B. monosperma* (Palash), *Z. mauritiana* (Ber), *F. religiosa* (Pipal), *F. bengalensis* (Bargad), *C. cajan* (Arhar), *Flemingia semialata* and *Flemingia macrophylla* (Bhalia) were evaluated with reference to the quantity of lac produced and developmental parameters. Ber was found to be the best host for lac production as maximum quantity was recorded on it (165.5 g per m). The highest fecundity (525.2 and 450.6 per female), female cell diameter (3.52 and 3.06 mm) and cell weight (14.21 and 10.12 mg) were recorded in *Baisakhi* (summer season) and *Katki* (rainy season) crop respectively. *E. amabilis* (Moore) (Lepidoptera: Noctuidae) and *P. pulverea* Meyr. (Lepidoptera: Blastobasidae) were recorded as the major predatory pests of lac insect.

Chen *et al*. (2011) reported that in China *Dalbergia szemaoensis*, *D. obtusifolia, Ficus altissima* and *F. racemosa* are common lac host tree.

Sharma *et al.* (2019) revealed that the mean initial density of settlement of crawlers varied from upper portion to lower portion of three host plants and ranged from 32-114, 30-110 and 23-120 crawlers per sq.cm of Ber, pigeonpea and *Flemingia* respectively with mean initial density of settlement of crawlers were 72.83, 77.40 and 93.93; 64.20, 66.63 and 68.60; and 67.98, 72.89 and 73.47 crawlers per sq.cm on upper, middle and lower portion of Ber, pigeonpea and *Flemingia* respectively during *Katki* season, 2017. The mean female cell weight recorded for Ber, pigeonpea and *Flemingia* were 22.54, 17.15 and 19.39 mg respectively during *Katki* season, 2017. The mean weight of resin recorded for Ber, pigeonpea and *Flemingia* 20.92, 15.57 and 17.82 mg respectively during *Katki* season, 2017. The mean weight of sticklac (kg) for Ber, pigeonpea and *Flemingia* were 3.69, 1.73 and 1.08 kg respectively. The sex ratio observed as mean per cent male insect 10.51, 11.02 and 11.17; 11.33, 13.23 and 13.59; 10.78, 11.17 and 11.86 per sq.cm were recorded on upper, middle and lower portion of Ber, pigeonpea and *Flemingia* respectively. The total life period of female cells of *Rangeeni* strain of lac insect in *Katki* season, 2017 on Ber, pigeonpea and *Flemingia* were 115, 120 and 118 days respectively from the date of inoculation to date of harvesting and the maximum mean fecundity (per female cell) 443.37 was recorded from the Ber. The mean scrapedlac yield (kg) was 0.74, 0.35 and 0.22 for Ber, pigeonpea and *Flemingia* respectively in *Katki* season during, 2017.

Lac production in India

According to a report (IINRG statistics 2014-15), India is the major producer of lac, accounting for more than 50 per cent of the total world production. The national production of sticklac during 2012-2013 was 19577 tons. In India, Jharkhand state with 50.83 per cent of total lac production, ranks 1st followed by Chhattisgarh (14.58 %), Madhya Pradesh (14.41 %), Maharashtra (8.98 %), Orissa (4.21 %), West Bengal (2.66 %) and Assam (1.68 %). Total export of lac and its value added products in 2012-2013 was 5,43,620.51 tons.

Jaiswal and Singh (2014) analysis of year wise lac production data in India during XI Plan (2007-2008 to 2011-2012) indicated average production by the country to the tune of 16.246 thousand ton. The Jharkhand state registered highest average annual production (6.306 thousand ton), sharing

38.82 per cent of total lac produced in the country. This is followed by Chhattisgarh (30.21%), Madhya Pradesh (13.66 %), West Bengal (6.97%), Maharashtra (4.96%), Odisha (2.27%), Uttar Pradesh (1.94 %), Assam (0.52%), Andhra Pradesh and Gujarat (0.30% each) and Meghalaya (0.06 %). In respect of state wise growth rate in lac production, the country registered negative growth rate to the tune of 8.38 per cent per annum.

Life cycle of Lac insect

Sharma *et al.* (1991) observed various attributes of lac insect life cycle and reported that *Kusmi* strain male emergence was 7-8 weeks after settlement and it takes about 142-160 days to mature, whereas in *Rangeeni* strain the male emergence was 6-7 weeks after its settlement and it takes about 120-137 days to mature in winter crop.

Sharma *et al.* (2018) studied life cycle of *Rangeeni* strain of lac insect *K. lacca* Kerr. on Ber, pigeonpea and *Flemingia* and reported the total life period of *Rangeeni* strain of lac insect in *Katki* crop season on Ber, *Flemingia* and pigeonpea was 115, 118 and 120 days, respectively. The fecundity of female cell was recorded to have 443.37, 387.70 and 336.07 crawlers (per female cell) on Ber, *Flemingia* and pigeonpea, respectively. The mean of scrapped lac yield recorded was 0.74, 0.35 and 0.22kg for Ber, pigeonpea and *Flemingia*, respectively.

Adult male emergence of Lac insect

Jaiswal and Sharma (2011) studied the adult male emergence of *Kusmi* and *Rangeeni* lac insect and reported that the male insect emerge 78 weeks after inoculation in case of *Kusmi* lac in *Aghani* lac crop and male insect emergence 6-7 weeks after inoculation in case of *Rangeeni* lac in *Katki* lac crop.

Mohanta *et al.* (2013) reported the longest life span of 8 months 5 days in *Baishakhi* (summer) crop and shortest life span of 3 months 16 days in *Katki* (rainy) crop of *Rangeeni* strain on Palas tree. The life span of adult male is 2-3 days and the life span of female insect varies between 62-148 days for different crops.

Patel (2013) reported that the adult male of *Kusmi* strain of *K. lacca* emerged at 70 days after BLI in winter crop on *Z. mauritiana*.

Vajpayee *et al.* (2019) reported adult male lac insects were observed in between 129th-143th day after BLI. The mean number of male lac insects maximum (6.67) with population density of 127.39 insects per 2.5cm^2, while minimum 1.39 in the population density of 60 insects per 2.5cm^2. The female to male ratio was highest (27.55:1) in the population density of 100 insects per 2.5cm^2 while the female to male ratio was lowest (10.87:1) in the population density of 127.39 insects per 2.5cm^2.

Phloem sap and insect response

Klingauf (1987) reported that variation in dietary concentrations of amino acids and sucrose affects aphid growth, survival and reproduction.

Cook and Denno (1994) reported that poor plant nutrition can have adverse effects on the performance and fitness of sap feeders.

Douglas (2003) reported that phloem sap is an extreme food source that is used as the dominant or sole diet of very few animals, specifically insects of the order Hemiptera, including aphids, whitefly, plant hoppers and some pentatomid bugs.

Prudic *et al.* (2005) reported that plant nutritional quality and plant defences that directly act on herbivores are altered by Nitrogen fertilization, and herbivorous insects can distinguish between plants receiving different Nitrogen applications.

Ahmed *et al.* (2007) found that the highest rates of Nitrogen resulted in the highest per leaf mean population of jassid, whitefly and thrips.

Gogi *et al.* (2012) reported development of plants depends on nutrient availability while that of insects depends on the quality of food available from its host plants.

Schepper *et al.* (2013) reported phloem flow is defined by the pressure difference between sources and sinks, it is influenced by the resistance of the phloem pathway. As phloem of higher plants has multiple functions in plant development, reproduction, signalling and growth.

MATERIAL AND METHODS

The present investigation entitled "**Study on the performance of *Rangeeni* lac insect (*Kerria lacca* Kerr.) on tall and long duration genotypes of *Cajanus cajan* (L.) Millsp.**" was conducted during *Kharif* 2019 – *Rabi* 2020 seasons. The materials used and methodologies followed to conduct the field experiment are concisely described in this chapter.

3.1. Experimental site

The field trial was conducted in the experimental field of JNKVV, Jabalpur, Madhya Pradesh from May 2019 to June 2020. The topography of the experimental area was fairly uniform. All physical facilities were adequately available on the experimental field to carry out the above field trial. The analytical works were done in the Laboratory of College of Agriculture, JNKVV, Jabalpur.

3.2. Weather

The weather of Jabalpur division is typically Sub humid, featured by hot dry summer and cool dry winter. The meteorological data for during the experimental period is mentioned in the Table – 1.

3.3. Experimental technique

The trial was laid out in Randomized Block Design during the rainy season of 2019-20, with ten treatments replicated thrice (Table 2 and 3).

Table 2: Experimental details of the treatments and notations used are as below

Location	:	Experimental field, JNKVV Jabalpur, M.P
Season	:	*Kharif* –*Rabi* 2019-20
Crop	:	Pigeonpea
Variety	:	TJT – 501+ 9 tall and long duration genotypes
Design	:	RBD
Replications	:	3
Treatments	:	10
Spacing	:	6 ft x 6 ft (plant to plant x row to row)

Table 3: Details of the treatments

Treatment	Genotypes	Source and location	District	Maturity duration (Days)
T_1	TJT-501	JNKVV , Jabalpur	Jabalpur	145-165
T_2	Lakhnadon-2	Farmer , Lakhnadon	Seoni	160-170
T_3	Korsar-3	Farmer , Korsar	Singrauli	240-270
T_4	Saraswahi	Farmer , Saraswahi	Jabalpur	140-150
T_5	Gadarwara	Farmer , Gadarwara	Narsinghpur	135-145
T_6	Amarkantak-1	Farmer , Amarkantak	Anuppur	135-145
T_7	Amarkantak-2	Farmer , Amarkantak	Anuppur	150-170
T_8	Amarkantak-3	Farmer , Amarkantak	Anuppur	160-170
T_9	Korsar-2	Farmer , Korsar	Singrauli	235-260
T_{10}	Amarkantak-4	Farmer , Amarkantak	Anuppur	150-165

3.4 Schedule of operations

Schedule of field operation during the course of experiment are mentioned (Table-4) in chronological order.

Table 4: Details of different field operations

S. no.	Field operations	Date	Plate no.
1.	Seed treatment and nursery raising	22.05.2019	1-2
2.	Land preparation and Layout of the experiment	24.06.2019-26.06.2019	3
3.	Filling of substrate in PPB, in field	28.06.2019-01.07.2019	4-5
4.	Transplanting of seedlings in PPB	05.07.2019	6
5.	Nipping of growing tips of plants	Upto September	7
6.	Bud initiation	September-October	
7.	Date of flowering	October	
8.	Date of podding	October-November	
9.	Brood lac inoculation	15.11.2019	10-12
10.	Spray of insecticides	Aug., Dec., and Jan.	9
11.	*Phunki* removal	06 .12.2019	13
12.	Slot marking	19.12.2019	14
13.	Digital counting of lac insect	January & May 2020	15-16
14.	Hand picking of mature pods (2 pickings)	January & April 2020	17
15.	Harvesting of *C. cajan* plant	12.06.2020	19
16.	Scrapping of raw lac	24.06.2020-25.06.2020	20-21
17.	Weighing of seed, raw lac and 100 lac cell	28.06.2020	22-24
18.	Growth stages of lac insect		25

***PPB: Polypropylene bag**

3.5 Nursery raising of *C. cajan*

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

The seedlings were sprayed with contact and systemic insecticides (Table no. 7) to prevent insect pest incidence. The growing tips of the seedlings were nipped at 10-12 days interval till its transplantation. Nipping was done to train the seedlings to a bush form.

3.6 Layout of the main field

The experiment was layout in plot size of 56 feet x 54 feet of the field to accommodate 90 *C. cajan* plants. The spacing between plant to plant and row to row in the main field was six feet. The spacing between replications was maintained at 10 feet.

3.7 Substrate

The substrate consisted of a mixture of river bed basin soil (*Kapu*) and well rotten Farmyard manure (FYM). The weight of substrate for each *C. cajan* plant the substrate used for growing in (PPB) was 65 kg *i.e.* 45 kg of *Kapu* + 20 kg of FYM (Patent application no. 201921005340 A Dated 01.03.2019). The *Kapu* and FYM in the above ratio were thoroughly mixed with the help of a spade to obtain a homogenized substrate. The physio-chemical property of the substrate is mentioned in the Table- 5.

Sixty-five kg of homogeneously mixed substrate was filled in a PPB. Each of the empty PPB weighed 125 g and had a dimension of 93 cm x 61 cm. The substrate was gradually filled into the PPB with help of a *tasala* followed by constantly shaking the bag to ensure proper compactness of the substrate in the PPB. The PPB when filled with 65 kg substrate attained a dimension of 46 cm height and 125 cm circumference. The PPB was filled with substrate on the designated spot in the layout of the experiment, such that it is not disturbed in future.

Table 5: Physico-chemical properties of the substrate (65kg) in PPB

Poly- propylene bag (PPB)

Constituents	Value (in g/65kg substrate)	Method used
Available N	136.15	Alkaline permanganate method (Subbiah and Asija,1956)
Available P_2O_5	45	Calorimeter method (Olsen *et al.* 1954)
Available K_2O	304	Flame Photometer method (Chapman and Pratt, 1961)

***Substrate:** = FYM (20kg) + *Kapu* (45kg) + *Trichoderma viridae*

3.8 Transplantation of *C. cajan* saplings

C. cajan saplings on attaining a height varying from 1.5 feet to 2 feet were transported to the main field. Each of the 90 saplings were place at adjacent to substrate filled PPB. The polythene bag of the *C. cajan* saplings was carefully removed without disturbing its root system. The sapling with substrate base was then carefully transplanted in the substrate filled PPB and pressed to minimizes air pockets, followed by watering. The transplantation was done in the evening hours of 05th July 2019.

3.9 Nipping

The transplanted *C. cajan* was again nipped at 10-12 days interval between 12th July 2019 the last week of September 2019.

3.10 Application of pesticides

Three preventive sprays of pesticides on *C. cajan* pants were carried out to protect lac insects from its predator and foliage feeders (Table-7).

Table 7. Spray schedule of pesticides

Spray	Pesticides	Dose	Day	Remarks
1st	Emamectin benzoate 5%SG	1g/litre	30 DAT*	To manage foliage feeders
2nd	Cartap Hydrochloride 50%SP	1g/litre	30 BLI**	To manage predators and parasites of lac insect
3rd	Cartap.+ Dithane M-45 75%WP	2g/litre	60 BLI	To manage predator and parasites of lac insect and sooty mold

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

3.11 Irrigation

Each of the PPB with *C. cajan* plant was irrigated at regular intervals. Between August to October, there was no irrigation due to rains, while from November to February the interval of irrigation was 15 days, but from March 2020 to June 2020, the irrigation schedule was at 10 days interval. Approximately 10 litres of water was given per plant during each irrigation (Table -6)

Table 6. Irrigation schedule

Irrigation schedule	Dates
1	02.11.2019
2	15.11.2019
3	30.11.2019
4	15.12.2019
5	30.12.2019
6	15.01.2020
7	30.01.2020
8	15.02.2020
9	25.02.2020
10	02.03.2020
11	11.03.2020
12	21.03.2020
13	31.03.2020
14	11.04.2020
15	21.04.2020
16	30.04.2020
17	10.05.2020
18	20.05.2020
19	31.05.2020
20	08.06.2020

3.12 Brood lac inoculation

Rangeeni brood lac was purchased from M/s Adarsh Lac Samiti, Jamankhari village, Tehsil Barghat, District Seoni, M.P. on 11.11.2019. Predator free good quality brood lac was sorted for its inoculation on *C. cajan*. Brood lac stick weighing 15 g was tied at the base of each *C. cajan* in the PPB on with the help of a twine as per the treatments mentioned in Table-3.

3.13 *Phunki* removal

Phunki removal pertains to the removal of brood lac twigs from *C. cajan* after complete emergence of lac nymphs from female cells. *Phunki* was carefully removed from *C. cajan* plant 21 days after BLI without damaging the lac insect settlement on the plants.

3.14 Harvest of pods

Hand picking of pods were done when 80 per cent of it on the plant attained maturity. They were handpicked separately per plant. The harvested pods were counted, dried weighed and threshed for recording grain yield during successive pickings.

3.15 Harvest of Lac crop

C. cajan with lac was harvested on 12.06.2020. The harvested *C. cajan* plant was shade dried for four days. All the branches with lac encrustation was separately kept measured and tagged. Lac was scrapped from the plant after keeping a clean polythene sheet at the base. The lac thus obtained was dried and weighed to record the data.

3.16 Observations

3.16.1 Plant growth

3.16.1.1 Height:

Plant height was recorded on 15 Oct' 2019, 20 Nov' 2019, 20 Dec' 2019, 29 Jan' 2020 and 01 Mar' 2020.

3.16.1.2 Thickness

The thickness of the stem, primary and secondary branches was recorded with the help of Vernier Caliper at 27 days before BLI. The following reading was taken at 32 to 55 days interval on 27 Dec. 2019, 25 Jan. 2020 and 25 Feb. 2020.

3.16.2 Lac insect count

Lac insects were counted from three fixed slots of 2.5 cm^2 (2.5 cm length and 1.0 cm width) on the stem or branch as the case may be with lac insect settlement.

3.16.2.1 Marking of slot

Usually 35 days after brood lac inoculation (BLI) majority nymphs of *K. lacca* leaves the brood lac and settles on the fresh branch of the host plant. Once lac insect insert its stylet into the phloem, it becomes sedentary. Thus thirty days after BLI, branches with good lac insect settlement were randomly selected for marking of slot. A slot of 1 cm width and 2.5 cm length was marked on the bark of the branch bearing good settlement of the lac insects. Three slots were made on plant each of 2.5 cm^2. Each slot was designated as S_1, S_2, and S_3. 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 (Plate-27). All the insect count was recorded from the slots only.

3.16.2.2 Digital recording

Lac insect settlement within the slot was digitally photographed with the help of a Digital Single Lens Reflex (DSLR) camera fitted with 100 mm micro lens by settling it in manual mode with ISO 400 and shutter speed of 4.5 to 6, several pictures of the slot was taken for clarity, finally the best click is selected (Plate-18).

3.16.2.3 Digital counting

The digital images from the DSLR camera were transferred to the Laptop with the help of memory card reader. The live lac insects within the slot were digitally counted followed the technology developed by JNKVV Jabalpur (Patent application 201921007852 A)

3.16.2.4 Frequency of lac insect count

Counting of live lac insects within the slots were done at 45, 90, 130, 155 and 190 days after BLI during 2019-20.

3.16.2.5 Emergence of male lac insects

The date of emergence of male lac insects as well as it duration of its presence on the lac insect settlement was recorded digitally.

3.17 Analysis of data:

Table 8. Skeleton of Analysis of Variance (ANOVA)

Source of variance	**d.f.**	**S.S**	**M.S.S**	**F.cal**	**F. tab**
Replication	(r-1)	SSR	VR	VR/VE	-
Treatments	(t-1)	SST	VT	VT/VE	F at 5% (t-1), (r-1) (t-1)
Error	(r-1) (t-1)	SSE	VE	-	-
Total	(rt – 1)	-	-	-	-

Where,

r = number of replications

t = number of treatments

VR= replication mean sum of square

VT=treatment mean sum of square

VE= error mean sum of square

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

Standard error of mean SEm± = $\sqrt{\frac{E.ms}{r}}$

Critical difference (C.D.) = SEm±x√2 x t 0.05

where,

Ems = error mean sum of square

t = 't' value at 5 % level at error d.f.

r = number of replications

SEm± = standard error of any treatment mean

CD= Critical difference

Plate:-1 Sowing in polythene bags	Plate:-2 Transporting seedlings to field

Plate:3 Layout of the field	Plate:4 Filling of substrate in PPB

Plate:5 Shifting of bags	Plate:6 Transplanting of *C. cajan*

Plate:7 Nipping of *C. cajan* plant

Plate:8 Irrigation

Plate:9 Spraying

Plate:10 Sorting of brood lac

Plate:-11 Predator free brood lac

Plate:12 Inoculation of brood lac

Plate:13 Phunki removal

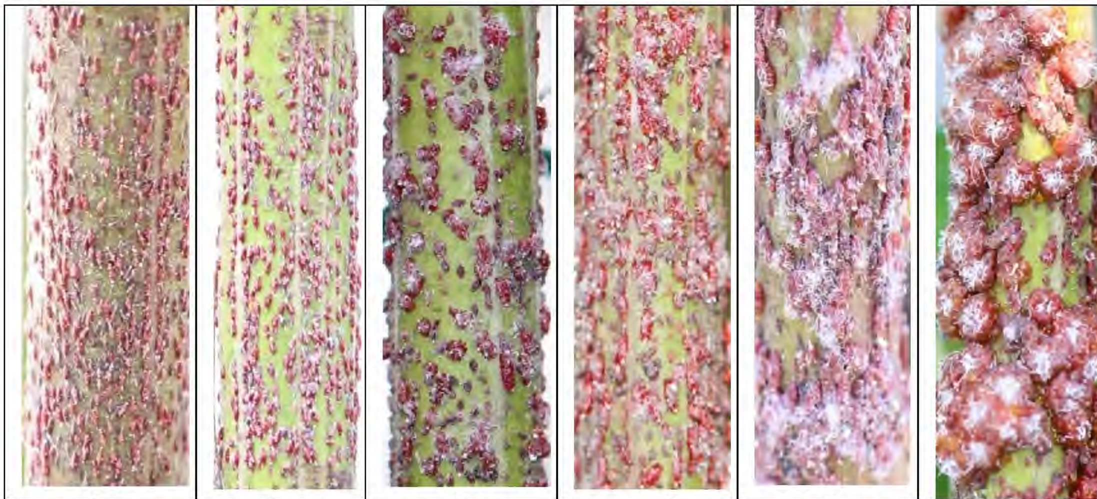
Plate:14 Slot making

Plate:15 Digital recording of live lac insects

		
Plate :16 Digital counting of live lac Insects	**Plate:17 Hand picking of mature pods**	**Plate : 18 Separating of seeds from pod**

		
Plate :19 Harvesting of Pigeonpea for lac crop	**Plate :20 Counting of sticklac**	**Plate:21 Scrapping of raw lac**

		
Plate :22 Weighing of pigeonpea seeds	**Plate :23 Weighing of 100 lac cells**	**Plate :24 Weighing of raw lac**



30th BLI	45th BLI	90th BLI	130th BLI	155th BLI	190th BLI

Plate :25 Growth stages of lac insects

Plate :26 Raw lac

Plate :27 100 lac cells

Plate :28 Female lac insect cell

Plate :29 Adult male lac insect

RESULTS

The results of the research entitled "**Study on the performance of *Rangeeni* lac insect (*Kerria lacca* Kerr.) on tall and long duration genotypes of *Cajanus cajan* (L.) Millsp***". was conducted during the year 2019-20 in the experimental field of JNKVV, Jabalpur is as below:

4.1 Live lac insects per 2.5 cm^2

4.1.1 Mean number of live lac insects (MNL) per 2.5cm^2 on 45^{th} day of BLI (30.12.2019)

The mean number of live lac insect per 2.5 cm^2 of branches was highest (168.72) in TJT-501 while it was lowest (147.67) in Amarkantak-1 on 45^{th} day of BLI. There was significant difference in TJT-501 and Gadarwara over rest of the genotypes, which were at par with each other (Table 9).

4.1.2 Mean number of live lac insects on 90^{th} day of BLI (15.02.2020)

The MNL per 2.5 cm^2 of branches was highest (149.39) in Lakhnadon-2 while it was lowest (118.39) in Amarkantak-2 on 90^{th} day of BLI. There was significant difference in Lakhnadon-2, TJT-501, Korsar-3, and Korsar-2. Rest of the genotypes were at par with each other.

4.1.3 Mean number of live lac insects on 130^{th} day of BLI (25.03.2020)

The MNL per 2.5 cm^2 of branches was highest (100.11) in TJT-501 while it was lowest (78.50) in Saraswahi on 130^{th} day of BLI. There was significant difference in TJT-501 over rest of the genotypes.

4.1.4 Mean number of live lac insects on 155^{th} day of BLI (20.04.2020)

The MNL per 2.5 cm^2 of branches was highest (90.61) in Lakhnadon-2 while it was lowest (64.94) in Saraswahi on 155^{th} day of BLI. There was significant difference in Lakhnadon-2 and Amarkantak-3 genotypes over Saraswahi. Rest of the genotypes at par with each other.

4.1.5 Mean number of live lac insects on 190^{th} day of BLI (25.05.2020)

The MNL per 2.5 cm^2 of branches was highest (61.78) in Lakhnadon-2 while it was lowest (37.94) in Amarkantak-4 on 195^{th} day of BLI. There was significant difference in all the genotypes over Saraswahi.

Table 9: - Mean number of lac insects settled/2.5 cm^2 on branches in different treatments after BLI

Treatments		Mean number of Live lac insects settled per 2.5 cm^2 on days after BLI					
No.	Genotypes	45th	90th	130th	155th	190th	Mean survival (%)
T1	TJT-501	168.72 (13.00)	148.50 (12.20)	100.11 (10.03)	84.72 (9.20)	46.67 (6.86)	27.66
T2	LAKHNADON-2	162.00 (12.75)	149.39 (12.24)	98.00 (9.91)	90.61 (9.49)	61.78 (7.89)	38.13
T3	KORSAR-3	162.39 (12.76)	140.50 (11.87)	93.50 (9.69)	81.67 (9.05)	55.28 (7.45)	34.04
T4	SARASWAHI	149.83 (12.25)	121.39 (11.03)	78.50 (8.87)	64.94 (8.08)	46.22 (6.83)	30.85
T5	GADARWARA	165.06 (12.86)	134.00 (11.59)	86.44 (9.29)	77.00 (8.80)	48.06 (6.96)	29.11
T6	AMARKANTAK-1	147.67 (12.17)	121.72 (11.06)	88.72 (9.44)	69.11 (8.34)	54.72 (7.42)	37.06
T7	AMARKANTAK-2	155.50 (12.49)	118.39 (10.90)	82.50 (9.09)	68.50 (8.30)	51.11 (7.18)	32.87
T8	AMARKANTAK-3	154.83 (12.46)	124.39 (11.15)	90.39 (9.51)	86.22 (9.24)	48.78 (7.01)	31.50
T9	KORSAR-2	159.83 (12.65)	138.44 (11.78)	94.83 (9.73)	73.83 (8.62)	52.67 (7.29)	32.95
T10	AMARKANTAK-4	152.33 (12.36)	131.83 (11.49)	90.89 (9.55)	73.94 (8.61)	37.94 (6.19)	24.91
SE(m)		0.22	0.27	0.38	0.38	0.15	
CD at 5 %		0.66	0.81	1.13	1.14	0.43	

***Figure in parenthesis are transformed values**

4.1.6 Survival of Lac insects

The per cent survival of lac insects between 45th to 190th day after BLI was highest (38.13%) in Lakhnadon-2 followed by Amarkantak-1 (37.06%), Korsar-3 (34.04%), Korsar-2 (32.95%), Amarkantak-2 (32.87%), Amarkantak-3 (31.50%), Saraswahi (30.85%), Gadarwara (29.11%), TJT-501 (27.66%) and it was lowest (24.91%) in Amarkantak-4(**Fig. 1**).

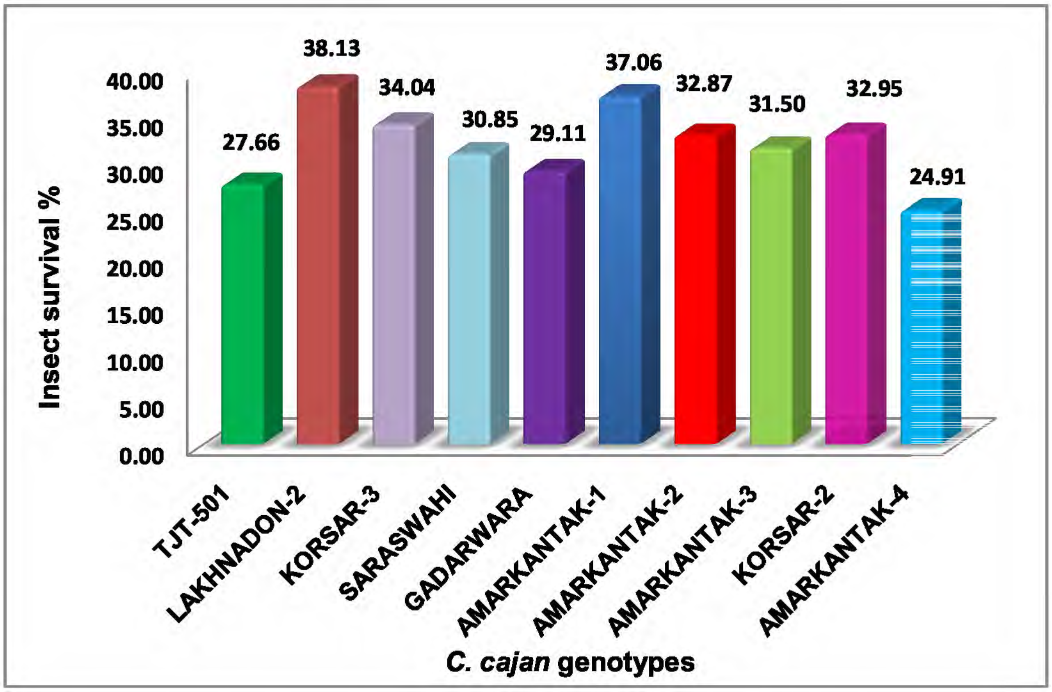


Fig.1 Per cent survival of lac insects from 45th to 190th day per 2.5 cm^2

4.1.7 Male to Female ratio in lac insects

Table 10: - Details of *Kerria lacca* on different genotypes of *C. cajan*

Treatments		Live lac insect count per 2.5 cm^2 slot					Male emergence after BLI
No.	Genotypes	Number		Percent		Male & female ratio	
		Male	Female	Male	Female		
T1	TJT-501	13.00	65.33	16.60	83.40	1 :5.03	123 days
T2	LAKHNADON-2	9.67	67.00	12.61	87.39	1 :6.93	122 days
T3	KORSAR-3	14.67	70.67	17.19	82.81	1 :4.82	123 days
T4	SARASWAHI	15.33	43.00	26.29	73.71	1 :2.80	119 days
T5	GADARWARA	27.33	56.33	32.67	67.33	1 :2.06	125 days
T6	AMARKANTAK-1	15.00	58.00	20.55	79.45	1 :3.87	115 days
T7	AMARKANTAK-2	11.00	62.00	15.07	84.93	1 :5.64	117 days
T8	AMARKANTAK-3	23.33	51.33	31.25	68.75	1 :2.20	115 days
T9	KORSAR-2	11.00	66.33	14.22	85.78	1 :6.03	122 days
T10	AMARKANTAK-4	27.00	51.67	34.32	65.68	1 :1.91	124 days

BLI: - 15 Nov. 2019

As mentioned earlier the adult male lac insects were observed in between 115th to 125th day of BLI.

The male and female ratio was highest (1:6.93) in Lakhnadon-2 while it was lowest (1:1.91) in Amarkantak-4. Adult male lac insects do not produce enough lac; Thus, presence of more female is a positive indication for lac production. On the basis of more female to less male, Lakhnadon-2 was the best genotype (Table-10).

4.2. Effect of lac insects on the growth of *C. cajan*

Table 11: Details of mean plant height (cm) of the *C. cajan* genotypes with lac insect

Treatments		Mean plant height (cm)					
		15/10/19	20/11/19	20/12/19	29/01/20	01/03/20	Increase %
No.	Genotypes						
T_1	TJT-501	144.83	195.17 (50.33)	209.67 (14.50)	216.50 (6.83)	218.67 (2.17)	50.98
T_2	LAKHNADON-2	127.00	171.00 (44.00)	219.00 (48.00)	228.00 (9.00)	231.00 (3.00)	81.89
T_3	KORSAR-3	133.00	180.50 (47.50)	225.17 (44.67)	240.83 (15.67)	243.67 (2.83)	83.21
T_4	SARASWAHI	129.50	162.17 (32.67)	192.33 (30.17)	202.33 (10.00)	204.83 (2.50)	58.17
T_5	GADARWARA	111.83	142.67 (30.83)	165.50 (22.83)	175.17 (9.67)	178.33 (3.17)	59.46
T_6	AMARKANTAK-1	114.83	159.50 (44.67)	197.33 (37.83)	211.00 (13.67)	213.33 (2.33)	85.78
T_7	AMARKANTAK-2	120.00	168.50 (48.50)	212.50 (44.00)	221.50 (9.00)	223.83 (2.33)	86.53
T_8	AMARKANTAK-3	117.17	166.00 (48.83)	197.17 (31.17)	209.50 (12.33)	211.67 (2.17)	80.65
T_9	KORSAR-2	123.67	152.50 (28.83)	194.00 (41.50)	210.17 (16.17)	212.50 (2.33)	71.83
T_{10}	AMARKANTAK-4	115.00	174.50 (59.50)	204.67 (30.17)	217.67 (13.00)	219.83 (2.17)	91.16
SE(M)		7.25	8.91	7.42	9.25	9.34	
CD at 5%		21.55	26.47	22.05	27.47	27.75	

Fig. in parenthesis are increase plant height in cm

4.2.1 Effect of lac insects on the height of *C. cajan*

The mean height of the *C. cajan* plant with and without lac insects were recorded from 15.10.2019 to 01.03.2020 (five observations). It was observed that there was an increase in plant height during successive growth period of *C. cajan*.

The mean plant height continuously increased between 15.10.2019 and 01.03.2020, i.e. in 138 days from BLI to adult male emergence in all the ten *C. cajan* genotypes. The mean plant height varied from 111.83 cm (Gadarwara) to 144.83 cm (TJT-501) during pre BLI. The mean final plant height varied from 178.33 cm (Gadarwara) to 243.67 cm (Korsar-3). It increased rapidly upto 20.12.19 after which the mean plant height increased at a slow rate (Table-11).

The mean increase in plant height during the period was maximum (91.16 %) in Amarkantak-4 while it was minimum (50.98 %) in TJT-501 (**Fig. 2**).

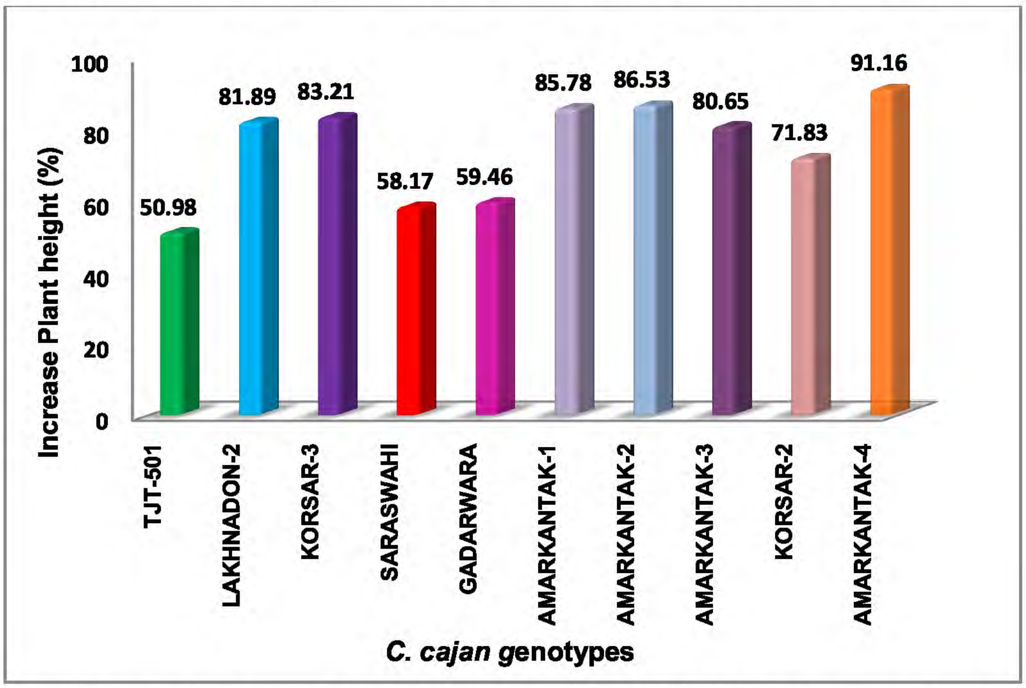


Fig.2 Per cent increase in the mean plant height of *C. cajan* genotypes with lac insects

4.2.2 Effect of lac insects on the stem thickness of *C. cajan*

Increase in the thickness of the stem and branches are another plant growth parameters recorded to observe if lac insects on the plant influence it. There was a significant difference in the stem thickness during growth period of the plant with different population densities.

4.2.2.1 Plant thickness of stem on 28^{th} day before BLI (18.10.2019)

On 18.10.2019 the mean thickness of stem of *C. cajan* was minimum (1.68 cm) in Amarkantak-4 and maximum (2.85 cm) in TJT-501. It was highest in TJT-501 (2.85) followed by Korsar-3 (2.81), Lakhnadon-2 (2.59), Korsar-2 (2.51), Gadarwara (2.31), Saraswahi (2.28), Amarkantak-3 (2.23), Amarkantak-2 (2.09), Amarkantak-1 (1.86) and Amarkantak-4 (1.68). There was significant difference in TJT-501, Korsar-3, Lakhnadon-2, Korsar-2, Gadarwara, Saraswahi, and Amarkantak-3 over Amarkantak-4. However Amarkantak-1 and Amarkantak-2 were at par with each other (Table-12).

4.2.2.2 Plant thickness of stem on 05^{th} day after BLI (20.11.2019)

On 20.11.2019, the mean thickness of stem of *C.cajan* was minimum (2.05 cm) in Amarkantak-4 and maximum (3.47 cm) in TJT-501. It was significantly highest in TJT-501 (3.47) followed by Korsar-3 (3.28), Korsar-2 (3.24), Lakhnadon-2 (3.01), Saraswahi (2.94), Gadarwara (2.83), Amarkantak-3 (2.62), Amarkantak-2 (2.55), T6 (2.26) and Amarkantak-4 (2.05). There was significant difference in the mean thickness of stem in TJT-501, Korsar-3, Korsar-2, Lakhnadon-2, Gadarwara and Saraswahi over Amarkantak-4. However Amarkantak-3, Amarkantak-1 and Amarkantak-2 were at par with each other.

4.2.2.3 Plant thickness of stem on 42^{th} day after BLI (27.12.2019)

On 27.12.2019, the mean thickness of stem of *C. cajan* was minimum (2.33 cm) in Amarkantak-4 and maximum (4.08 cm) in Korsar-3 It was significantly highest in Korsar-3 (4.08) followed by Korsar-2 (3.77), TJT-501 (3.70), Lakhnadon-2 (3.60), Saraswahi (3.39), Amarkantak-3 (3.25), Gadarwara (3.13), Amarkantak-2 (2.98), Amarkantak-1 (2.65) and Amarkantak-4 (2.33). There was significant difference in the mean thickness of stem of Korsar-3, Korsar-2, TJT-501, Lakhnadon-2, Saraswahi, Amarkantak-3, Gadarwara and Amarkantak-2 over Amarkantak-4. However, Amarkantak-1 and Amarkantak-4 were at par with each other.

4.2.2.4 Plant thickness of stem on 70^{th} day after BLI (25.01.2020)

On 25.01.2020, the mean thickness of stem of *C. cajan* was minimum (2.75 cm) in Amarkantak-4 and maximum (4.56 cm) in Korsar-3. It was significantly highest in Korsar-3 (4.56) followed by Korsar-2 (4.20), TJT-

501 (3.89), Lakhnadon-2 (3.81), Saraswahi (3.63), Amarkantak-3 (3.39), Gadarwara (3.35), Amarkantak-2 (3.31), Amarkantak-1 (2.87) and Amarkantak-4 (2.75). There was significant difference in the mean thickness of stem Korsar-3, Korsar-2, TJT-501, Lakhnadon-2 and Saraswahi over Amarkantak-4. However Amarkantak-3, Gadarwara, Amarkantak-2, and Amarkantak-1 were at par with Amarkantak-4.

Table 12: - Details of mean stem thickness (cm) of the *C. cajan* genotypes

Treatments		Stem thickness (cm)					
No.	Genotypes	1st	2nd	3rd	4th	5th	Increase %
T_1	TJT-501	2.85	3.47 (0.62)	3.70 (0.23)	3.89 (0.19)	4.00 (0.11)	40.46
T_2	LAKHNADON-2	2.59	3.01 (0.42)	3.60 (0.59)	3.81 (0.21)	4.01 (0.19)	54.63
T_3	KORSAR-3	2.81	3.28 (0.47)	4.08 (0.80)	4.56 (0.47)	5.01 (0.45)	78.19
T_4	SARASWAHI	2.28	2.94 (0.66)	3.39 (0.45)	3.63 (0.25)	3.77 (0.14)	65.64
T_5	GADARWARA	2.31	2.83 (0.52)	3.13 (0.30)	3.35 (0.22)	3.49 (0.14)	51.34
T_6	AMARKANTAK-1	1.86	2.26 (0.40)	2.65 (0.39)	2.87 (0.22)	3.01 (0.14)	61.54
T_7	AMARKANTAK-2	2.09	2.55 (0.46)	2.98 (0.43)	3.31 (0.33)	3.50 (0.19)	67.81
T_8	AMARKANTAK-3	2.85	3.47 (0.39)	3.70 (0.63)	3.89 (0.15)	3.69 (0.30)	65.30
T_9	KORSAR-2	2.59	3.24 (0.65)	3.77 (0.53)	4.20 (0.43)	4.59 (0.40)	77.58
T_{10}	AMARKANTAK-4	1.68	2.05 (0.37)	2.33 (0.28)	2.75 (0.43)	2.88 (0.13)	70.99
SE(M)		0.17	0.19	0.25	0.28	0.25	
CD at 5%		0.50	0.56	0.73	0.82	0.73	

Fig. in parenthesis are increase stem thickness in cm

4.2.2.5 Plant thickness of stem on 100th day after BLI (25.02.2020)

On 25.02.2020, the mean thickness of stem of *C. cajan* was minimum (2.88 cm) in Amarkantak-4 and maximum (5.01 cm) in Korsar-3. It was significantly highest in Korsar-3 (5.01) followed by Korsar-2 (4.59), Lakhnadon-2 (4.01), TJT-501 (4), Saraswahi (3.77), Amarkantak-3 (3.69), Amarkantak-2 (3.50), Gadarwara (3.49), Amarkantak-1 (3.01) and Amarkantak-4 (2.88). There was significant difference in the mean thickness of stem Korsar-3, Korsar-2, TJT-501, Lakhnadon-2, Saraswahi and Amarkantak-3 over Amarkantak-4. However, Amarkantak-1, Gadarwara and Amarkantak-2 were at par with Amarkantak-4.

4.2.2.6 Per cent increase in the mean thickness of the stem *C. cajan*

The per cent increase in the mean thickness of the stem between first observation and the last observation (130 days) was highest (78.19%) in Korsar-3 followed by Korsar-2 (77.58%) and Amarkantak-4 (70.99%). It was least (40.46%) in TJT-501 (**Fig. 3**).

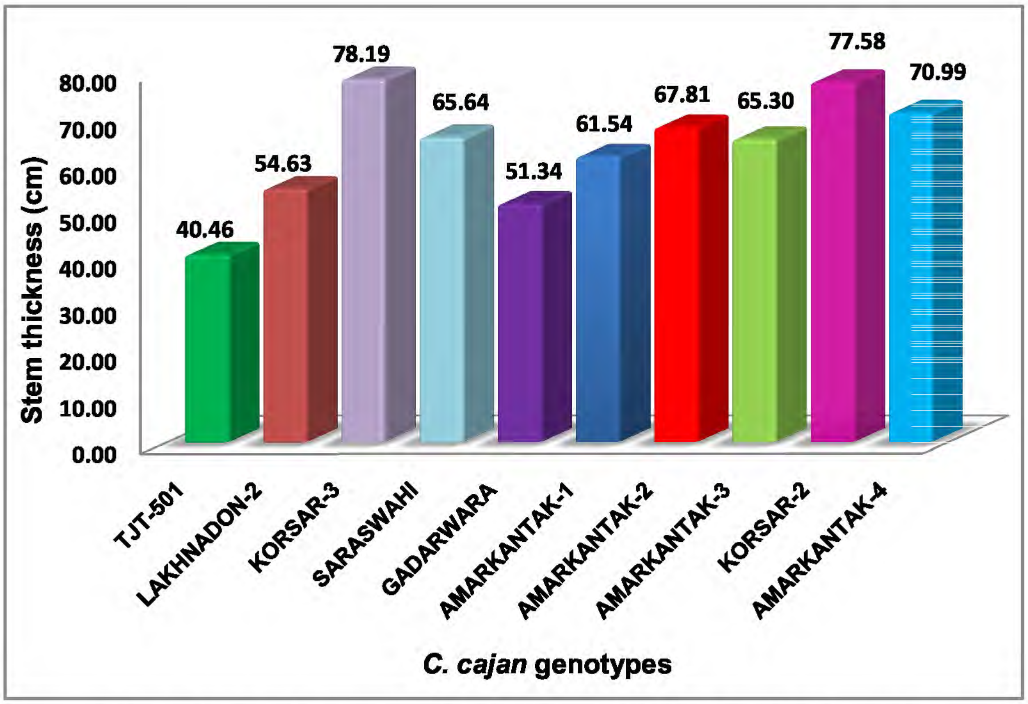


Fig.3 Per cent increase in the mean thickness of stem between 18.10.2019 to 25.02.2020

4.2.3 Thickness of primary branches of *C. cajan*

As majority of the settlement of lac insects were on primary and secondary branches of *C. cajan*, there was necessity to investigate whether insect influences the growth of branches.

4.2.3.1 Plant thickness of primary branches on 27th day before BLI (18.10.2019)

On 18.10.2019, the mean thickness of primary branches of *C. cajan* varied from 0.76 cm (Amarkantak-1) to 1.16 cm (Korsar-2). There was significant difference in Korsar-2, Korsar-3, Saraswahi, Lakhnadon-2 and Amarkantak-2 over Amarkantak-1. However, Gadarwara, TJT-501, Amarkantak-4 and Amarkantak-3 were at par with Amarkantak-1 (Table-13).

4.2.3.2 Plant thickness of primary branches on 05th day after BLI (20.11.2019)

On 20.11.2019, the mean thickness of primary branches of *C. cajan* varied from 0.95 cm (Amarkantak-1) to 1.44 cm (Korsar-2). There was significant difference in Korsar-2, Korsar-3, Amarkantak-2 and Saraswahi over Amarkantak-1. However, Lakhnadon-2, Amarkantak-3, TJT-501, Amarkantak-4 and Gadarwara were at par with Amarkantak-1.

Table 13: - Details of the mean thickness (cm) of primary branches of *C. cajan* genotypes

Primary branches thickness (cm)							
Treatments		1st	2nd	3rd	4th	5th	Increase %
No.	Genotypes						
T_1	TJT-501	0.86	1.14 (0.27)	1.42 (0.28)	1.48 (0.06)	1.51 (0.02)	74.59
T_2	LAKHNADON-2	1.02	1.21 (0.19)	1.51 (0.30)	1.57 (0.06)	1.60 (0.02)	56.84
T_3	KORSAR-3	1.07	1.35 (0.27)	1.64 (0.29)	1.84 (0.20)	1.87 (0.03)	74.64
T_4	SARASWAHI	1.03	1.26 (0.23)	1.48 (0.22)	1.52 (0.04)	1.54 (0.02)	49.54
T_5	GADARWARA	0.81	1.00 (0.19)	1.17 (0.17)	1.35 (0.18)	1.39 (0.03)	70.34
T_6	AMARKANTAK-1	0.76	0.95 (0.19)	1.18 (0.22)	1.31 (0.13)	1.35 (0.04)	77.82
T_7	AMARKANTAK-2	0.99	1.27 (0.28)	1.58 (0.31)	1.77 (0.18)	1.80 (0.03)	81.83
T_8	AMARKANTAK-3	0.94	1.18 (0.23)	1.40 (0.22)	1.59 (0.18)	1.62 (0.03)	71.87
T_9	KORSAR-2	1.16	1.44 (0.28)	1.80 (0.36)	1.99 (0.19)	2.03 (0.05)	75.78
T_{10}	AMARKANTAK-4	0.87	1.12 (0.24)	1.44 (0.33)	1.60 (0.16)	1.62 (0.02)	84.91
SE(M)		0.07	0.09	0.13	0.15	0.16	
CD at 5%		0.21	0.25	0.39	0.46	0.46	

Fig. In parenthesis are increase primary branches thickness in cm

4.2.3.3 Plant thickness of primary branches on 47th day after BLI (27.12.2019)

On 27.12.2019, the mean thickness of primary branches of *C. cajan* varied from 1.17 cm (Gadarwara) to 1.80 cm (Korsar-2). There was a significant difference in Korsar-2, Korsar-3 and Amarkantak-2 over Gadarwara. However, Lakhnadon-2, Saraswahi, Amarkantak-4, TJT-501, Amarkantak-3 and Amarkantak-1 were at par with Gadarwara.

4.2.3.4 Plant thickness of primary branches on 70th day after BLI (25.01.2020)

On 25.01.2020, the mean thickness of primary branches of *C. cajan* varied from 1.31 cm (Amarkantak-1) to 1.99 cm (Korsar-2). There was a significant difference in Korsar-2 and Korsar-3 over Amarkantak-1. Rest of the treatments were at par with each other.

4.2.3.5 Plant thickness of primary branches on 100th day after BLI (25.02.2020)

On 25.02.2020, the mean thickness of primary branches of *C. cajan* varied from 1.35 cm (Amarkantak-1) to 2.03 cm (Korsar-2). There was significant difference in Korsar-2 and Korsar-3 over Amarkantak-1. Rest of the treatments were at par with each other.

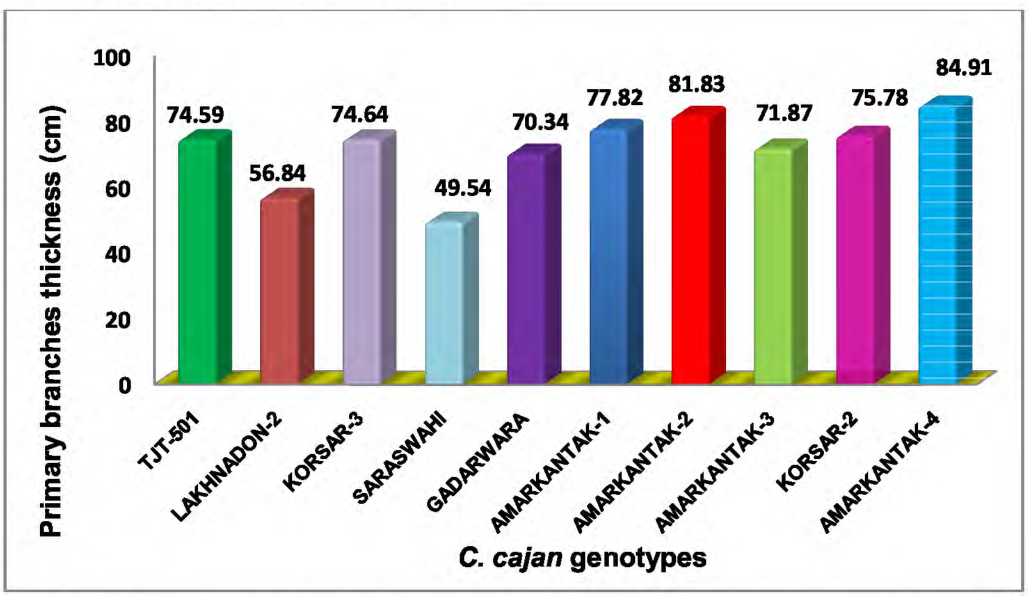


Fig.4 Per cent increase in the mean thickness of primary branches of *C. cajan* genotypes

4.2.3.6 Per cent increase thickness of primary branches

Thus, the mean thickness of primary branches of Korsar-2 was highest during all the observations. However the per cent increase in the mean thickness of the primary branches between 18.10.2019 and 25.02.2020 was highest (84.91%) in Amarkantak-4 followed by Amarkantak-2 (81.83%) and Amarkantak-1 (77.82%). It was least (49.54%) in Saraswahi (**Fig. 4**).

4.2.4 Thickness of secondary branches on *C. cajan*

4.2.4.1 Plant thickness of secondary branches 27th day before BLI (18.10.2019)

On 18.10.2019, the mean thickness of secondary branches of *C. cajan* varied from 0.50 cm (Amarkantak-1) to 0.92 cm (Korsar-3). The mean thickness of the secondary branches in Korsar-3 was significantly higher than that over Amarkantak-1, Gadarwara, Amarkantak-3, Amarkantak-2, Amarkantak-4, Saraswahi and Lakhnadon-2. However, Gadarwara, Amarkantak-3, Amarkantak-2, Amarkantak-4, Saraswahi, TJT-501 and Lakhnadon-2 were at par with each other (Table-14).

4.2.4.2 Plant thickness of secondary branches on 05th day after BLI (20.11.2019)

On 20.11.2019, the mean thickness of secondary branches of *C. cajan* varied from 0.58 cm in (Amarkantak-1) to 1.23 cm (Korsar-3). The mean thickness of the secondary branches in Korsar-3, Korsar-2 and TJT-501 were significantly higher than that over Amarkantak-1. However, Lakhnadon-2, Saraswahi, Amarkantak-4, Amarkantak-2, Amarkantak-3 and Gadarwara were at par with each other.

4.2.4.3 Plant thickness of secondary branches on 47th day of BLI (27.12.2019)

On 27.12.2019, the mean thickness of secondary branches of *C. cajan* varied from 0.71 cm (Gadarwara) to 1.34 cm (Korsar-3). The mean thickness of the secondary branches in Korsar-3 and Korsar-2 were significantly higher than that over Amarkantak-1. However, Lakhnadon-2, TJT-501, Saraswahi, Amarkantak-2, Amarkantak-4, Amarkantak-3 and Amarkantak-1 were at par with each other.

4.2.4.4 Plant thickness of secondary branches on 70th day of after BLI (25.01.2020)

On 25.01.2020, the mean thickness of secondary branches of *C. cajan* varied from 0.84 cm (Amarkantak-1) to 1.39 cm (Korsar-3). The mean thickness of the secondary branches in Korsar-3 and Korsar-2 were significantly higher than that over Amarkantak-1. However, Amarkantak-4, Lakhnadon-2, TJT-501, Amarkantak-3, Saraswahi, Amarkantak-2 and Gadarwara were at par with each other.

Table 14: - Details of the mean thickness (cm) of secondary branches of *C. cajan* genotypes

Treatments		Secondary branches thickness (cm)					
No.	Genotypes	1st	2nd	3rd	4th	5th	Increase %
T_1	TJT-501	0.70	0.86 (0.16)	0.96 (0.10)	0.99 (0.03)	1.00 (0.02)	42.88
T_2	LAKHNADON-2	0.69	0.80 (0.10)	0.96 (0.16)	1.07 (0.11)	1.09 (0.03)	57.88
T_3	KORSAR-3	0.92	1.23 (0.32)	1.34 (0.10)	1.39 (0.06)	1.44 (0.05)	57.32
T_4	SARASWAHI	0.60	0.78 (0.18)	0.90 (0.12)	0.95 (0.05)	0.96 (0.02)	60.25
T_5	GADARWARA	0.52	0.62 (0.10)	0.71 (0.09)	0.86 (0.15)	0.90 (0.03)	71.18
T_6	AMARKANTAK-1	0.50	0.58 (0.09)	0.72 (0.14)	0.84 (0.12)	0.87 (0.03)	75.59
T_7	AMARKANTAK-2	0.59	0.73 (0.15)	0.89 (0.16)	0.94 (0.05)	0.96 (0.01)	63.53
T_8	AMARKANTAK-3	0.53	0.63 (0.10)	0.81 (0.18)	0.97 (0.16)	1.05 (0.08)	99.45
T_9	KORSAR-2	0.78	1.01 (0.23)	1.08 (0.07)	1.31 (0.23)	1.33 (0.02)	71.40
T_{10}	AMARKANTAK-4	0.57	0.71 (0.15)	0.84 (0.13)	1.03 (0.19)	1.08 (0.04)	83.36
SE(M)		0.09	0.08	0.09	0.11	0.11	
CD at 5%		0.27	0.25	0.27	0.32	0.33	

Fig. In parenthesis are increase secondary branches thickness in cm

4.2.4.5 Plant thickness of secondary branches on 100th day of BLI (25.02.2020)

On 25.02.2020, the mean thickness of secondary branches of *C. cajan* varied from 0.87 cm (Amarkantak-1) to 1.44 cm (Korsar-3). The mean thickness of the secondary branches in Korsar-3 and Korsar-2 were significantly higher than that over Amarkantak-1. However, Lakhnadon-2, Amarkantak-4, Amarkantak-3, TJT-501, Saraswahi, Amarkantak-2 and Gadarwara were at par with each other.

4.2.4.6 Per cent increase thickness of secondary branches

The mean thickness of all the branches was higher in Korsar-3 in all the observations. The per cent increase in the mean thickness of the secondary branches between 18.10.19 and 25.02.20 was highest (99.45%) in Amarkantak-3 followed by Amarkantak-4 (83.36%) and Amarkantak-1 (75.59%). It was lowest (42.88%) in TJT-501 (**Fig. 5**).

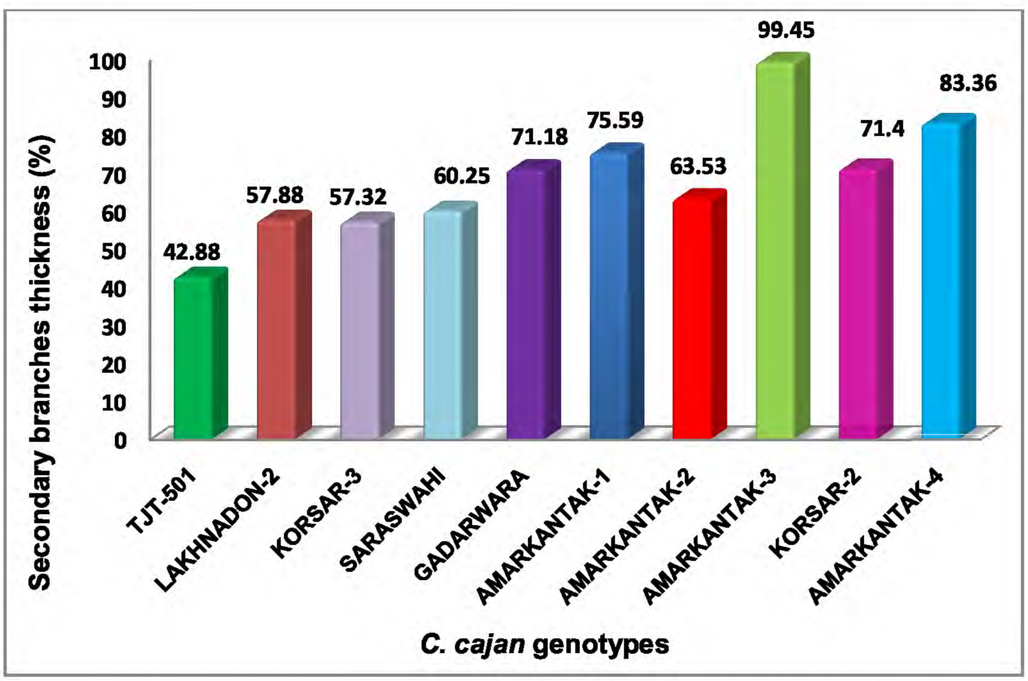


Fig.5 Per cent increase in the mean thickness of secondary branches between 18.10.19 and 25.02.20

4.2.5. Branches per plant

The number of primary and secondary branches of *C. cajan* was recorded, as these were important for settlement of lac insect crawlers on Brood lac inoculation (BLI).

4.2.5.1 Primary branches and secondary branches per *C. cajan*

The mean number of primary branches per plant varied from a minimum (2.17) in Amarkantak-1 to maximum (3.50) in Korsar-2. Among Saraswahi, Gadarwara, Amarkantak-1, Amarkantak-2, Amarkantak-3 and Amarkantak-4 were at par with each other. In terms of mean number of primary branches per plant in Korsar-2 was significantly highest over all the genotypes except TJT-501 and Lakhnadon-2 with which it was at par **(**Table-15).

The mean number of secondary branches per plant varied from a minimum (5.50) in Amarkantak-4 to maximum (11.17) in Korsar-2. Lakhnadon-2, Korsar-3, Saraswahi, Gadarwara, Amarkantak-2, Amarkantak-3 and Amarkantak-1 were at par. In terms of mean number of secondary branches it was significantly highest in Korsar-2 over all the genotypes but was at par with TJT-501 and Korsar-3.

Table 15:- Mean number of primary and secondary branches per plant different genotypes of *C. cajan*

Treatments		Mean number of branches/plant	
No.	Genotypes	Primary	Secondary
T_1	TJT-501	3.17	9.50
T_2	LAKHNADON-2	3.00	8.83
T_3	KORSAR-3	3.33	9.00
T_4	SARASWAHI	2.33	8.67
T_5	GADARWARA	2.50	8.00
T_6	AMARKANTAK-1	2.17	6.83
T_7	AMARKANTAK-2	2.33	7.33
T_8	AMARKANTAK-3	2.50	8.17
T_9	KORSAR-2	3.50	11.17
T_{10}	AMARKANTAK-4	2.33	5.50
SE(m) ±		0.28	0.76
CD at 5%		0.83	2.27

4.2.6. Settlement of lac insects on primary and secondary branches

Brood lac inoculation (BLI) on *C. cajan* was done on 15.11.2019. Settlement of lac insects on *C. cajan* branches is very important as it decides the lac production on it.

4.2.6.1 Primary and secondary branches of *C. cajan* with lac insects

After brood lac inoculation (BLI) on 15.11.2019, the larvae of lac insects crawled to settle on the main stem, primary and secondary branches of the *C. cajan*. Comparatively, the settlement of lac insects were very less on main stem therefore, the settlement on primary and secondary branches were recorded as it was of economical importance.

The mean number of primary branches per plant among 10 genotypes of *C. cajan* with lac insect settlement on 32nd day after BLI varied from 3.67 (Gadarwara) to 5.07 (Lakhnadon-2). It was significantly highest in Lakhnadon-2 over all the genotypes, except Korsar-2, Amarkantak-3 and TJT-501 with which it was at par. In Lakhnadon-2, 76.39 per cent of its primary branches had lac insect settlement while it was least (41.67%) in Gadarwara and Amarkantak-2 (**Fig. 6**).

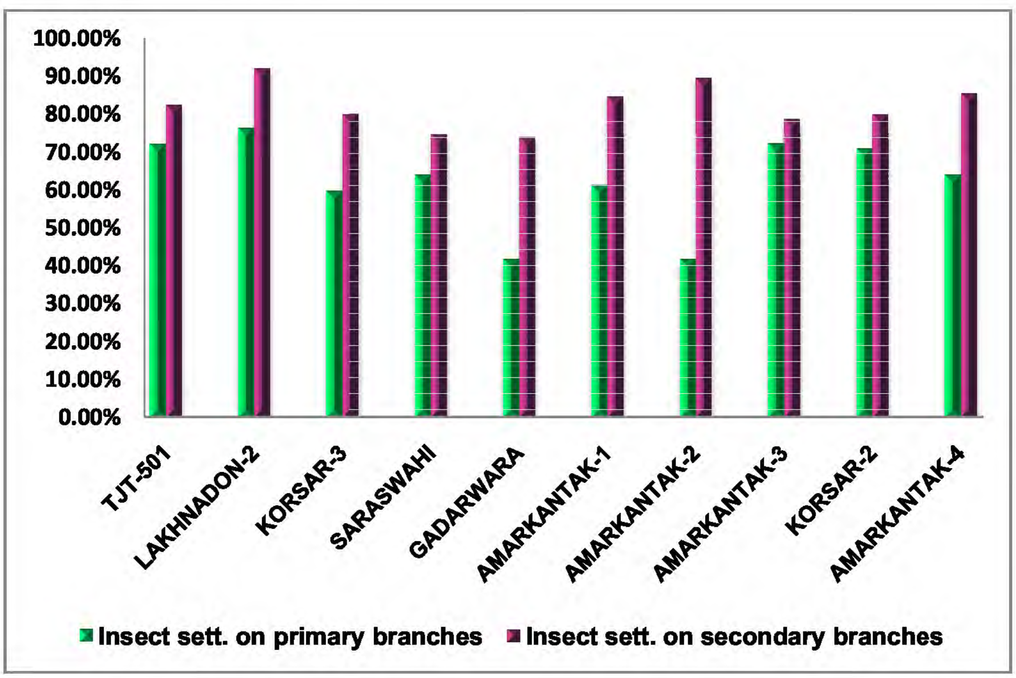


Fig.6 Lac insect settlement on branches (%)

It was observed that lac insects preferred secondary branches of *C. cajan* over the primary branches for its settlement. The number of secondary branches per plant with lac insect settlement varied from 4.98 (Gadarwara) to 5.58 (Lakhnadon-2). It was significantly highest in Lakhnadon-2 over all the genotypes except Amarkantak-2 and Amarkantak-4 with which it was at par. Lakhnadon-2 was the most preferred *C. cajan* genotypes as 76.37 and 92.12 per cent of its primary and secondary branches respectively had lac insect settlement. Thus, in terms of lac insect settlement in both primary and secondary branches Lakhnadon-2 was the best while Gadarwara was least preferred (Table-16).

Table 16: -Mean number of primary and secondary branches per *C. cajan* plant with lac insect settlement among the different genotypes

Treatments		Primary	Secondary
No.	Genotypes		
T_1	TJT-501	72.22 (4.92)	82.39 (5.28)
T_2	LAKHNADON-2	76.39 (5.07)	92.12 (5.58)
T_3	KORSAR-3	59.72 (4.46)	79.99 (5.20)
T_4	SARASWAHI	63.89 (4.63)	74.54 (5.02)
T_5	GADARWARA	41.67 (3.67)	73.85 (4.98)
T_6	AMARKANTAK-1	61.11 (4.53)	84.58 (5.34)
T_7	AMARKANTAK-2	41.67 (3.71)	89.52 (5.50)
T_8	AMARKANTAK-3	72.22 (4.83)	78.62 (5.15)
T_9	KORSAR-2	70.83 (4.89)	79.89 (5.20)
T_{10}	AMARKANTAK-4	63.89 (4.64)	85.40 (5.37)
SE(M)		0.36	0.12
CD at 5%		1.06	0.36

***figure in parenthesis are transformed values (sin)**

4.3 Yield of *C. cajan*

Lac production on *C. cajan* influence the yield of the crop is a general speculation. Generally phloem sap feeders has a negative influence on the yield of the crop, therefore it was very important to review the yield of the crop in terms of number of pod, dry pod weight, dry seed weight per plant as well as 100 seed weight.

4.3.1 Mean number of pods per *C. cajan* plant

There were two hand pickings from *C. cajan* genotypes when 80 per cent of the pods on the plant attained maturity.

4.3.1.1 Mean number of pods per plant (1st picking)

During the 1st picking, the mean number of pods per plant varied from 977.17 (Amarkantak-4) to 2958.67 (Lakhnadon-2). It was significantly highest in Lakhnadon-2 over all the genotypes (Table-17). Among Amarkantak-4 and Amarkantak-1 as well as Gadarwara, Amarkantak-3 and Saraswahi it was at par. There was a significant difference in the mean number of pods per plant in Lakhnadon-2, TJT-501, Amarkantak-2, Saraswahi, Amarkantak-3 and Gadarwara over Amarkantak-4. As Korsar-2 and Korsar-3 were late podding genotypes, there was no picking (Table-17).

4.3.1.2 Mean number of pods per plant (2nd picking)

During the second picking all the genotypes were harvested. The mean number of pods per plant was lowest 887.99 in Amarkantak-4 and highest 8582.50 in Korsar-2. The mean number of pods in Korsar-2, Korsar-3, Lakhnadon-2 and TJT-501 were significantly higher than that of Amarkantak-4. It was at par with each other among Amarkantak-1, Gadarwara, Amarkantak-3, Amarkantak-2 and Saraswahi. The mean number of pods per plant was significantly highest in Korsar-2 followed by that of Korsar-3 and Lakhnadon-2. The later two genotypes significantly differed among the genotypes.

4.3.1.3 Mean of total number of pods per plant (1st and 2nd picking)

Mean number of pods per plant (i.e. mean of 1st and 2nd picking) varied from 1900 (Amarkantak-4) to 8582.50 (Korsar-2) It was significantly highest in Korsar-2 over all the genotypes. Similarly the total pod number per plant in Amarkantak-2 (3274), TJT-501 (4065), Lakhnadon-2 (5404.67) and Korsar-3 (5406) were significantly higher than all the genotypes. Rest were at par with each other (Table-17).

4.3.1.4 Per cent difference in the mean number of pods per plant between 1st and 2nd picking

There was a difference in the mean number of pods among the two pickings. During the second picking the mean number of pods per plant was comparatively lesser than that during the 1st picking. The difference in mean number of pods during the two pickings was least (5.56 %) in Amarkantak-4 while it was highest (17.67 %) in Amarkantak-3 (Table-17).

Table 17: - Mean number of pods per plant in different *C. cajan* genotypes

Mean number of pods/plant					Difference (%)
Treatments		Picking		Total	
No.	Genotypes	1st	2nd		
T_1	TJT-501	2226.33	1838.67	4065.00	17.41
T_2	LAKHNADON-2	2958.67	2446.00	5404.67	17.33
T_3	KORSAR-3	-	5406.50	5406.50	-
T_4	SARASWAHI	1517.17	1253.83	2771.00	17.36
T_5	GADARWARA	1425.67	1176.50	2602.17	17.48
T_6	AMARKANTAK-1	1058.17	974.00	2032.17	7.95
T_7	AMARKANTAK-2	1795.67	1478.33	3274.00	17.67
T_8	AMARKANTAK-3	1511.83	1360.83	2872.67	9.99
T_9	KORSAR-2	-	8582.50	8582.50	-
T_{10}	AMARKANTAK-4	977.17	922.83	1900.00	5.56
SE(M)		94.54	298.87	328.47	
CD at 5%		286.76	887.99	975.92	

.4.3.2 Mean weight (g) of pods per *C. cajan* plant

4.3.2.1 Mean weight (g) of pods per plant (1st picking)

During the 1st picking the mean pod weight per plant varied from 596.50 g (Amarkantak-1) to 1745.50 g (Lakhnadon-2).It was at par among Amarkantak-4 and Amarkantak-1. Similar pattern were found among Amarkantak-4 and Gadarwara as well as Amarkantak-3 and Gadarwara. There was a significant difference in the mean pod weight per plant in Lakhnadon-2, TJT-501, Amarkantak-2 and Saraswahi over Amarkantak-1, Amarkantak-4 and Gadarwara (Table-18).

4.3.2.2 Mean weight (g) of pods per plant (2nd picking)

The mean pod weight per plant was significantly higher in Korsar-2 over all the *C. cajan* genotypes during the 2nd picking. It was lowest (510 g) in Amarkantak-4 while highest (3874.83 g) in Korsar-2. The mean of pod weight per plant in Korsar-2, Korsar-3, Lakhnadon-2 and TJT-501 were significantly higher than that of Amarkantak-4. The mean pod weight per plant in Amarkantak-4, Amarkantak-1, Gadarwara, Saraswahi, Amarkantak-3 and Amarkantak-2 were at par with each other. It was significantly higher in Korsar-2 followed by that of Korsar-3 and Lakhnadon-2. The later two genotypes differed significantly.

Table 18: - Mean weight of pods per plant among *C. cajan* genotypes

Mean weight of pods/plant (g)					
Treatments		Picking		Total	Difference %
No.	Genotypes	1st	2nd		
T_1	TJT-501	1426.17	1126.33	2552.50	21.02
T_2	LAKHNADON-2	1745.50	1446.00	3191.50	17.16
T_3	KORSAR-3	-	2469.33	2469.33	-
T_4	SARASWAHI	1015.50	822.83	1838.33	18.97
T_5	GADARWARA	803.67	578.83	1382.50	27.98
T_6	AMARKANTAK-1	596.50	515.67	1112.17	13.55
T_7	AMARKANTAK-2	1024.17	857.33	1881.50	16.29
T_8	AMARKANTAK-3	804.17	717.83	1522.00	10.74
T_9	KORSAR-2	-	3874.83	3874.83	-
T_{10}	AMARKANTAK-4	635.00	510.00	1145.00	19.69
SE(M)		67.72	161.09	190.74	
CD at 5%		205.41	478.61	566.72	

4.3.2.3 Per cent difference in mean pod weight per plant between 1st and 2nd picking

The mean pod weight per plant among the two pickings differed; it was lesser in 2nd picking in comparison to the first picking. The difference in mean pod weight per plant was least (10.74 %) in Amarkantak-3 while it was highest (27.98 %) during 2nd picking in Gadarwara.

Thus, the impact of lac insect on Amarkantak-3 had least effect. This indicates that local *C. cajan* variety Amarkantak-2 more tolerant to the phloem feeders. The difference in the mean pod weight per plant between 1st and 2nd picking was highest (29.78%) in Gadarwara in comparison to all local *C. cajan* variety. It indicates that Gadarwara variety is comparatively more vulnerable to the biotic stress caused by the phloem feeding lac insects. Though there was only one picking in Korsar-2 (3874.33 g) and Korsar-3 (2469.33 g), yet these two genotypes had highest yields (Table-18).

4.3.2.4 Mean weight of total pods per plants (1st and 2nd picking)

The mean weight of total pods per plant (i.e. total of 1st and 2nd picking) varied from 1112.17 g (Amarkantak-1) to 3874.33 g (Korsar-2). It was significantly highest in Korsar-2 over all the genotypes. Similarly, the mean weight of total pod per plant in TJT-501, Lakhnadon-2 (3191.50 g), Korsar-3 (2469.33 g) and Saraswahi (1838.33 g) were significantly higher than the rest of the genotypes. Rest were at par with each other (Table-18).

4.3.3 Mean weight (g) of seeds per *C. cajan* plant

4.3.3.1 Mean weight (g) of seeds per plant during 1st picking

During the 1st picking the mean seed yield plant varied from 322.50 g (Amarkantak-1) to 771.50 g (Lakhnadon-2). It was significantly highest to Lakhnadon-2. Korsar-3 and Korsar-2 being late podding genotypes there was no picking of pods during 1st picking. The mean seed yield per plant among Amarkantak-1, Amarkantak-4, Gadarwara and Amarkantak-3 as well as TJT-501, Saraswahi and Amarkantak-2 were at par. There was a significant difference in the mean seed yield per plant in Lakhnadon-2, TJT-501, Amarkantak-2 and Saraswahi over Amarkantak-3, Gadarwara, Amarkantak-4 and Amarkantak-1 (Table-19).

4.3.3.2 Mean weight (g) of seeds per plant during 2nd picking

During the second picking the mean seed yield per plant was lowest (272.83 g) in Gadarwara while it was highest (956 g) in Korsar-2. The mean of seed yield per plant in Korsar-2 and Korsar-3 were significantly higher than that of rest of the genotypes. Gadarwara, Amarkantak-1, Amarkantak-4, Amarkantak-3 and Amarkantak-2 were at par with each other. It was significantly higher in Korsar-2 followed by that of Korsar-3 and Lakhnadon-2. Both Korsar-2 and Korsar-3 were significantly differed with rest of treatments. It may be noted that these two genotypes had only one picking.

4.3.3.3 Per cent difference in mean seed yield per plant between 1st and 2nd picking

There was a difference in the mean seed yield per plant among the 2 pickings. It was comparatively less during the second picking. The difference in mean seed weight was lowest (14.15 %) in Lakhnadon-2 and highest (28.72 %) in Amarkantak-4 (Table-19).

Table 19: - Mean seed yield per *C. cajan* plant

Mean seed yield/plant (g)					
Treatments		Picking			Difference
No.	Genotypes	1st	2nd	Total	(%)
T_1	TJT-501	615.17	522.67	1137.83	15.04
T_2	LAKHNADON-2	771.50	662.33	1433.83	14.15
T_3	KORSAR-3	-	870.50	870.50	-
T_4	SARASWAHI	563.00	460.83	1023.83	18.15
T_5	GADARWARA	388.33	272.83	661.17	29.74
T_6	AMARKANTAK-1	322.50	275.17	597.67	14.68
T_7	AMARKANTAK-2	558.33	400.17	958.50	28.33
T_8	AMARKANTAK-3	414.83	335.50	750.33	19.12
T_9	KORSAR-2	-	956.00	956.00	-
T_{10}	AMARKANTAK-4	386.50	275.50	662.00	28.72
SE(M)		38.13	48.61	71.67	
CD at 5%		115.67	144.43	212.93	

4.3.3.4 Mean of total seed yield per plant (1st and 2nd picking)

The mean of total seed yield per plant (i.e. total of 1st and 2nd picking) varied from 597.67 g (Amarkantak-1) to 1433.83 g (Lakhnadon-2). The latter was significantly highest over all the genotypes. It was followed by TJT-501 (1137.38 g), which was at par with Saraswahi (1023.83 g). Rest of the genotypes were at par with each other in terms of mean of total seed yield per plant (Table-19).

4.3.4 Mean weight of 100 seed *C. cajan* genotypes with lac insects during 1st picking

During the 1st picking the mean weight of 100 seed varied from 9.51 g (Gadarwara) to 16.76 g (Amarkantak-1). Gadarwara and TJT-501, Lakhnadon-2 and Amarkantak-4 as well as Amarkantak-2 and Amarkantak-3 were at par in terms of mean weight of 100 seeds. There was a high significant difference in the mean weight of 100 seed in Amarkantak-2 and

Amarkantak-3 over Amarkantak-4. The mean weight of 100 seed in Amarkantak-2 was significantly higher than Gadarwara. The mean weight of 100 seeds in Amarkantak-1 was significantly highest over all the genotypes (Table-20).

Table 20: - Mean weight of 100 seeds of *C. cajan* genotypes with lac Insect

Treatments		Mean of 100 seeds weight (g)		
No.	Genotypes	1st Picking	2nd Picking	Difference %
T_1	TJT-501	10.17	9.91	2.56
T_2	LAKHNADON-2	11.17	10.36	7.22
T_3	KORSAR-3	-	9.56	-
T_4	SARASWAHI	15.01	14.43	3.82
T_5	GADARWARA	9.51	9.27	2.52
T_6	AMARKANTAK-1	16.76	15.68	6.45
T_7	AMARKANTAK-2	12.62	11.96	5.26
T_8	AMARKANTAK-3	12.56	11.71	6.81
T_9	KORSAR-2	-	7.39	-
T_{10}	AMARKANTAK-4	11.60	11.59	0.11
SE(M)		0.31	0.31	
CD at 5%		0.93	0.92	

4.3.5 Mean weight of 100 seeds *C. cajan* genotypes with lac insect during 2nd picking

During the second picking the mean weight of 100 seeds was comparatively less in almost all the genotypes harvested. The mean weight of 100 seeds varied from 7.39 g (Korsar-2) to 15.68g (Amarkantak-1). The mean weight of 100 seeds in all the genotypes was significantly higher than that of Korsar-2. The mean weight of 100 seeds was at par among TJT-501, Korsar-3 and Gadarwara. Similar pattern was observed among Amarkantak-4, Amarkantak-3 and Amarkantak-2. The latter three were significantly higher than Lakhnadon-2. The mean weight of 100 seed was significantly higher in Amarkantak-1 followed by that of Saraswahi. However both these genotypes differed significantly in terms of mean of 100 seeds during the 2nd picking (Table 20).

4.3.6 Per cent difference in mean weight of 100 seeds between 1st and 2nd picking

There was a difference in the mean weight of 100 seeds among the two pickings. In comparison to first picking it was less in the second picking. The difference in mean weight of 100 seed varied from (0.11%) in Amarkantak-4 to (7.22%) in Lakhnadon-2 (Table-20).

4.3.7 Mean 100 seed weight of *C. cajan* genotypes without lac insects during 1st picking

There were two handing picking of the mature pods on January 2020 and April 2020 among *C. cajan* genotypes without lac insects also. As Korsar-3 and Korsar-2 were late podding genotypes, there was no picking of pods during 1st picking. During the 1st picking the mean weight of 100 seeds of *C. cajan* genotypes without lac insects varied from 9.61 g (Gadarwara) to 17.81 g (Amarkantak-1). Lakhnadon-2 and Amarkantak-4 were at par with each other. The mean weight of 100 seeds in Amarkantak-3 was significantly higher than Gadarwara, TJT-501, Amarkantak-4, Lakhnadon-2 and Amarkantak-2. The mean weight of 100 seeds in Amarkantak-1 and Saraswahi was significantly highest over all the genotypes (Table-21).

4.3.8 Mean weight of 100 seeds *C. cajan* genotype without lac insect during 2nd picking

During the second picking the mean weight of 100 seeds in *C. cajan* genotypes without lac insects was lowest (7.80 g) in Korsar-2 while it was highest (16.07g) in Amarkantak-1. The mean of 100 seeds in all the genotypes were significantly higher than that of Korsar-2. It was at par among Lakhnadon-2 and Amarkantak-4 as well as Amarkantak-3 and Amarkantak-2 (Table-21). The mean weight of 100 seeds in TJT-501 was significantly higher than Korsar-3, Gadarwara and Korsar-2. It was significantly higher in Amarkantak-1 followed by that of Saraswahi. Both these genotypes were differed significantly (Table 21).

Table 21: - Mean weight of 100 seeds of *C. cajan* genotype without lac insect

Treatments		Mean of 100 seed weight (g)		
No.	Genotypes	1st Picking	2nd Picking	Difference %
T1	TJT-501	10.41	10.50	0.86 %
T2	LAKHNADON-2	11.40	11.07	-2.89 %
T3	KORSAR-3	-	10.04	-
T4	SARASWAHI	14.95	15.30	2.34 %
T5	GADARWARA	9.61	9.37	-2.50 %
T6	AMARKANTAK-1	17.81	16.07	-9.77 %
T7	AMARKANTAK-2	12.47	12.51	0.32 %
T8	AMARKANTAK-3	13.28	12.35	-7.00 %
T9	KORSAR-2	-	7.80	-
T10	AMARKANTAK-4	11.55	11.34	-1.82 %
SE(M)		0.11	0.11	
CD at 5%		0.33	0.32	

4.3.9 Per cent difference in the mean weight of 100 seeds between 1st and 2nd picking

There was a difference in the mean weight of 100 seeds among the 2 pickings. During 2nd picking it was 2.34 per cent more in Saraswahi over the 1st picking and 0.32 per cent in Amarkantak-2 followed by 0.86 per cent in TJT-501. Rest of *C. cajan* genotype, it was less during the 2nd picking (Table-21).

Table 22: - Mean 100 seed weight of *C. cajan* with and without lac insect

Mean weight of 100 seeds (g)												
Treatments		Genotypes with lac insects					Genotypes without lac insects					Diff. in seed wt. With & without lac (%)
No.	Genotypes	Pickings		Difference		Mean (g)	Pickings		Difference		Mean (g)	
		1st (g)	2nd (g)	(g)	%		1st (g)	2nd (g)	(g)	%		
T_1	TJT-501	10.17	9.91	0.26	2.56	10.04	10.41	10.5	-0.09	-0.86	10.46	3.97
T_2	LAKHNADON-2	11.17	10.36	0.81	7.25	10.77	11.4	11.07	0.33	2.89	11.24	4.18
T_3	KORSAR-3	-	9.56	-	-	9.56	-	10.04	-	-	10.04	4.78
T_4	SARASWAHI	15.01	14.43	0.58	3.86	14.72	14.95	15.3	-0.35	-2.30	15.13	2.68
T_5	GADARWARA	9.51	9.27	0.24	2.52	9.39	9.61	9.37	0.24	2.50	9.49	1.05
T_6	AMARKANTAK-1	16.76	15.68	1.08	6.44	16.22	17.81	16.07	1.74	9.77	16.94	4.25
T_7	AMARKANTAK-2	12.62	11.96	0.66	5.23	12.29	12.47	12.51	-0.04	-0.32	12.49	1.60
T_8	AMARKANTAK-3	12.56	11.71	0.85	6.77	12.14	13.28	12.35	0.93	7.00	12.82	5.31
T_9	KORSAR-2	-	7.39	-	-	7.39	-	7.8	-	-	7.80	5.26
T_{10}	AMARKANTAK-4	11.6	11.59	0.01	0.09	11.60	11.55	11.34	0.21	1.82	11.45	-1.31
SE(M)		0.31	0.31				0.11	0.11				
CD at 5%		0.93	0.92				0.33	0.32				

Table 23: - Comparison mean weight of 100 seeds of *C. cajan* genotypes with and without lac insects in the two pickings.

Treatments		Mean of 100 seed weight (g) 1st picking					Mean of 100 seed weight (g) 2nd picking					Diff.% 1st & 2nd picking
		Without lac	With lac	Difference		Mean	Without lac	With lac	Difference		Mean	
No.	Genotypes	1st picking	1st picking	(g)	%		2nd picking	2nd picking	(g)	%		
T_1	TJT-501	10.41	10.17	0.24	2.31	10.29	10.5	9.91	0.59	5.62	10.21	0.83
T_2	LAKHNADON-2	11.4	11.17	0.23	2.02	11.29	11.07	10.36	0.71	6.41	10.72	5.05
T_3	KORSAR-3	-	-	-	-	-	10.04	9.56	-	-	-	-
T_4	SARASWAHI	14.95	15.01	-0.06	-0.40	14.98	15.3	14.43	0.87	5.69	14.87	0.77
T_5	GADARWARA	9.61	9.51	0.1	1.04	9.56	9.37	9.27	0.1	1.07	9.32	2.51
T_6	AMARKANTAK-1	17.81	16.76	1.05	5.90	17.29	16.07	15.68	0.39	2.43	15.88	8.16
T_7	AMARKANTAK-2	12.47	12.62	-0.15	-1.20	12.55	12.51	11.96	0.55	4.40	12.24	2.47
T_8	AMARKANTAK-3	13.28	12.56	0.72	5.42	12.92	12.35	11.71	0.64	5.18	12.03	6.89
T_9	KORSAR-2	-	-	-	-	-	7.8	7.39	-	-	-	-
T_{10}	AMARKANTAK-4	11.55	11.6	-0.05	-0.43	11.58	11.34	11.59	-0.25	-2.20	11.47	0.95
SE(M)		0.11	0.31				0.11	0.31				
CD at 5%		0.33	0.93				0.32	0.92				

4.3.10 Mean weight of 100 seeds of *C. cajan* genotypes with lac insects

The two handing pickings of the mature pods were on January 2020 and April 2020. As Korsar-3 and Korsar-2 were late podding genotypes there was no picking of pods during 1st picking. During the 1st picking the mean weight of 100 seeds varied from 9.51 g (Gadarwara) to 16.76 g (Amarkantak-1). Gadarwara and TJT-501 as well as Lakhnadon-2 and Amarkantak-4, Amarkantak-2 and Amarkantak-3 were at par with each other in term of mean 100 seed weight. There was a high significant difference in the mean weight of 100 seeds in Amarkantak-2 and Amarkantak-3 over Amarkantak-4. The mean weight of 100 seeds in Amarkantak-2 was significantly higher than Gadarwara. It was significantly highest in Amarkantak-1 over all the treatments (Table-22).

During the second picking the mean weight of 100 seeds was comparatively less in almost all the genotypes were harvested. The mean weight of 100 seeds varied from 7.39 g in (Korsar-2) to 15.68 g in (Amarkantak-1). It was significantly higher all the genotypes over Korsar-2. The mean weight of 100 seeds was at par among TJT-501, Korsar-3 and Gadarwara similar pattern was observed among Amarkantak-2, Amarkantak-3 and Amarkantak-4. The latter three were significantly higher than Lakhnadon-2. It was significantly higher in Amarkantak-1 followed by that of Saraswahi. These both differed significantly.

There was a difference in the mean weight of 100 seeds among the 2 pickings. The seed weight of 100 seeds among the 2 pickings. The difference in mean weight of 100 seed in the two pickings varied from (0.09%) in Amarkantak-4 to (7.25%) in Lakhnadon-2.

4.3.11 Mean weight of 100 seeds of *C. cajan* without lac

During the 1st picking the mean weight of 100 seeds of *C. cajan* genotypes without lac insects varied from 9.61 g (Gadarwara) to 17.81 g (Amarkantak-1). It was at par among Lakhnadon-2 and Amarkantak-4, while in Amarkantak-3 it was significantly higher than Gadarwara, TJT-501, Amarkantak-4, Lakhnadon-2 and Amarkantak-2. The mean weight of 100 seed in Amarkantak-1 and Saraswahi was significantly highest over all the treatments.

The mean weight of 100 seeds was lowest (7.80 g) in Korsar-2 while it was highest (16.07g) in Amarkantak-1. In all the genotypes it was significantly higher than that of Korsar-2. The mean weight of 100 seeds was at par among Lakhnadon-2 and Amarkantak-4 as well as Amarkantak-3 and Amarkantak-2. In TJT-501 it was significantly higher than Korsar-3, Gadarwara and Korsar-2. In Amarkantak-1 it was significantly higher followed by that of Saraswahi. These both were significantly differed.

. There was a difference in the mean weight of 100 seeds among the 2 pickings. In comparison to the second picking it was higher in first picking in Saraswahi (2.34 %), TJT-501 (0.86 %), Amarkantak-2 (0.32 %) and lower in Amarkantak-1 (9.77%), Amarkantak-3 (7.00%), Lakhnadon-2 (2.89%), Gadarwara (2.50%) and Amarkantak-4 (1.82%).

Thus, if the mean weight of 100 seeds of *C. cajan* genotypes was compared among those with and without lac during two pickings. The mean weight of 100 seeds during the 1st picking in *C. cajan* genotypes without lac, was more in five genotypes in TJT-501 (2.31%), Lakhnadon-2 (2.02%), Gadarwara (1.04%), Amarkantak-1 (5.09%) and Amarkantak-3 (5.31%). The mean weight of 100 seeds with lac insects was more in Saraswahi (0.40%), Amarkantak-2 (1.20%) and Amarkantak-4 (0.43%). The data reveals that the difference in the mean weight of 100 seeds of *C. cajan* genotypes with and without lac during 1st picking was negligible (Table-23).

Similarly during the 2nd picking the mean weight of 100 seeds of *C. cajan* genotypes without lac was more in TJT-501 (5.62%), Lakhnadon-2 (6.41%), Saraswahi (5.69%), Gadarwara (1.07%), Amarkantak-1 (2.43%), Amarkantak-2 (4.40%) and Amarkantak-3 (5.18%), while in Amarkantak-4, the mean weight of 100 seeds was more in plant with lac insect by 2.20 per cent (Table-23).

Thus, the data revels that, during the 2nd picking the mean weight of 100 seeds were more in plants without lac but it ranged from 1.07 to 5.69 per cent this is again negligible.

This process that the presence of lac do not significantly affect the mean weight of 100 seeds in the *C. cajan* genotypes in comparison to that on plants without lac insects.

Plate: 30 Seeds of different genotypes of *Cajanus cajan*

Table 24: Details of mean pod and seed yield per plant in different genotypes of *C. cajan* with lac insect

Treatments		Mean of 1st picking/plant				Mean of 2nd picking/plant				Overall mean of total 1st and 2nd picking			
No.	Genotypes	Pod no.	Pod weight (g)	Seed wt (g)	100 seed weight (g)	Pod no.	Pod weight (g)	Seed wt (g)	100 seed weight (g)	Pod no.	Pod weight (g)	Seed wt (g)	100 seed weight (g)
T_1	TJT-501	2226.33	1426.17	615.17	10.17	1838.67	1126.33	522.67	9.91	4065.00	2552.50	1137.83	9.94
T_2	LAKHNADON-2	2958.67	1745.50	771.50	11.17	2446.00	1446.00	662.33	10.36	5404.67	3191.50	1433.83	10.77
T_3	KORSAR-3	*	*	*	*	5406.50	2469.33	870.50	9.56	5406.50	2469.33	870.50	9.56
T_4	SARASWAHI	1517.17	1015.50	563.00	15.01	1253.83	822.83	460.83	14.43	2771.00	1838.33	1023.83	14.72
T_5	GADARWARA	1425.67	803.67	388.33	9.51	1176.50	578.83	272.83	9.27	2602.17	1382.50	661.17	9.39
T_6	AMARKANTAK-1	1058.17	596.50	322.50	16.76	974	515.67	275.17	15.68	2032.17	1112.17	597.67	16.22
T_7	AMARKANTAK-2	1795.67	1024.17	558.33	12.62	1478.33	857.33	400.17	11.96	3274.00	1881.50	958.50	12.29
T_8	AMARKANTAK-3	1511.83	804.17	414.83	12.56	1360.83	717.83	335.50	11.71	2872.67	1522.00	750.33	12.14
T_9	KORSAR-2	*	*	*	*	8582.50	3874.83	956.00	7.39	8582.50	3874.83	956.00	7.39
T_{10}	AMARKANTAK-4	977.17	635.00	386.50	11.60	922.83	510.00	275.50	11.59	1900.00	1145.00	662.00	11.60
SE(M)		94.54	67.72	38.13	0.31	298.87	161.09	48.61	0.31	328.47	190.74	71.67	0.25
CD at 5%		286.76	205.41	115.67	0.93	887.99	478.61	144.43	0.94	975.92	566.72	212.93	0.75

*Late genotypes therefore only one picking.

The mean weight of 100 seeds during 1st picking was more than that during the 2nd second picking in all the genotypes. However the difference was less the overall mean weight of 100 seed was highest (16.22 g) in Amarkantak-1 followed by Saraswahi (14.72 g), Amarkantak-2 (12.29 g), Amarkantak-3 (12.14 g) Amarkantak-4 (11.60 g), Lakhnadon-2 (10.72 g), TJT-501 (9.94 g), Korsar-3 (9.56 g) and Gadarwara (9.39 g) (Table-24).

4.4 Effect of *Kerria lacca* (Kerr.) on lac production

Lac production is the ultimate economical goal of the enterprise. However, the economic returns depend on the level of productivity (*i.e.,* production per unit area). Besides timely BLI, good lac insect settlement and nutrient status of the host, the important deciding factors for good lac productivity are:

a. Mean length of lac encrustation on the branches on the host plant (sticklac),
b. Mean lac yield per plant
c. Mean lac yield per 2.5cm^2 slot
d. Mean weight of 100 lac cells

4.4.1 Mean length of lac encrustation on the branches on the host plant (sticklac)

The mean of length of sticklac per plant was significantly highest in Lakhnadon-2 (790.50 cm) followed by Korsar-2 (706.33 cm), TJT-501 (647.67 cm), Amarkantak-2 (542.83 cm), Korsar-3 (518.17 cm), Amarkantak-3 (509.50 cm), Amarkantak-1 (488.17 cm), Gadarwara (416.83 cm), Saraswahi (396.33 cm) and Amarkantak-4 (229.17 cm). There was significant difference in all genotypes over Amarkantak-4. The sticklac length among Saraswahi and Gadarwara, Amarkantak-3, Korsar-3 and Amarkantak-2 as well as TJT-501 and Korsar-2 were at par (Table-25).

4.4.2 Mean lac yield per plant

The *C. cajan* plant were harvested on 12.06.2020 for lac yield by cutting it from the base. The mean lac yield per plant was highest in Lakhnadon-2 (414.50 g) followed by Korsar-2 (349.33 g), TJT-501 (340 g), Amarkantak-2 (245.83 g), Korsar-3 (245.17 g), Amarkantak-3 (240 g), Amarkantak-1 (221.83 g), Saraswahi (209.33 g), Gadarwara (205.67 g) and

Amarkantak-4 (131.83 g). There was significant difference the mean lac yield per plant in all genotypes over Amarkantak-4. The mean lac yield among Gadarwara, Saraswahi and Amarkantak-1 as well as Amarkantak-3, Korsar-3 and Amarkantak-2 were at par (Table-25).

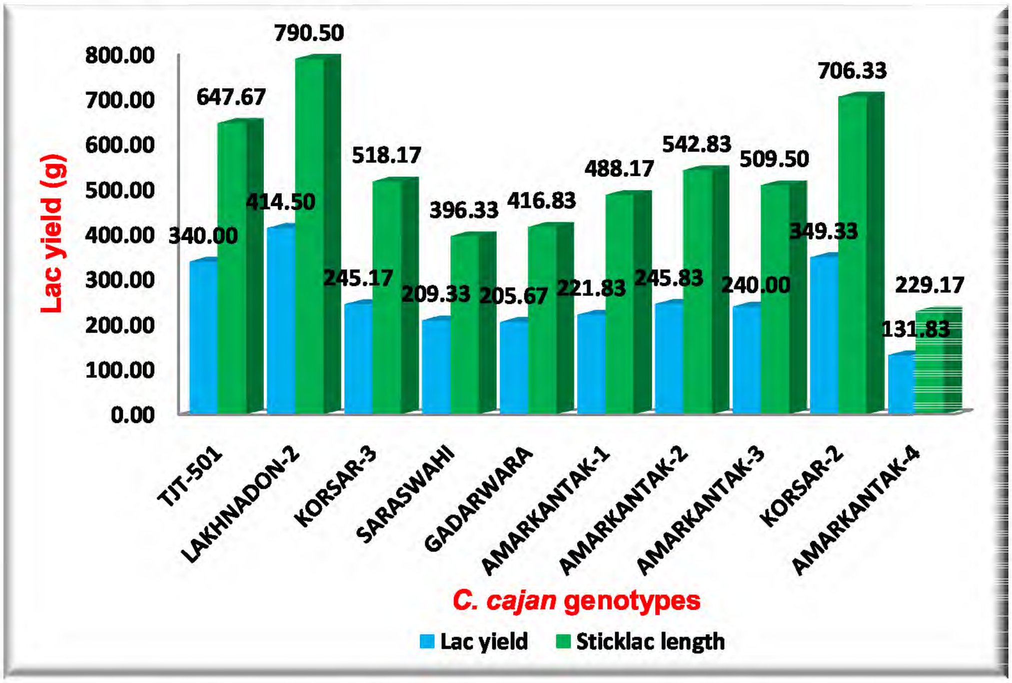


Fig.7 Mean length of sticklac and lac yield of *C. cajan* genotypes

Table 25:-Mean lac yield per plant on *C. cajan* genotypes

Genotypes		Sticklac length (cm)	Lac yield/plant (g)	100 Lac cell weight (g)	Lac weight (g) Per 2.5 cm^2 Slot
T_1	TJT-501	647.67	340.00	2.56	1.06
T_2	LAKHNADON-2	790.50	414.50	3.27	1.33
T_3	KORSAR-3	518.17	245.17	3.14	0.83
T_4	SARASWAHI	396.33	209.33	3.07	1.06
T_5	GADARWARA	416.83	205.67	2.79	0.86
T_6	AMARKANTAK-1	488.17	221.83	3.09	1.04
T_7	AMARKANTAK-2	542.83	245.83	3.05	1.15
T_8	AMARKANTAK-3	509.50	240.00	2.91	0.74
T_9	KORSAR-2	706.33	349.33	2.43	1.01
T_{10}	AMARKANTAK-4	229.17	131.83	2.54	0.45
SE(M)		29.18	7.21	0.07	0.07
CD at 5%		86.71	21.43	0.22	0.22

4.4.3 Mean weight of 100 Lac cell

The mean weight of 100 lac cells was significantly highest in Lakhnadon-2 (3.27 g) followed by Korsar-3 (3.14 g), Amarkantak-1 (3.09 g), Saraswahi (3.07 g), Amarkantak-2 (3.05 g), Amarkantak-3 (2.91 g), Gadarwara (2.79 g), TJT-501 (2.56 g), Amarkantak-4 (2.54 g) and Korsar-2 (2.43 g). There was significant difference in the mean weight of 100 lac cells in Lakhnadon-2, Korsar-3, Amarkantak-1, Saraswahi, Amarkantak-2, Amarkantak-3 and Gadarwara over Korsar-2. The mean weight of 100 lac cell among Korsar-2, TJT-501 and Amarkantak-4; Gadarwara and Amarkantak-3 as well as Amarkantak-2, Saraswahi, Amarkantak-1 and Lakhnadon-2 at par with each other (Fig. 8).

4.4.4 Mean lac yield per 2.5cm^2

The mean lac yield per 2.5 cm^2 slot was significantly highest in Lakhnadon-2 (1.63 g) followed by Amarkantak-2 (1.45 g), TJT-501 (1.36 g), Saraswahi (1.36 g), Amarkantak-1 (1.34 g), Korsar-2 (1.31g), Gadarwara (1.16 g), Korsar-3 (1.13 g), Amarkantak-3 (1.04 g) and Amarkantak-4 (0.75 g). There was significant difference in all genotypes over Amarkantak-4. The mean lac yield of 2.5 cm^2 slot among Amarkantak-3, Korsar-3 and Gadarwara as well as Korsar-2, Amarkantak-1, Saraswahi, TJT-501 and Amarkantak-2 were at par (**Fig. 8**).

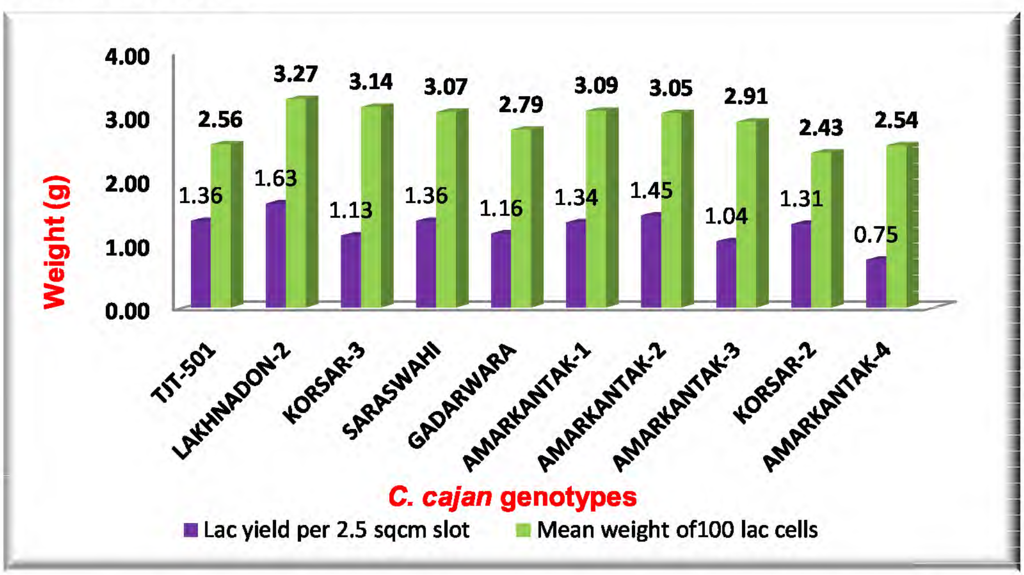


Fig.8 Mean weight of 100 lac cells and lac yield per 2.5 cm^2 slot on *C. cajan* genotypes

4.5 Fuel wood

4.5.1 Mean dry shoot weight of fuel wood/plant (g)

After scrapping of raw lac from the harvested *C. cajan* plant, the dry shoot and root weighed. These two are used by farmer as fuel wood. The mean dry weight of shoot per plant was a significant difference in mean dry weight of shoot in Korsar-2, Korsar-3, Lakhnadon-2, Amarkantak-2, Amarkantak-3 and Saraswahi over Amarkantak-4. The mean weight of shoot per plant Korsar-2 was significantly highest over rest all the genotypes. The mean weight of (shoot) per plant was at par with TJT-501, Saraswahi, Amarkantak-2 and Amarkantak-1. Among Lakhnadon-2 and Korsar-3 there was a significant difference (Table-26).

Table 26:- Mean weight of fuel Wood/plant (g)

No.	Genotypes	Shoot (g)	Total (g)
T_1	TJT-501	1422.50	1762.83
T_2	LAKHNADON-2	2343.33	2713.33
T_3	KORSAR-3	3354.00	3784.00
T_4	SARASWAHI	1599.17	1872.50
T_5	GADARWARA	1387.33	1674.00
T_6	AMARKANTAK-1	676.83	983.50
T_7	AMARKANTAK-2	1768.33	2075.00
T_8	AMARKANTAK-3	1655.00	1888.33
T_9	KORSAR-2	4326.67	4746.67
T_{10}	AMARKANTAK-4	659.50	836.17
SE(M)		302.22	303.50
CD 5%		897.95	913.62

4.5.2 Mean total (shoot + root) weight of fuel wood/plant (g)

The mean dry weight of total fuel (shoot + root) varied from a minimum 836.17 g (Amarkantak-4) to maximum 4746.67 g (Korsar-2). There was a significant difference in the mean total fuel weight in genotypes Korsar-2, Korsar-3, Lakhnadon-2, Amarkantak-2, Amarkantak-3 and Saraswahi over Amarkantak-4. The mean weight of total fuel per plant in genotypes Korsar-2 was significantly highest over all the genotypes. The mean dry weight of total fuel wood among TJT-501, Saraswahi, Amarkantak-2 and Amarkantak-3 were at par with each other. Similar, it was at par among Gadarwara, Amarkantak-1 and Amarkantak-4. There was a significance difference among Lakhnadon-2 and Korsar-3 and also between Korsar-3 and Korsar-2.

4.6 The economics of lac production on all the ten genotypes of *C. cajan*

The economics of lac production on all the ten genotypes of *C. cajan* is mentioned in the Table-27. There was three produce from the same plant i.e. seed, lac and fuel wood. The selling price of lac (Rs 280/kg) was calculated from Barghat lac mandi in Seoni district in June 2020. The selling price of pigeonpea (Rs 50/kg) from Jabalpur mandi and of fuel wood (Rs 3/kg) from the village in Jabalpur district. The highest mean gross return of Rs 195.89 per plant i.e. Rs 71.69 of seed, Rs 116.06 worth lac and Rs 8.14 worth fuel wood was from Lakhnadon-2. It was closely followed by Korsar-2 (Rs 159.85/plant) and TJT-501 (Rs 157.38/plant). The mean gross return per plant was lowest in genotype Amarkantak-4 (Rs 72.52) and Amarkantak-1 (Rs 94.95).

The mean cost per plant form raising of it in nursery to harvest and scrapping of lac was Rs. 55. Thus, the net return per plant varied from Rs. 140.89 in Lakhnadon-2 to Rs. 17.52 in Amarkantak-4.

Table 27: - Economics of lac production on *C. cajan* genotypes

Selling price of produce/plant (Rs)												
Treatments		Seed @ Rs 50/kg*			Lac @ Rs 280/kg**			Fuel wood @ Rs 3/kg***			Total	
No.	Genotypes	Yield/plant(g)	Rs/plant	Rs/acre	Yield/plant(g)	Rs/plant	Rs/acre	Yield/plant(g)	Rs/plant	Rs/acre	Rs/plant	Rs/acre
T_1	TJT-501	1137.83	56.89	68838.92	340.00	95.20	115192.00	1762.83	5.29	6399.09	157.38	190430.00
T_2	LAKHNADON-2	1433.83	71.69	86746.92	414.50	116.06	140432.60	2713.33	8.14	9849.40	195.89	237028.92
T_3	KORSAR-3	870.50	43.53	52665.25	245.17	68.65	83062.47	3784.00	11.35	13735.92	123.52	149463.64
T_4	SARASWAHI	1023.83	51.19	61941.92	209.33	58.61	70922.13	1872.50	5.62	6797.18	115.42	139661.23
T_5	GADARWARA	661.17	33.06	40000.58	205.67	57.59	69679.87	1674.00	5.02	6076.62	95.67	115757.07
T_6	AMARKANTAK-1	597.67	29.88	36158.83	221.83	62.11	75157.13	983.50	2.95	3570.11	94.95	114886.07
T_7	AMARKANTAK-2	958.50	47.93	57989.25	245.83	68.83	83288.33	2075.00	6.23	7532.25	122.98	148809.83
T_8	AMARKANTAK-3	750.33	37.52	45395.17	240.00	67.20	81312.00	1888.33	5.67	6854.65	110.38	133561.82
T_9	KORSAR-2	956.00	47.80	57838.00	349.33	97.81	118354.13	4746.67	14.24	17230.40	159.85	193422.53
T_{10}	AMARKANTAK-4	662.00	33.10	40051.00	131.83	36.91	44665.13	836.17	2.51	3035.29	72.52	87751.42
One ha. (Area) = 43560 feet^2 Spacing 6x6 1210 plant/acre or 2990 plant/ha												

* Selling price of pigeonpea Jabalpur mandi in June 2020 **Selling price of lac in Barghat lac mandi in June 2020 *** Selling price of fuel wood collected from village

Plate:- 31 Inauguration of Jawahar model by Hon'ble Vice Chancellor of JNKVV

Plate:- 32 Visit of Hon'ble Vice Chancellor to the field

Plate: -33 Interacting with Hon'ble Vice Chancellor of JNKVV

Plate: -34 Visit of Dean faculty of Agriculture, JNKVV

Plate: -35 Visit of Shri Digvijay Singh Former C.M., GoMP

Plate:-36 Visit of Dr Shiv Kumar Agrawal, ICARDA

Plate:- 37 Water tank for irrigation

Plate: -38 Visit of ADG (Horti.) ICAR

Plate:- 39 Visit of 3 former DDGs (Agri Engg.) ICAR

Plate: -40 Visit of former Director of ICAR, ATARI Zone-9

Plate:- 41 Visit of Hon'ble Members of Board, JNKVV

Plate: -42 Interacting with students

Plate: -43 Visit of students from Jabalpur

Plate:- 44 Visit of students from Sarasvati Siksha Mandir H.S. School Jabalpur

Plate:- 45 Visit of students from Chandra Shekhar Azad University of Kanpur U.P.

Plate:- 46 Visit of students from Ravindranath Tagore University of Agriculture Bhopal

Plate:- 47 Visit of farmers from Seoni

Plate:- 48 Visit of tribal farm women from Damoh

Plate:-49 Visit of pharmacist

Plate:- 50 Visit of farmers from Odisha

Plate:- 51 Visit of farmers from Dindori

Plate:- 52 Visit of farmers from Katni

Plate:- 53 Visit of farmers from Patan

Plate:- 54 Visit of farmers from Singrauli

Plate:- 55 Visit of farmers from Chhindwara

Plate:- 56 Visit of farmers from Shahpura

Plate:- 57 Visit of farmers from Damoh

Plate:- 58 Visit of farmers from Patan

Plate:- 59 Visit of farmers

Plate:- 60 Visit of farmers from C.G.

Plate:- 61 Visit of farmers from Balaghat

DISCUSSION

The results of the research entitled "**Study on the performance of *Rangeeni* lac insect (*Kerria lacca* Kerr.) on tall and long duration genotypes of *Cajanus cajan* (L.) Millsp**" are discussed below in light of earlier work conducted by other workers:

5.1 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 sap access to it (Cook and Denno, 1994; Kehr, 2006) as well as protection from its natural enemies (Jhangel *et al.,* 2014, Engla, 2011). Survival of any insect on a crop or variety (Singh *et al.,* 2009) indicates its compatibility (Horikoshi *et al.,* 2016) and preference (McGuinness, 1987; Gogi *et al.,* 2012).

In the present study, it was observed that lac insects preferred to settle more on secondary branches over primary branches. There was reduction in the MNL from 45 days to 190 days after BLI, though the per cent varied on different *C. cajan* genotypes. There was a reduction in the MNL after BLI and last observation (190 days after BLI). In the present case the survival of lac insect varied from 24.91 to 38.13 per cent. As mentioned earlier the survival per cent of lac insect depends on the host (Ogle *et al.*, 2006, Shah *et al,.* 2015), season of lac crop (Ghosh *et al.,* 2014), strain of the lac insect (Sharma *et al.,* 2017), nutrient management (Sharma *et al.,* 2017, Ghugal *et al.,* 2015, Namdev *et al.,* 2015), predator management (Virendra *et al.,* 2017, Mohanasundaram *et al.,* 2018, Aditya and Singh 2018) or even location of the host trees (Kalahal *et al.,* 2017*)*. Survival of lac insects from BLI to maturity of crop reported by many workers as 10.71 to 17.21 per cent (Shah *et al.*, 2014), 34.08 to 51.53 per cent (Gurjar, 2016), 33.53 to 41.77 per cent (Sharma *et al.*, 2015), 20.86 to 26.05 per cent (Kumar *et al.*, 2017), 19.63 to 20.58 per cent (Namdev *et al.*, 2015) and 20.47 to 23.52 per cent (Shah *et al.*, 2018), 52.13 to 81.53 per cent (Vajpayee *et al.*, 2019).

5.1.1 Male to female ratio in lac insects

In present study the male and female ratio observed between 1:1.91 to 1:6.93. Adult female lac insect plays a major role in lac production from its emergence till the harvest of lac crop and has a life period of 3-5 days. Adult male insect on the contrary has a very short life span of 3 to 5 days, when it aggressively mates with it females. Thus emergence of adult male as well as its mating with adult female lac insects has significance in terms of lac production. Unlike the sedentary female lac insects from its settlement on the host to its maturity, the adult males are either wingless or winged form and agile. Counting them in the fixed slot of 2.5 cm^2 is very difficult. The digital counting method (Patent application 201921007852 A) developed is more reliable and accurate. Each larvae of lac insects secrets a protective resin lac cells over its body. As the insect grow and attain maturity the male lac cells acquire cigar shaped protective covering over its body while female lac cell appears spherical in shape and comparatively bigger in size. Pupal and adult stages of male lac insect do not secrete lac (Wang *et al.,* 2019). Counting these cells from the digital photo of the lac insect population, one can segregate them of the basis of sex. Sex ratio of lac insects has been reported by earlier workers.

Sharma (2016) reported sex ratio between 20-50 per cent depending upon various biotic and abiotic factors. Chauhan (1988) reported that sex ratio in Meghalaya lac insect differs significantly on different host plants. It was observed to be 72 per cent in favour of males on *F. macrophylla*, 82 per cent on *C. cajan* and 98 per cent on *Z. mauritiana*. Similarly, Sharma and Ramani (1997) observed 39.76 and 37.28 per cent males in *Rangeeni* and *Kusmi* strains of *K. lacca* on *F. macrophylla* that increased to 70.05 and 62.65 per cent when reared on *C. moschata*. In MP, the female to male lac insect ratio has been reported to Vajpayee *et al.* 2019 varied from 10.87:1 to 27.55:1 in different genotypes on *C. cajan*.

5.1.2 Male emergence

Another important aspect is the date of adult male emergence. In present study the emergence of male was observed between on 115^{th} to 125^{th} after BLI. The earliness of the emergence of adult male lac insects indicates early maturity of the male. One of the factors of this earliness is quality and quantity of phloem sap of the host plant available to lac insects. The earliness at also depends on weather as well as more mating opportunities. The emergence of adult male is counted in days from the date of BLI. Similarly higher adult female means more lac production. Thus higher female to male ratio is considered as positive trend. Early mating also leads to more days for female lac insects to produce and reproduced in comparative to those mated late. These micro factors of lac production were never captured before for analysis. Wang *et al.*, 2019 reported that adult female lac insects secrete large amount of resin, while pupal and adult male lac insects do not secrete lac. Male emergence of lac insects has been reported by earlier workers. Patel (2013) reported that the adult male of *Kusmi* strain of *K. lacca* emerged at 70 days after BLI in winter crop on *Z. mauritiana*. Saikia *et al.* (2019) reported male emergence of lac insect was started 45 days after inoculation which continued for 12 days. Vajpayee *et al.* (2019) reported adult male lac insects were observed in between 129th-143th day after BLI.

5.2 Effect of lac insects on the growth of *C. cajan*

5.2.1 Mean plant height (cm) of *C. cajan* genotypes

The common indicators of plant growth are increase in height, stem thickness and number of branches (Singh and Diwakar, 1995). There was a continuous increase in the mean height of *C. cajan* genotypes with lac insects between 15.10.2019 and 20.12.2019. During this period lac insects were in its immature stage, the phloem sap intake may have been less. It may have exerted less biotic stress on the host plants, so the increase in plant height remained unaffected. Increase in plant height of *C. cajan* with lac insect was reported by Vajpayee *et al.* (2019) and Patidar (2019). Comparatively slow increase in plant height after 20.12.2019 may be due to the abiotic stress due to cool weather during of December 2019 and January 2020. Podding and rapidly growing lac insect may exerted extra biotic stress on the plant. The combination of abiotic and biotic stress may have contributed to slow increase in the plant after December 2019. Phloem feeders influence plant height and cause stunted growth in Cotton (Horowitz *et al.*, 2018, Sarwar *et al.*, 2014, Pandi, 1997) and in Mustard (Malik *et al.*, 1998, Sarvan and Kumar, 2017).

5.2.2 Effect of *K. lacca* on the thickness of *C. cajan*

Increase in thickness of stem and branches are other indicators of plant growth. There was continuous increase in the thickness of stem and branches in all the *C. cajan* genotypes with lac insect, indicating that the insects presence did not influence normal plant growth pattern. The increase in stem thickness varied among the genotypes and it may be a genotypical character. However, earlier workers have reported that the stem due to incidence of phloem feeders (Uchida, 2000; Patidar, 2019). There are reports that the stem thickness was influenced by phloem feeders (Heckroth *et al.,* 1999). Flaih (2017) reported that incidence of white fly (phloem feeder) on cauliflower shorten plant age and reduce yield. But this was not observed on lac insect infected *C. cajan* in the present study.

5.2.3 Branches per plant

The number of primary and secondary branches of *C. cajan* was recorded, as these were important for settlement of lac insect crawlers after brood lac inoculation (BLI).

5.2.3.1 Number of primary and secondary branches per *C. cajan* plant

The increase in the number of primary and secondary branches in different *C. cajan* genotypes was evaluated. It may be due to its phenotypic character as well as nipping effect. Nipping of growing tips influence branching in crop (Vajpayee *et al.,* 2019). However the remaining nine tall and long duration *C. cajan* genotypes were collected from farmers had no previous study on this attributes. Yunzheng *et al.,* (1980) reported that *C. cajan* spacing of 3 feet x 6 feet accommodated 9990 plants/ha, and produced significantly 49,950 viable branches for lac production .i.e. about 5 branches per plant. In the present study there were 3025 *C. cajan* plant per ha and mean number of secondary branches per plant varied from 5.50 to 11.17.

5.2.4 Settlement of lac insects on primary and secondary branches

Brood lac inoculation (BLI) on *C. cajan* was done on 15.11.2019. Settlement of lac insects on *C. cajan* branches is very important as it decides the lac production on it.

5.2.4.1 Primary and secondary branches of *C. cajan* with lac insects

Lac insects prefer succulent branches for its settlement (You-qing *et al.,* 2004, Hazarika *et al.,* 2018) that is one reason of pruning of host plants of lac insects are routinely carried out (Ghosal *et al.,* 2009, Jaiswal *et al.,* 2011; Namdev *et al.,* 2015; Shah *et al.,* 2014). As *C. cajan* is an annual shrubs, its secondary branches may be comparatively more succulent than the primary branches. This may be a reason for preference of secondary branches by lac insects.

5.3 Yield of *C. cajan*

5.3.1 Mean yield (g) of seeds per *C. cajan* plant

The mean seed yield per plant of *C. cajan* genotypes evaluated were exceptionally higher as it varied from 597.67 g to 1433.83 g. This was because of the technology of Jawahar model for doubling of income of resource constrained marginal farmers developed in JNKVV Jabalpur (Patent application no. 201921044327 A). The mean seed yield per plant of TJT-501 under traditional cultivation practice is 50 to 75 g (GoI, 2017), but the same variety in the above model with lac insects on it gave 1137 g in two pickings.

Vajpayee *et al* (2019,a & b) also recorded from 1058.33 g to 1442.50 g mean seed per plant of TJT-501 with lac insect in the above technology. Patidar 2019 under the same technology reported a mean seed yield per plant of TJT-501 from 1066.67 g to 1254.83 g. However other workers like Jamdar *et al*. (2014) and Ramesh (2017) reported per plant yield 269.33 g and 24.8 g respectively with lac insect. These workers may have grown *C. cajan* plant at closer spacing with no or few nipping operations. In the present study as mentioned earlier, the plants were transplanted in substrate filled PPB with a spacing of 6 feet apart with nipping at 10-12 days interval during the vegetative growth stage of *C. cajan.*

5.3.2 Mean weight (g) of 100 seeds with lac insect

The overall mean weight of 100 seeds varied from 9.51 g to 16.76 g during first picking and 7.39 g to 15.68 g during second picking. A reduction in the mean dry weight of 100 seed during second picking was evident from the data. Though the difference was negligible but it indicates that lac insect exerts biotic stress on the *C. cajan* between 1st and 2nd picking i.e. between 45th day and 165 days after BLI. This is the period when adult female lac insects mate and its reproductive phase was in progress. The female lac insects during its reproductive phase increase the phloem sap intake as evident from the increase in the size of lac cell. The size increases due to excessive secretion of resin, as a result of increase in the intake of phloem sap. Another indication is excessive deposition of sooty mould on the leaves due excessive secretion of honey dew (Dandre, 2018; Barr, 1987; Hughes, 1951). Lohot *et al.*, (2018) also reported an overall reduction of 100 seed weight and seed yield of *C. cajan* with lac insect by 5.4 and 10.5 per cent respectively. In the present study reduction in the weight of 100 seed varied from 1.82 to 9.77 per cent. However the overall seed yield per plant was exceptionally high as it varied from 597.67 g to 1433.83 g. Ghosh *et al.*, (2014) also reported a reduction in the mean weight of 100 seeds and seed yield per plant of *C. cajan* with lac to 13.03 and 12.08 per cent respectively.

5.3.3 Mean dry weight (g) of 100 seeds without lac insect

The overall mean weight of 100 seeds without lac insect during first picking varied from 9.61 g to 17.81 g and 7.39 g to 16.22g during second picking. The mean weight of 100 seeds during the 2nd picking was comparatively lesser in *C. cajan* genotypes in both cases of with and without lac insects. This indicate that lesser weight of seeds during second picking is a general trend and mainly influenced by the abiotic stress of higher atmospheric temperature, dry air and soil moisture stress. Secondary the difference in the seed weight was marginal, but what ultimately counts in the overall high yield of seeds per plant. The mean weight of 100 seeds of all the genotypes was higher in both the pickings of *C. cajan* without lac insects, when compared to those plants of the same genotypes with lac insects. This indicates that lac insects influence yield of the *C. cajan*. However this do not matter much because the per plant seed yield was always higher with lac insect when grown under Jawahar model technology.

Nine tall and long duration local genotypes local genotypes of pigeonpea along with a released variety TJT- 501 was evaluated of lac production and seed yield. There were two sets one set was with lac insects and another without lac insects. There were two hand picking of matured pods. Seedlings of pigeonpea grown in nursery in May 2019 and transplanted in first week of July 2019. Transplantation was done in 65 kg substrate filled PPB. One set of 10 genotypes were inoculated with 15 g of broodlac in the first week of November 2019 while the other set of 10 genotypes of pigeonpea without lac insects.

The 1st hand packing of mature pods was at 52 days after BLI in January 2020, while the 2nd hand picking was in April 2020 after 165 days after BLI. The male of lac insects emerged on 2nd week of March. Usually the adult male of lac insect dies after 3-5 days its emergence. Before it dies male mates with a couple of female lac insect. The female grows in size faster in size after mating by feeding more phloem sap from its host plant. It exerts more sensors on the after more biotic stress on the host after March till harvest of lac crop.

Higher atmospheric temperature from March to June (summer months), exerts abiotic stress of high temperature, evapo-transpiration and moisture. Thus the second picking is the product of the biotic and abiotic stress these host plant experienced. Pod filling is allocation of nutrients by plants after overcoming the nutrient rich phloem been drawn out by the lac insects and abiotic stress.

In contrast to the 2nd picking, the 1st picking was in the month of January 2020. Between November (BLI) and January month the weather was cool, evapo-transpiration was lesser, thereby the plant was under comparatively lesser abiotic stress.

Similarly during this period the lac insect was in the late larval stage and pupal stage thus the drawing of phloem sap also was comparatively lesser over that from month of March onwards. Thus both abiotic and biotic stress was less.

5.4 Effect of *Kerria lacca* (Kerr.) on lac production

5.4.1 Total length of branches on the host plant with lac insect (sticklac)

Female lac insect remain sedentary all it life period after setting on the branches of the host plant. It is also the main produce of lac. The encrustation of lac insect on the host plant at maturity is called sticklac (Sharma *et al.,* 2015, Shah *et al.,* 2014). Thus the length of lac encrustation (sticklac) decides the raw lac yield from the host plant at harvest (Meshram *et al.,* 2018). In the present case, the mean length of sticklac per plant varied from 229.17cm (Amarkantak-4) to 790.50 cm (Lakhnadon-2). Various workers in the past has also reported the sticklac length vary from 506.33 cm to 654 cm (Vajpayee *et al.,* 2019). Thus it appears from the data that Lakhnadon-2 is the best *C. cajan* genotype for the lac production.

5.4.2 Mean yield of lac per plant (g)

The sticklac was scrapped to obtain raw lac. Raw lac is the marketable produce. The mean raw lac yield per *C. cajan* plant varied from 131.83 (Amarkantak-4) to 414.50 g (Lakhnadon-2). This indicates the productivity of lac also depends on the variety Sharma *et al*., 2018 reported 350g of lac from *C. cajan*. Earlier workers have reported the per plant yield of lac 7.80 to 36.25 g (Kumar *et al.,* 2019), 332.33 g to 446 g (Vajpayee *et al.,* 2019) in *C. cajan*. Thus when compared to wild lac host trees with *B. monosperma* it was 0.58 kg to 2.10 kg (Sharma *et al.,* 2015), 2.03 kg to 4.01 kg (Ghugal *et al.,* 2014) *and Z. mauritiana* 3.83 to 5.08 kg (Namdev *et al.,* 2015), the lac production from *C. cajan* shrub was quite good.

5.4.3 Mean weight of 100 lac cell (g)

Female lac insects are sedentary and secrete resin from its three pairs highly specialized resin glands continuously over its soft body continuous resin secretion by the lac insects over its body forms layers after layers over the insect forming protective cell. This protective cell is called lac thus each cell is produced by a single female cell. In the early adult stage of female lac insect Wang *et al*., (2019) observed fastest secretion of lac at the rate of 4.82 x 10^{-1} mg/d in *K. chinensis*. 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 (Kumar *et al.,* 2017). The secretion of lac decreased gradually in the mid late adult stage of female lac insect (Wang *et al*., 2019).

Keeping this in mind if the present data is analysed is observed the mean weight of 100 lac cell was highest (3.27 g) in Lakhnadon-2 followed by, Korsar-3 (3.14), Amarkantak-1 (3.09), Saraswahi (3.07), Amarkantak-2 (3.05), Amarkantak-3 (2.91), Gadarwara (2.79), Amarkantak-4 (2.54), TTJ-501 (2.56) and Korsar-2 (2.43).

This means *C. cajan* genotypes Lakhnadon-2 provides better quality and quantity of phloem sap, which lead lac insect to secrete more resin. The lac production per female lac insect on Lakhnadon-2 was 0.033 g in comparison to 0.031g (Korsar-3 and Amarkantak-1).

The mean weight of 100 lac cell reported by earlier workers was 13.16 to 38.33 mg (Mishra *et al.,*1999) 2.02g to 2.12g (Engla, 2011), 2.24g to 2.54g (Janghel, 2013), 1.79g to 3.42g (Patel, 2013), 5.54g to 6.90g (Shah *et al.,* 2014), 5.18g to 6.30g (Namdev *et al.,* 2015), 3.82g to 5.18g (Ghugal *et al.,* 2015), 3.03g to 3.68g (Sharma *et al.,* 2015), 4.66g to 6.33g (Gurjar, 2016), 4.95g to 8.21g (Kumar *et al.,* 2017), 3.03 to 3.12 (Vajpayee *et al.,* 2019), 2.78 to 3.01(Patidar, 2019).

5.4.4 Mean weight of lac (g) per 2.5cm^2

The mean total length of sticklac was maximum 790.50 cm on Lakhnadon-2 while it was minimum 229.17 cm on Amarkantak-4 genotype. The mean weight of lac per 2.5cm^2 was 1.33 on Lakhnadon-2 while it was least 0.45 g on Amarkantak-4 genotype. The mean weight of lac per 2.5 cm^2 reported by earlier worker it was 0.25 g to 0.97 g (Vajpayee *et al.*, 2019).

5.5 Mean dry weight of total fuel (shoots + roots)

The mean dry weight of total fuel (shoot + root) varied from 836.17 g to 4746.67 g. In Jawahar model technology of lac production on *C. cajan*, the farmer gets three productions from the same plant grown in 65 kg substrate with the same input and effort. The first produce was the seed, the yield of which was exceptionally higher (Vajpayee *et al.,* 2019, Patidar, 2019) the second was raw lac after the harvest of the plant. Lac is again a cash crop (Thomas *et al.,* 2011, Shah *et al.,* 2014). After scrapping of the lac from the harvest *C. cajan* plant and the third produce is fuel wood, which is again of economic importance to small and marginal farmers (Thomas *et al.,* 2016). The fuel wood obtained is from shoot and root. As the soil in the PPB is exposed to sun in June for solar sterilization for the next season crop, the root in the bags is removed, dried and used as fuel. Yude *et al.,* (1993) reported that pigeonpea dry stems are important household fuel woods in many countries. A normal pigeonpea crop produces about 10-12 t ha-1 of dry fuel wood. The quality of pigeonpea fuel wood has been estimated to be excellent, yielding energy @ 4350K-cal kg^{-1}. Matthews and Saxena (2000) observed that dry stems of pigeonpea are an important source of fuel in rural India and produces about 10 to 12 tons per ha of dry woods. Snapp, (2014) reported 15-20 tons/ha of fuel wood from pigeonpea crop can provide energy @ 4,000 kcal/kg (ICRISAT, 2013).

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

The present research work entitled "**Study on the performance of *Rangeeni* lac insect (*Kerria lacca* Kerr.) on tall and long duration genotypes of *Cajanus cajan* (L.) Millsp**." grown with nine tall and long duration genotypes of *C. cajan* and compared with TJT-501 variety of *C. cajan* was conducted during the year 2019 – 20 in the experimental field of, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur with the following objectives

1. To study the performance of *Kerria lacca* Kerr. on *C.cajan* genotypes.
2. Assessment of seed and lac yield on *C.cajan* genotypes.

6.1 Summary

In India lac is mainly produced by two strains of lac insect viz., "*Rangeeni* and *Kusmi*". *Rangeeni* lac is produced on the tree of *B. monosperma* and *Z. mauritiana*. *Kusmi* lac is mainly produced on *S. oleosa* and to some extent on Ber tree. *Rangeeni* strain of *K. lacca* (Kerr.) was most suitable for lac production on pigeonpea. India is the largest producer of Lac in the world. Jharkhand is the largest producer in India followed by Chhattisgarh and Madhya Pradesh. Seoni district in is the largest producers of lac in the state, Anuppur district is the largest producer and seller of brood lac with 0.6 to 1.00 lakh quintal in M.P. during 2018-19. Lac is a cash crop in different countries of south, southeast and east Asian countries including India, China. Pigeonpea [*Cajanus cajan* (L.) Millsp.], an important grain legume of Asia, has a unique place in Indian farming, and India accounts for about 90 per cent of the global production. It is the second most important pulse crop next to chickpea, which has diversified uses as food, feed, fodder and fuel, and mainly consumed as dry split dal also one among the 400 host plants of lac insect.

The field trial was conducted in Randomized Block Design, with ten treatments and three replications from May 2019 to June 2020. Plant to plant and row to row spacing was 6 feet, total plot size was 54x56 sqft and with total number of plants ninety. During the field trail there were 14 operations from nursery raising to scrapping of raw lac (25.06.2020). Transplanting was done on 5th July 2019. Nipping was done up to September at 10-12 days interval. Irrigation was done from November to February at 15 days interval with 10 litres of water per plant. However March to June at 10 days interval with 10 litres of water per plant. Spraying was done at 3 times 30 days after transplanting, 30 days after BLI and 60 days after BLI for management of predator, parasitoids and foliage feeder. Brood lac was inoculated on 15th November 2019. After 21 days of BLI phunki removal was done at 6th December 2019.

The impact of lac insect on *C. cajan* was studied in relation to the plant growth, seed yield and lac yield. Apart from this the fuel wood per plant was also recorded. Observations were recorded on plant height, number of primary and secondary branches thickness, stem thickness, thickness of primary and secondary branches, survival percent of lac insect, male female ratio, date of male emergence, flowering date, podding date, picking date, pod number/picking, pod weight/picking, seed weight/picking, 100 seed weight/picking, sticklac length, lac yield, 100 lac cell weight, lac weight/2.5cm^2 slot.

Mean live lac insects per 2.5 cm^2 on branch and sex ratio

The mean number of live lac insect settlement per 2.5 cm^2 of branches was maximum (168.72) in TJT-501 while it was minimum (147.67) in Amarkantak-1 after 45 days of BLI. The per cent survival of the mean lac insect per 2.5 cm^2 of the branch between 45th day and 190th day after BLI was maximum (38.13%) in Lakhnadon-2 and minimum (24.91%) in Amarkantak-4. Adult male emergence was first observed on 115th day of BLI till 125th day of BLI. The male and female ratio was highest (1:6.93) in Lakhnadon-2 while it was lowest (1:1.91) in Amarkantak-4.

Effect of lac insects on the growth of *C. cajan*

In the five observation period of recording the plant height, it was observed that there was increase in plant height during successive growth period. In all the recording stages there was significant difference among treatment in the mean height of the *C. cajan* plant. The mean height of *C. cajan* varied from 111.83 cm (Gadarwara) to 144.83 cm (TJT-501) 27 days before BLI. The mean height of the plant was minimum (178.33 cm) in Gadarwara while it was maximum (243.67 cm) in Korsar-3 on 108th day after BLI. It was observed that the increase in height was higher during initial 30 days of BLI. There was a significant difference in the stem thickness during growth period of the plant. A per cent increase in stem thickness was maximum (78.19%) in Korsar-3 genotype while minimum (40.46%) in TJT-501. Majority of the lac insect settlement was on the secondary branches of *C. cajan* over primary branches and stem. Similarly the cumulative increase in the mean thickness of the secondary branches was minimum (42.88%) in TJT-501 while maximum (99.45%) in Amarkantak-3 genotype.

Branches per *C. cajan* plant

The mean number of primary branches per plant of *C. cajan* genotypes varied from a minimum 2.17 (Amarkantak-1) to maximum 3.50 (Korsar-2). There was a significant difference in mean number of primary branches per plant. In Korsar-2, it was significantly highest (3.50) over all the genotypes except TJT-501(3.17) and Lakhnadon-2 (3) with which it was at par. The mean number of secondary branches per plant varied from a minimum (5.50) in Amarkantak-4 to maximum (11.17) in Korsar-2. It was significantly highest in Korsar-2 over all the genotypes but was at par with TJT-501(9.50) and Korsar-3 (9).

Brood lac inoculation (BLI) on *C. cajan* was done on 15.11.2019. *K. lacca* preferred to settle on secondary branches over the main stem and primary branches of *C. cajan*. The per cent of primary branches of *C. cajan* with lac insect settlement was maximum (76.39%) in Lakhnadon-2 genotype, while it was minimum (41.67%) in both Gadarwara and Amarkantak-1. It was significantly highest in Lakhnadon-2 over all the varieties, except Korsar-2 (70.83%), Amarkantak-3 (72.22%) and TJT-501 (72.22%) with which it was at par. The percentage of secondary branches of *C. cajan* with lac insect settlement was maximum (92.12%) in Lakhnadon-2, while it was minimum (73.85%) in Gadarwara. There was significantly highest in Lakhnadon-2 over all the genotypes except Amarkantak-2 (41.67%) and Amarkantak-4 (63.89%) with which it was at par.

Yield of *C. cajan*

There were two hand pickings of mature pods on January 2020 and April 2020. As Korsar-3 and Korsar-2 were late genotypes there was no picking of pods during 1st picking. The mean number of total pods/plant of the two picking was maximum (8582.50) in Korsar-2 while it was minimum (922.83) in Amarkantak-4. The mean dry weight of total seeds/plant of all the two pickings was maximum (1433.83 g) in Lakhnadon-2 while it was minimum (597.67 g) in Amarkantak-1. The overall mean dry weight of 100 seeds with lac insect during the first and second picking was highest (16.22 g) in Amarkantak-1 while minimum in (7.39 g) in Korsar-2. The overall mean dry weight of 100 seeds without lac insect during the first and second picking was highest (16.94 g) in Amarkantak-1 while minimum in (7.80 g) in Korsar-2. The difference in the mean weight of 100 seeds of *C. cajan* genotypes with and without lac insect was negligible.

Mean weight of lac yield per plant

The mean lac yield per *C. cajan* varied from 131.83 g (Amarkantak-4) to 414.50 g (Lakhnadon-2). The mean lac yield per *C. cajan* in all the genotypes differed significantly over Amarkantak-4. The lac yield per plant among Gadarwara, Saraswahi and Amarkantak-1 as well as Amarkantak-3, Korsar-3 and Amarkantak-2 were at par. The mean lac yield per plant was significantly highest in Lakhnadon-2 over all the other genotypes.

Mean weight 100 lac cell

The mean weight 100 lac cell varied from 2.43 g (Korsar-2) to 3.27 g (Lakhnadon-2). There was a significant difference in the mean weight of 100 lac cells in Lakhnadon-2, Korsar-3, Amarkantak-1, Saraswahi, Amarkantak-2, Amarkantak-3 and Gadarwara over Korsar-2. Among Korsar-2, TJT-501 and Amarkantak-4, Gadarwara and Amarkantak-3 as well as Amarkantak-2, Saraswahi, Amarkantak-1 and Lakhnadon-2 it was at par with each other.

Fuel wood of *C. cajan* genotypes

After scrapping of raw lac from the harvest *C. cajan* plant, the dry shoot and root weighed. These two are used by farmer as fuel wood. The mean dry weight of shoot per plant varied from a minimum 659.50 g (Amarkantak-4) to maximum 4326.67 g (Korsar-2). There was a significant difference in mean dry weight of shoot in Korsar-2 (4326.67g), Korsar-3 (3354g), Lakhnadon-2 (2343.33g), Amarkantak-2 (1768.33g), Amarkantak-3 (1655g) and Saraswahi (1599.17g) over Amarkantak-4 (659.50g). The mean weight of shoot per plant in Korsar-2 was significantly highest over all the genotypes. The mean dry weight of total fuel (shoot + root) varied from a minimum 836.17 g (Amarkantak-4) to maximum 4746.67 g (Korsar-2). The mean weight of total fuel per plant in variety Korsar-2 was significantly highest over rest all the genotypes.

6.2 Conclusions

- Doubling of farmers' income is possible through lac production on pigeonpea in Jawahar model.
- There was a seed saving (90-95%) in *C. cajan* under Jawahar model Generally 15-20 kg / ha seed is required but in this technology only 800-900 g seed /ha is required.
- Seed yield per plant generally occurs 50-100 g/plant but during the present trial per plant yield varied from 600-1400 g seed yield.
- Under traditional *C. cajan* cultivar fuel wood produced about 50-60q/ha (GoI, 2017) but in this technology fuel wood varied from 20q to 140q/ha depends on genotypes with less plants.
- Per drop more crop is also possible as with 200 litres of additional water.
- Best 3 genotypes for lac production is Lakhnadon-2, TJT-501 and Korsar-3
- Best 3 genotypes for fuel wood and lac production is Korsar-2, Korsar-3 and Lakhnadon-2.

6.3 Suggestions for further work

1. As Lakhnadon-2 genotype was found to be the best among the 10 genotypes evaluated, field trial with spacing and water management may be conducted for further refining of technology.

2. Qualitative analysis of seeds may done to find the impact of lac insect on nutrient status of seeds.

REFERENCES

ACIAR. 1998. Australian Centre for International Agricultural Research aciar.gov.au

Ade UK, Dambale AS and Jadhav DB. 2018. Effect of Phosphorus and Biofertilizer on Growth, Yield and Economics of Pigeonpea (*C. cajan* L. Millsp.) Under Rainfed Condition. International Journal of Current Microbiology and Applied Sciences. (6): 1408-1416.

Ahmad A, Ramani R, Sharma KK, Vidyarthi AS and Ramamurthy VV. 2014. Distinction of Indian commercial lac insect lines of *Kerria* spp. (Homoptera: Coccoidea) based on their morphometrics Journal of Insect Science 14(263):1-10.

Ahmed S, Habibullah SS and Ali MC. 2007. Effect of different doses of nitrogen fertilizer on sucking insect pests of cotton, *Gossypium hirsutum*. J Agric. Res. 2007; 45(1):43-48.

Anonymous. 2010. A profile, AICRP on Pigeonpea Indian Institute of pulse research, Kanpur, 2010.

Anonymous. 2015. Department of Agriculture Cooperation & Farmers Welfare agricoop.nic.in

Anonymous. 2015. IIPR Indian institute of pulses research. 2015. http//.www.iipr.com

Anonymous. 2017. ENVIS centre of Madhya Pradesh State of Environment, Ministry of Environment, Forests and Climate change, Govt. of india.

Anonymous. 2018. Directorate of Economics and Statistics http//des.mp.gov.in

Anonymous. 2018. United Nation's Food and Agriculture Organization. Rome, Italy. 2018. Available online: http://www.fao.org/faostat/en/#data/pp (accessed on 11 May 2018).

Ayenan MAT, Danquah A, Ahoton LE and Ofori K. 2017. Utilization and farmers' knowledge on pigeonpea diversity in Benin, West Africa. J Ethnobiol Ethnomed. 2017;13:37. doi:10.1186/s13002-017-0164-9.

Babu KR, Ramakrishna S, Harish KR, Lakshmi G, Naidu NV, Sadak S, Basha and Bhaskar M. 2009. Metabolic alterations and molecular mechanism in silkworm larvae during viral infection: A review African Journal of Biotechnology Vol. 8 (6), pp. 899-907, 20 March, 2009

Basiago AD. 1999. Economic, social, and environmental sustainability in development theory and urban planning practice. The Environmentalist 19: 145-161.

Beck SD and Reese JC. 1976. Insect-Plant Interactions: Nutrition and Metabolism. In: Wallace JW, Mansell RL (eds) Biochemical Interaction Between Plants and Insects. Recent Advances in Phytochemistry, vol 10. Springer, Boston, MA. https://doi.org/10.1007/978-1-4684-2646-5_2

Bhalerao KR. 2013. Study on Predator surveillance and its management on *Rangeeni* lac in Barghat block district Seoni Madhya Pradesh. M.Sc. (Ag.) Thesis submitted in JNKVV, Jabalpur.

Bhatnagar VS. and Davies JC. 1978. Factors affecting populations of gram pod borer, *Halitosis armigera* (Hübner) (Lepidoptera: Noctuidae) in the period 1974–77 at Patancheru (Andhra Pradesh). Bull. Entomol. 19: 52–64.

Biere A and Bennett AE. 2013. Three-way interactions between plants, microbes and insects Functional Ecology 2013, 27, 567–573 doi: 10.1111/1365-2435.12100

Blackburn TM and Ewen JG. 2017. Parasites as Drivers and Passengers of Human-Mediated Biological Invasions EcoHealth 14, S61–S73, 2017 DOI: 10.1007/s10393-015-1092-6

Bruce E, Yves C, Timothy J, Dennehy, Shai M, Mark S. Sisterson, Richard TR, Anthony MS, Jian-Zhou Z. 2003. Insect Resistance to Transgenic Bt Crops: Lessons from the Laboratory and Field, *Journal of Economic Entomology*, Volume 96, Issue 4, 1 August 2003, Pages 1031–1038

Chen Y, Li Q, Chen YL and Chen Y. 2011. Effects of different land-use on grasshopper diversity in lac agro-ecosystems. Terrestrial Arthropod Reviews 4(3):255-269.

Chen Y, Li Q, Wang S and Yang Y. 2010. Lac production, arthropod biodiversity and abundance and pesticide use in Yunnan province, China. Tropical Ecology 51: 255-263.

Choudhary AK, Sultana R, Pratap A, Nadarajan N and Jha UC. 2011. Breeding for abiotic stresses in pigeonpea. J. Food Leg. 24: 165–174.

Colton HS. 1984. The anatomy of the female American lac insect Tachardiella larea Bull. Mus. Nth. Arizona Flagstaff 21:1-24.

Cook AG and Denno RF. 1994. Planthopper/Plant Interactions: Feeding Behavior, Plant Nutrition, Plant Defense, and Host Plant Specialization. In: Denno R.F., Perfect T.J. (eds) Planthoppers. Springer, Boston, MA. https://doi.org/10.1007/978-1-4615-2395-6_3

DeHaan LR, Van T and DL Cox TS. 2005. Perennial grain crops: a synthesis of ecology and plant breeding. Renewable agriculture and food systems 20, 5–14.

Douglas AE. 2003. Nutritional physiology of aphids. Adv. Insect Physiol, 2003; 31:73-140.

Duke JA. 1983. Handbook of energy crops. only.mawhrin.net/~alexey/cajanus. Html

Egbe OM, and Vange T. 2008. Yield and agronomic characteristics of 29 pigeonpea Genotype at Otobi in Southern Guinea Savannah of Nigeria. Nature and Science. 6:112.

Egebe OM, and BA Kalu. 2009. Evaluation of pigeonpea genotypes for intercropping with tall sorghum in Southern Guinena savannah of Nigeria. 4:1-12.

Engla Y. 2011. Study on predator management on *Baishakhi* crop of *Rangeeni* on *Zizyphus mauritiana* in Janamkhari village, Seoni district, Madhya Pradesh. M.Sc. (Ag.)

Essa CM, Franklin S and Gideon. 2012. Obare factor productivity in smallholder pigeonpea production systems: Empirical evidence from Northern Tanzania Journal of Agricultural Economics and Development Vol. 1(6), pp. 138-144, December 2012 ISSN 2327-3151.

Faris DG and Singh U. 1990. "Pigeonpea: Nutrition and products. In: Nene, Y.L., Hall, S.D. and Sheila, V.K. Eds." The pigeonpea, CAB International, Wallingford, pp. 401-434.

Francis CA. 1985. Development of plant genotypes for multiple cropping systems. In: Frey, K.J. (ed.) Plant Breeding II, Kalyani Publishers, New Delhi (2nd Reprint), India, pp. 179–231.

Fu Y, Zu Y, Liu W, Hou C, Chen L, Li S, Shi X and Tong M. 2007. Preparative separation of vitexin and isovitexin from pigeonpea extracts with macroporous resins. J. Chromatogr. A 1139: 206–213.

Gassmann AJ, Onstad DW and Pittendrigh BR. 2009. Evolutionary analysis of herbivorous insects in natural and agricultural environments Society of Chemical Industry 16 September 2009 https://doi.org/10.1002/ps.1844

Ghosh J, Jyoti A, Lohot VD, Sinha NK, Ghosal S, Thamilarasi K and Thakur VV. 2018. Consequence of lac cultivation on pigeonpea (*Cajanus cajan*) seeds and seedling establishment, An International Refereed, Peer Reviewed & Indexed Quarterly Journal in Science, Agriculture & Engineering. (8): 289-292.

Ghosh J, Lohot VD, Singhal V, Ghosal S and Sharma KK. 2014. Pigeonpea-Lac Insect Interaction: Effect of Lac Culture on Grain Yield and Biochemical Parameters in Pigeonpea, In J Genet Pl Breeding, 74 (4).

Ghugal SG, Thomas M and Pachori R. 2015. Performance of *Katki* Lac on Nutrient Managed of *Butea monosperma* (Lam.) Taub. Trends in Biosciences 8(24), Print : ISSN 0974-8431, 6873- 6877.

Ghugal SG, Thomas M., Upadhyay A and Sharma HL. 2016. Foliar Application of Nutrients and PGR on *Butea monosperma* and Survival of *Kerria lacca* (Kerr). Advances in Life Sciences 5(1): 159-163.

Glover PM. 1937. Lac cultivation in India (2nd revised edition). Indian Lac Research Institute, Namkum, Ranchi.: 8.

Gogi MD, Arif JM, Asif M, Abdin Z, Bashir HM and Arshad M. 2012. Impact of nutrient management schedules on infestation of *Bemisia tabaci* on and yield of non BT- cotton *Gossypium hirsutum* under unsprayed conditions. Pakistan Entomologist. 2012; 34(1):87-92.

Grez AA Zaviego T, Gardiner MM.2014. Local predator composition and landscape affects biological control of aphids in alfalfa fields Biological Control Volume 76 September 2014.

Gurjar R. 2016. Study on the Effect of Foliar Application of Nitrogen and PGR on *Butea monosperma* on *Katki* Crop Production. M.Sc. Thesis. Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, M.P.

Gwata ET and Siambi M. 2009. "Genetic enhancement of pigeonpea for high latitude areas in Southern Africa." African Journal of Biotechnology, vol. 8, pp. 4413-4417.

Hazarika LK, Das P, Saikia R and Islam AN. 2018. Settlement behavior of lac insect, *Kerria lacca* crawlers. Journal of Entomology and Zoology Studies; 6(6): 1267-1269

Horikoshi, M., Beaumont, R., Day, F. *et al.* Genome-wide associations for birth weight and correlations with adult disease. *Nature* 538, 248–252 (2016).

Høgh-Jensen H, Myaka FA, Sakala WD, Kamalongo D, Ngwira A, Vesterager JM, Odgaard R and Adu-Gyamfi JJ. 2007. Yields and qualities of pigeonpea varieties grown under smallholder farmers' conditions in Eastern and Southern Africa, African Journal of Agricultural Research Vol. 2(6), pp. 269-278, June 2007 ISSN 1991- 637X © 2007.

Igene F, Isaka M, Oboh S and Ekundayo D. 2012. Replacement Value of Boiled Pigeonpea (*Cajanus cajan*) on Growth Performance, Carcass and Haemotological Responses of Broiler Chickens. Asian Jounral of Poultry Science.

IINRG Statistics Annual report for the year 2014-15, Indian Institute of Natural Resins and Gums, Namkum, Ranchi. 92 pp.

Jaiswal AK and Sharma KK. 2011. Recent Advances in Lac Culture. Biotic factor affecting productivity of lac insect. Indian Institute of Natural Resin and Gums Namkum, Ranchi. 63-6.

Jaiswal AK and Singh JP. 2014. A review of Lac production in India during XI plan. Indian Forester 140(9): 907-920.

Jaiswal AK, Sharma KK and Kumar KK. 2006. Importance of Lac in the socioeconomic life of tribals in Ranchi District (Jharkhand).J. NonTimber Forest Prod 13(1):47-50.

Jaiswal AK. 2011. Estimation of crop yield on the basis of correlation and regession analysis in lac host trees. Journal of Non-Timb Forest Product 8(1/2):379-81.

Janghel S, Thomas M, Thakur AS, Nema S and Sharma HL. 2014. Study on Bio Efficacy of Insecticides in the predator management of *Katki* Lac crop. Bioengineering and Bioscience 2(2): 15-22.

Janghel SK, Thomas M, Thakur AS and Nema S. 2016. Evaluation of Newer Insecticides for Predator Management of *Kerria lacca* (Kerr). Indian Journal of Ecology 43.

Janghel SK. 2013. Study on comparative efficacy of insecticides in the predator management of *Katki* lac crop in Malhara village, Barghat block, Seoni district, M.P, M.Sc. (Ag.) Thesis submitted in JNKVV, Jabalpur.

Kaiwei H, Jinyuan L, Fengshu L, and Peng Y. 1988. The effect of getting rid of flower buds on the yield and quality of brood lac. Forest Research 1(1):41–46.

Kalahal C, Swami H and Lekha. 2017. Productivity-linked parameters of the *Rangeeni* strain Lac Insect, *Kerria lacca* (Kerr) on Pigeonpea, *Cajanus cajan* Linn. Journal of Entomology and Zoology Studies 5(3): 1745-1751.

Kaushik S, Pushker AK , Lakhanpaul S, Sharma KK , Ramani R.2012. Investigations on some of the important host plants of Kerria lacca with reference to phloem distance. EurAsian Journal of Biosciences Eurasia J Biosci 6,32-38 (2012) DOI:10.5053/ejobios.2012.6.0.4 Das P, Saikia R, Hazarika LK, Islam AN and Saikia P. 2020. Effect of weather parameters on life cycle duration of lac insect (*Kerria* spp.) (Kerridae: Hemiptera). Journal of Pharmacognosy and Phytochemistry 2020; 9(4): 224-227

Kehr J. 2006. Phloem sap proteins: their identities and potential roles in the interaction between plants and phloem-feeding insects. Journal of Experimental Botany 57 (4): 767–774.

Khaki N. 2014. Evaluation of Malawi Pigeonpea accessions for tolerance to moisture stress and superior agronomic traits in Uganda. M.Sc. diss., University of Makerere. Lilongwe.

Khobragade D, Thomas M, Pachori R, Sharma JL and Shrivastava A. 2012. Farmer participatory trial on the predator management of Lac insect *K. lacca* (Kerr) in Anuppur District, Madhya Pradesh. Journal of Tropical Forestry, 28(1&2): 38-45.

Khobragade D. 2010. Studies on the Incidence on major predators of *Kerria lacca* Kerr. and their management in *Baishakhi* lac crop in Anuppur district, Madhya Pradesh. M.Sc. (Ag.) Thesis submitted in JNKVV, Jabalpur.

Kirar NS, Sasode DS, Rawat GS, Joshi E and Mahor S. 2020. Performance of Pigeonpea (Cajanus cajan L.) sown on different land configuration techniques Journal of Pharmacognosy and Phytochemistry 2020; 9(4): 224-227

Klingauf FA. 1987. Host finding and acceptance. In: Minks, A.K., Harrewijn, P. eds: Aphids, their Biology, Natural Enemies and Control. Vol. A. Elsevier, New York, 1987, 209-223.

Kumar A, Kumawat MM and Meena NK. 2007. Lac host plants recorded from southern Rajasthan and their relative performance. Department of Zoology and Agricultural Entomology, Rajasthan college of Agriculture, Maharana Pratap University of Agriculture and Technology, Entomon 32(2):129-132.

Kumar A. 2017. Influence of soil nutrient combination on *Flemingia semialata*, lac insect growth and lac insect pest, Forest Research Institute, Dehradun-248006 (Uttarakhand) 6(3): 86-92.

Kumar P and Joshi PK. 2014. Changing consumption pattern of pulses in India: Past trends and projections. International Food Policy Research Institute, Washington, D.C. http://www.slideshare.net/southasia-ifpri/ifpri-changing-consumption-pattern-of-pulses.

Kumar R and Paslawar AN. 2017. Effect of conservation tillage on biomass partitioning and quality of pigeonpea based intercropping system under Vidarbha region. The Bioscan. 2017; 12(1):571-574.

Kumar S, Thomas M, Lal N, Virendra and Markam VK. 2017. Effect of nutrition in *Palas* (*Butea monosperma* Lam.) on the survivability of lac insect, The Pharma Innovation Journal 6(8): 193-197.

Lindah LH, Alfred OO, Paramu M, Nkanyiso JS and Lembe SM. 2017. Characterisation of pigeonpea (*Cajanus cajan*) landraces grown in two climatic zones in KwaZuluNatal province, South Africa ISSN: 0257-1862

Lisa L and Kaigui D. 1980. The preliminary study on quantity of brood lac under per tree of Pigeonpea - the fine host plant. Developing Status of Lac Production 4:18–23.

Lohot VD, Ghosh J, Ghosal S, Thamilarasi K, Gunjan and Sharma KK. 2018. Effect of lac culture on seed quality traits of Pigeonpea [*Cajanus cajan* (L.) Millsp.]. Journal of Entomology and Zoology Studies 6(2): 2293-2298.

Makelo MN, Melis R, and Githiri M. 2013. Analysis of stakeholders in the Pigeonpea [*Cajanus cajan* (l.) millsp.] value chain for determination of a hybrid breeding agenda in keny int'l journal of agric. and rural dev Volume 16 (2): 1493-1502, 2013.

Makoka D. 2009. "Small Farmers' Access to High-Value Markets: What Can We Learn from the Malawi pigeonpea Value Chain?" MPRA Paper No. 15397. Centre for Agricultural Research and Development, University of Malawi.

Malik YP and Bhagwan D. 1998. Impact of aphid (*Lipaphis erysimi*) intensity on plant growth and seed characters of Indian mustard. Indian Journal of Entomology 60: 3642.

Mapfumo P, Giller KE, Mpepereki S and Mafongoya PL. 1999. Dinitrogen fixation by pigeonpea of different maturity types on granitic sandy soil in Zimbabwe. Symbiosis 7: 305–318.

Mathews C and Saxena KB. 2003. Prospects for pigeonpea evaluation in drought-prone areas of South Africa. Pigeonpea Newsletter 8: 52–53.

McGuinness KA. 1987. Disturbance and organisms on boulders. *Oecologia* 71**,** 420–430 (1987).

Meena B, Srivastava CP and Sharma RP. 2010. Seasonal incidence of pod fly, *Melangromyza obtusa* Malloch) on long duration pigeonpea, (*Cajanus cajan* L.), Ann. Pl. Protec. Sci. 18: 394- 399.

Minja EM, Shanower TG, Songa JM, Ong'aro JM, Kawong WT, Mviha PJ, Myaka FA, Slumpa S, Okurut-Akol H and Opiyo C. 1997. Studies of pigeonpea insect pests and their management in Kenya, Malawi, Tanzania, and Uganda. African Crop Science Journal 7:59-69.

Mishra YD, Sushil SN, Bhattacharya A, Kumar S, Mallick A and Sharma KK. 1999. Intra specific variation in host plants affecting productivity of Indian lac insect, *Kerria lacca* (Kerr). Journal of Non Timber Forest Products 6 (3/4): 114-116.

Mohanta J, Dey DG and Mohanty N. 2014. Studies on lac insect (*Kerria lacca*) for conservation of biodiversity in Similipal Biosphere Reserve, Odisha. Journal of Entomology and Zoology Studies 2 (1): 1-5.

Mohanta J, Mohanty N and Dey DG. 2013. Life cycle of lac insect, *Kerria lacca* Kerr. in simipal biosphere reserve. Indian Journal of Entomology. 75: 26-30.

Nagaraju J and Goldsmith MR. 2002. Silkworm genomics - progress and prospects. Current Science, Vol. 83 No. 4, 25 Aug 2002.

Namdev BK, Thomas M, Kurmi A, Thakur AS and Upadhyaya A. 2015. Impact of nutrient management of *Zizyphus mauritiana* (lamb.) On the yield of *Kusmi* lac. An International Quarterly Journal of life science. 10(3): 1219-1222.

Namdev BK. 2014. Study on the performance of *Aghani* crop of *Kusmi* lac on nutrient managed *Zizyphus mauritiana* under heavy rainfall condition. M. Sc. (Ag.) thesis submitted in JNKVV, Jabalpur.

Namdew BK, Thomas M, Kurmi A, Thakur AS and Updhyaya A. 2014. Impact of Nutrient Management of *Zizyphus Mauritiana* (Lamb.) on The Yield of *Kusmi* Lac. The Bioscan 10(3): 1219-1222.

Nene YL and Shiela VK. 1990. Pigeonpea: Geography and importance. In: Nene YL, Hall SD, Shiela VK (Eds.) The Pigeonpea.). ICRISAT, Patancheru 502 324, A.P. India. CAB International, U.K. pp. 1-14.

Odeny DA. 2007. The potential of pigeonpea (*C. cajan* (L.) Millsp.) in Africa. Pages 297–305 in Natural Resources Forum 31.

Ogle A, Thomas M and Tiwari LM. 2006. Technical consultancy report on strategic development of lac in Madhya Pradesh. Enterplan limited UK. pp. 61-65.

Orr A, Amede T, Tsusaka T, Tiba Z, Dejen A, Deneke TT and Phiri A. 2017. Smallholder Risk Management Solutions (Srms) in Malawi and Ethiopia: Risk Management Scoping Study; Oxford Policy Management: Oxford, UK, 2017; p. 58

Pal G, Jaiswal AK and Bhattacharya A. 2011. Lac statistics at a glance 2010. Technical Bulletin No. 01/2011, Indian Institute of Natural Resins and Gums, Ranchi: 1-24.

Pal G. 2011. Socio-economic Characteristics of Lac Growers in Kanker District of Chhattisgarh. Indian Forester, [S.l.], p. 1294-1297, nov. 2011. ISSN 2321-094X.

Pal S, Ghosh A and Dhar A. 2013. On determination of ETL – a distributional approach. Biometrical Letters, 50: 107-116.

Palaniswamy P and Bodnaryk R. 1994. a wild brassica from sicily provides trichome-based resistance against flea beetles, phyllotreta cruciferae (goeze) (coleoptera: chrysomelidae). The Canadian Entomologist*, 126* (5), 1119-1130. doi:10.4039 /Ent1261119-5

Parr JF, Stewart BA, Hornick SB and Singh RP. 1990. Improving the sustainability of dryland farming systems: a global perspective. Adv. Soil Sci. 13, 1–8.

Patel B. 2013. Comparative performance of *Kusmi* and *Rangeeni* lac on Ber, *Zizyphus mauritiana* at Kachana village Barghat Block, Seoni district, MP. M.Sc. (Ag.) Thesis submitted in JNKVV, Jabalpur.

Patidar, N. 2011. Assessment of the role of *Madhya bharat lac utpadhak sangh* in dissemination of lac production technology and its impact on lac growers of Mediaraas village, Anuppur district, Madhya Pradesh. M.Sc. (Ag) thesis submitted, JNKVV, Jabalpur.

Patidar, R. 2019. Study on the performance of *Kerria lacca* (Kerr.) on *Cajanus cajan* (L.) Millsp. grown on substrate treated with soil microbes Jabalpur, Madhya Pradesh. M.Sc. (Ag) thesis submitted, JNKVV, Jabalpur.

Peoples MB, Herridge DF and Ladha JK. 1995. Biological nitrogen fixation: An efficient source of nitrogen for sustainable agricultural production? Plant and Soil, 174: 3 –28.

Pizzol J, Desneux N and Wajnberg E. 2012. Parasitoid and host egg ages have independent impact on various biological traits in a *Trichogramma* species. J Pest Sci 85, 489–496 (2012).

Prasad N, Kumar KK and Jaiswal AK. 2004. Energy Requirement in Lac Production. Agricultural Mechanization in Asia, Africa and Latin America.VOL.35 NO.1.

Prudic KL, Oliver JC and Bowers MD. 2005. Soil nutrient effects on oviposition preference, larval performance and chemical defense of a specialist insect herbivore. Oecolgia, 2005; 143:578-587.

Ramani R. 2011. National strategy for enhancing lac production. Current issues related to lac production Indian Institute of Natural Resin and Gums, Namkum, Ranchi. 1-3.

Rathore V. 2011. Comparative performance of three local *Rangeeni* Lac cultivar on *Zizyphus maurtiana* in Dharna village, Seoni district, Madhya Pradesh. M.sc. (Ag) Thesis, submitted, JNKVV,Jabalpur.

Roonwal ML, Raizada MB, Chatterjee RN and Singh B. 1958. Descripitive account of the host plants of the lac insect, *Laccifer lacca* (Kerr.) and the allied plants in the indian Region, Indian lac Cess Committee, Ranchi. pp. 157-179.

Sahu S. 2016. Survival and Yield of *Rangeeni* Lac insect on *Butea monosperma* (Lam) treated with different Micronutrients and Humic acid at Malhara Village Barghat Block, Seoni district, MP. M.Sc. (Ag.) Thesis submitted in JNKVV, Jabalpur.

Sardana V, Sharma P and Sheoran P. 2010. Growth and production of pulses. In: Verheye WH (ed.), Soils, plant growth and crop production, 3:1-9. vol 3. Oxford: Encyclopedia of Life Support Systems. Available at http://www.eolss.net/sample-chapters/c10/e1-05a44-00.pdf

Saxena A, Choudhary K, Saxena RK and Rajeev KV. 2018. Breeding Pigeonpea cultivars for intercropping: synthesis and strategies Breeding Science 68: 159–167 (2018) doi:10.1270/jsbbs.17105.

Saxena KB and Kumar RV. 1999, Development of cytoplasmic male-sterility in Pigeonpea. Progress Report 1998. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. 38 pp.

Saxena KB and Nadarajan N. 2010. Prospects of pigeonpea hybrids in indian agriculture. Electronic Journal of Plant Breeding, 1(4): 1107-1117.

Saxena KB and Sharma D. 1990. Pigeonpea Genetics. In: Nene, Y.L. (ed.) The Pigeonpea, CAB International, Wallingford, UK, pp. 137–158.

Saxena KB, Kumar RV and Sultana R. 2010. Quality nutrition through pigeonpea—a review, International Crops Research Institute for the Semi-Arid Tropics, Patancheru, India 2(11): 1335-1344.

Saxena KB. 1999. Pigeonpea in Srilanka. International crops research institute for the Semi-Arid tropics, Patancheru 502 324, A.P. India. p. 98.

Saxena KB. 2000. Pigeonpea in China: Traditional and alternative uses of pigeonpea in China. A compilation. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.

Schepper VD, Swaef TD, Bauweraerts I and Steppe K. 2013. Phloem transport: a review of mechanisms and controls Journal of Experimental Botany, Vol. 64, No. 16, pp. 4839–4850, 2013 doi:10.1093/jxb/ert302.

Shah TH and Thomas M. 2015. Survival of *Kusumi* Lac insect (*Kerria lacca Kerr.*) on Nutrient managed *Zizyphus mauritiana*. Indian Journal of Entomology, 80(1): 56-63.

Shah TH, Mushtaq R and Thomas M. 2018. Impact of nutrient management in *Zizyphus mauritiana* (Lamb.) on the weight of lac cells International Journal of Advanced research in Science and Engineering volume no. 07 Special issue no. 04 March 2018.

Shah TH, Thomas M and Bhandari R. 2014.Impact of nutrient management in *Z. mauritiana* (Lamb.) on the survivability of lac insect and the yield of *Aghani* crop of *Kusmi* lac. Journal of Entomology and Zoology Studies 2(5):160-163.

Shah TH, Thomas M and Bhandari R. 2015. Lac production, constraints and management. International Journal of Current Research 7(3): 13652-13659.

Sharma H, Ghugal SG, Gurjar R, Thomas M and Rajwat BS. 2015. Performance of *Kerria lacca* (Kerr) in response to foliar application of Nutrients on *Butea monosperma*. An International Quarterly Journal of Environmental Science. Special issue 8l: 355-359.

Sharma H, Ghugal SG, Thomas M. and Pachori R. 2015. Impact of Nutrient Management in *Butea Monosperma* (Lam.) Taub. on the Survivability of *Kerria lacca* (Kerr). An International Quarterly Journal of Life Science 8 (23): 6682-6687.

Sharma KK, and Jaiswal AK, and Kumar KK.2006. "Role of Lac Culture in Biodiversity Conservation: Issues at Stake and Conservation Strategy." *Current Science* 91, no. 7 (2006): 894-98. Accessed November 8, 2020. http://www.jstor.org/stable/24094286.

Sharma KK, Ramani R and Mishra YD. 1997. An additional list of the host plants of lac insects, *Kerria* spp. (Tachardidae: Homoptera). J. Non-Timber For. Prod. 4: 151–155.

Sharma KK. 2017. Lac Insects and Host Plants. In: Omkar (eds) Industrial Entomology. Springer, Singapore. https://doi.org/10.1007/978-981-10-3304-9_6

Sharma S, Paul PJ, Sameer Kumar CV and Nimje C. 2020. Utilizing Wild *Cajanus platycarpus*, a Tertiary Genepool Species for Enriching Variability in the Primary Genepool for Pigeonpea Improvement. *Front. Plant Sci.* 11:1055. doi: 10.3389/fpls.2020.01055.

Sherchan D, Pilbeam C & Gregory P. 1999. Response of wheat–rice and maize/millet systems to fertilizer and manure applications in the mid-hills of nepal. Experimental Agriculture, *35*(1), 1-13. doi:10.1017/ S00144797 990010 -52.

Shrestha Jb. 2008. Honeybees: the pollinator sustaining crop diversity The Journal of Agriculture and Environment Vol:.9, Jun.2008

Shrivastava P, Khare YR, Sharma A and Pahalwan DK. 2018. Effect of Raised Bed Sowing of Pigeonpea in Vertisols in Central Narmada Valley AgroClimatic Zone of Madhya Pradesh. International Journal Current Microbiology and Applied Sciences 7(3): 2904-290.

Siddiqui SA. 2004. Lac the versatile natural resin. Natural product Radiance vol 3 (5) September- October 2004.

Singh AK, Singh JP, Yogi RK, Jaiswal AK, Sequeira D and Singh A. 2015. Impact of Lac cultivation on economic strengthening of tribal woman. International Journal of Tropical Agriculture.Vol.33, No.2.

Singh JP, Jaiswal AK and Monobrullah MD. 2014. First Record of Some on Commercial Lac Host Plant, *Ziziphus mauritiana* from India. Proc. National Academic of Science India, Section B Biological Science.DOI 10.1007/ s40011-014-0400-1.

Singh SN, Singh VK, Singh RK and Rakesh KS. 2007. Adoption Constraints of Pigeonpea Cultivation in Lucknow District of Central Uttar Pradesh Indian Res. J. Ext. Edu. 7 (1), January 2007.

Singh SR and Nath P. 2011. Effect of biorational approaches on Pigeonpea pod and grain damage by pod bug (*Clavigralla gibbosa* Spinola). Ann. Pl. Protec. Sci. 19 (1): 75-79.

Snapp S. 2014. Agriculture redesign through perennial grains. In: Batello, C., Wade, L., Cox,S.,Pogna,N., Bozzini, A.,Choptiany, 2013, J.(Eds.), Perennial crops for food security – proceedings of FAO expert workshop August 2013, Rome, pp. 148–155.

Sogbedji JM, Van Es HM and Agbeko KL. 2006. Cover cropping and nutrient management strategies for maize production in Western Africa. Agronomy Journal 98(4):883-889.

Straub CS and Snyder WE. 2006. Experimental Approaches to Understanding the Relationship Between Predator Biodiversity and Biological Control. In:

Brodeur J., Boivin G. (eds) Trophic and Guild in Biological Interactions Control. Progress in Biological Control, vol 3.

Tabashnik BE and Gould F.2012. Delaying Corn Rootworm Resistance to Bt Corn, *Journal of Economic Entomology*, Volume 105, Issue 3, 1 June 2012, Pages 767–776, https://doi.org/10.1603/EC12080

Vajpayee S, Patidar R, Kakade S, Thomas M, Tripathi N, Bhowmick A.K., Gontia A.S., Kulhare P.S. and Sharma H.L. 2019 Effect of Population density of *Kerria lacca Kerr.* on its growth and survival International Journal of Current Microbiology and Applied Sciences Int.J.Curr.Microbiol.App.Sci (2019) 8(12): 912-924 ISSN: 319-7706.

Vashishtha A, Sharma KK & Lakhanpaul S. 2011. Co-Existence, Phylogeny and Putative Role of *Wolbachia* and Yeast-Like Symbiont (YLS) in *Kerria lacca* (Kerr). *Curr Microbiol* 63, 206–212 (2011).

Waldman KB, Ortega DL, Richardson RB and Snapp SS. 2017. Estimating demand for perennial Pigeonpea in Malawi using choice experiments. Ecological Economics, 131: 222–230.

Willey RW and Reddy S. 1981. "A field technique for separating above and below ground interaction for intercropping experiments with pearl millet/groundnut." Experimental Agriculture, vol. 17, pp. 257-264.

Williams HH, MacKenzie K and McCarthy AM. 1992. Parasites as biological indicators of the population biology, migrations, diet, and phylogenetics of fish. *Rev Fish Biol Fisheries* 2, 144–176 (1992).

Yogi RK, Bhattacharya A, Jaiswal AK and Kumar A. 2014. Lac plant resins and gums statistics At a Glance, IINRG Namkum, Ranchi, Jharkhand India. Bulletin no. 07/2015; 01-08.

Yunzheng Z, Yiehou L, Shixiang L and Jifen X. 1980. Preliminary study on population trial on pigeonpea. Developing Status of Lac Production 4; 19–21.

Zhenghong L and Fuji L. 1997. Development prospect on pigeonpea resources for fodder and food. Pages 127–130 in Papers collection of deliberating conference - Industry and Market development of special animals and plants in Yunnan. Kunming, China: Scientific and Technological Publishing House of Yunnan.

Zhenghong Li, Saxena KB, Chaohong Z, Jianyun Z, Yong G, Xuxiao Z and Shiying Y. 2001. Pigeonpea: An excellent host for lac production. International chickpea and pigeonpea Newsletter (8): 58-60.

Appendix-1 Weekly Meteorological data during Kharif-Rabi season, 2019-2020 at Jabalpur (Madhya Pradesh) (May 2019 – June 2020)

SW	Temprature		Sun Shine hrs.	Rainfall (mm)	Relative humidity		Wind Speed	Vapour Pressure (MM)		Evapo (mm)	Rainy days
	T max.	Tmin.			Morning	Evening		Morning	Evening		
19	40.1	21.2	9.7	0.4	47	35	5.5	14.2	17.9	8.9	0
20	39.7	22.2	10.2	0.0	52	43	4.9	15.5	20.2	8.5	0
21	41.8	24.9	10.3	0.0	49	32	5.9	16.8	19.5	10.3	0
22	43.3	26.6	8.3	0.0	51	33	4.6	18.6	21.2	8.8	0
23	44.4	27.3	8.3	0.0	56	33	4.7	19.9	22.0	8.3	0
24	40.9	26.3	7.8	37.5	69	46	5.4	20.9	22.7	7.6	3
25	37.1	25.9	7.2	0.0	73	48	5.9	21.7	21.1	6.8	0
26	36.6	25.1	6.6	29.4	80	59	5.9	22.3	24.2	5.8	2
27	29.9	23.1	1.3	178.8	94	87	5.9	22.5	24.5	2.9	3
28	31.4	25.0	2.6	59.8	82	64	6.9	22.3	22.8	5.0	1
29	34.9	25.0	8.7	24.4	82	59	4.8	22.8	23.7	5.3	2
30	32.3	24.0	3.5	48.0	88	74	4.0	22.9	24.6	3.7	3
31	29.6	23.9	1.5	47.6	93	81	5.1	23.6	24.5	2.5	4
32	29.9	23.5	2.7	210.0	92	81	3.3	23.0	23.8	2.8	4
33	28.6	22.9	2.9	302.1	91	83	3.2	22.4	22.9	1.9	4
34	29.2	22.5	1.4	212.9	97	83	2.1	23.0	23.6	4.9	7
35	30.9	23.4	3.3	57.2	93	75	0.7	23.5	24.5	3.2	4
36	31.6	23.4	3.8	185.0	94	79	1.8	23.9	25.0	4.9	5
37	28.5	23.4	1.2	101.4	93	83	1.9	22.9	23.7	2.5	5
38	31.7	22.7	4.5	53.1	91	78	1.1	22.7	22.5	3.5	3
39	29.5	22.1	2.5	77.6	93	78	1.6	21.4	21.7	2.7	4
40	30.1	21.0	7.2	14.3	90	66	1.1	20.6	20.2	3.0	2
41	30.3	18.0	8.4	0.0	91	56	0.6	17.7	17.9	3.3	0
42	29.2	18.7	5.6	2.2	93	63	0.6	17.9	17.4	2.3	0
43	27.1	19.1	0.9	1.0	92	60	2.0	17.5	16.2	1.8	0
44	30.3	17.7	5.3	0.0	92	52	1.1	17.3	16.5	2.3	0
45	29.6	14.0	6.5	0.0	92	52	1.5	14.3	15.7	2.3	0
46	28.7	10.3	8.7	0.0	92	41	1.4	11.3	11.8	2.3	0
47	28.2	10.5	6.8	0.0	91	48	1.4	11.3	13.2	2.0	0
48	29.1	11.3	6.4	0.0	94	49	1.2	11.8	14.2	1.9	0
49	25.8	8.4	6.8	0.0	90	46	1.6	9.9	11.0	2.0	0
50	24.8	12.1	3.6	12.4	95	70	2.5	12.9	14.7	1.4	2
51	21.0	6.3	5.3	0.0	89	55	2.2	8.9	10.0	1.4	0
52	22.1	6.7	5.9	0.0	87	50	3.0	7.9	9.2	1.8	0
1	20.3	10.3	3.5	17.9	91	62	2.7	10.2	11.1	1.4	2
2	22.0	8.0	7.7	15.8	89	48	2.5	8.7	9.4	2.0	1
3	23.8	11.2	5.9	0.4	89	51	3.0	10.5	10.8	1.8	0
4	24.1	9.1	7.8	0.0	84	44	2.6	8.8	9.6	1.9	0
5	24.2	8.3	7.3	0.0	88	41	3.6	8.7	8.1	2.7	0
6	22.2	7.9	6.6	8.7	85	40	3.5	8.5	8.4	2.3	1
7	26.8	7.5	9.8	0.0	90	32	2.1	8.4	8.2	2.7	0
8	28.8	14.1	6.4	0.0	86	49	3.8	11.7	13.6	3.1	0
9	29.2	12.7	8.3	1.8	87	34	3.1	12.6	10.8	2.7	0
10	28.5	13.1	7.4	0.8	84	45	2.9	13.3	13.9	3.1	0
11	29.9	14.7	7.6	0.5	81	35	2.9	15.0	12.0	3.4	0
12	31.6	16.9	7.2	36.4	69	40	2.4	16.7	15.5	3.2	1
13	34.5	20.4	7.5	0.9	61	33	3.0	18.4	16.1	3.4	0
14	36.8	20.3	7.1	0.0	45	22	3.0	15.4	12.6	4.0	0
15	38.9	21.6	9.4	0.0	37	21	2.6	15.3	12.5	4.6	0
16	38.7	24.5	7.7	0.0	45	23	3.3	18.2	13.8	4.4	0
17	37.9	23.0	7.8	0.0	51	28	3.3	19.3	15.7	4.1	0
18	39.3	24.0	10.0	0.0	50	26	3.2	20.4	15.9	4.7	0
19	39.2	24.6	5.4	0.0	54	29	5.2	18.7	17.0	4.8	0
20	40.1	23.9	8.8	2.3	60	25	4.6	17.1	13.5	5.5	0
21	42.4	24.5	10.5	0.0	40	23	5.0	13.0	14.3	9.3	0
22	39.2	25.2	8.0	1.5	59	42	5.8	18.4	18.5	7.8	0
23	34.2	23.9	6.2	25.8	83	49	5.3	21.3	19.6	4.0	2
24	37.0	25.5	5.1	6.4	80	54	4.1	22.1	22.3	5.3	0

APPENDIX – II

Mean number of live lac insects settlement per 2.5 cm^2 on branch

ANOVA 1: (1st observation 30/12/2019)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	1.2	0.619252	4.15	3.554557	S
Treatment	9	2.0	0.224065	1.50	2.456281	NS
Error	18	2.7	0.149099			
Total	29					

SE(m) ± 0.22 CD at 5% 0.66

ANOVA 2: (2nd observation 15/02/2020)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	1.0	0.475365	2.14	3.554557	NS
Treatment	9	6.5	0.718097	3.23	2.456281	S
Error	18	4.0	0.222287			
Total	29					

SE (m) ± 0.27 CD at 5% 0.81

ANOVA 3: (3rd observation 25/03/2020)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	1.0	0.498136	1.14	3.554557	NS
Treatment	9	3.4	0.381832	0.87	2.456281	NS
Error	18	7.9	0.437025			
Total	29					

SE(m) ± 0.38 CD at 5% 1.13

ANOVA 4: (4th observation 20/04/2020)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	4.0	2.003033	4.53	3.554557	S
Treatment	9	5.8	0.646216	1.46	2.456281	NS
Error	18	8.0	0.442357			
Total	29					

SE(m) ± 0.38 CD at 5% 1.14

ANOVA 5: (5th observation 25/05/2020)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	1.9	0.971069	15.34	3.554557	S
Treatment	9	5.6	0.622953	9.84	2.456281	S
Error	18	1.1	0.063303			
Total	29					

SE(m) ± 0.15 CD at 5% 0.43

Effect of lac insects on the growth of *C. cajan*

ANOVA 6: (1st observation 15/10/2019)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	1435.8	717.9083	4.55	3.554557	S
Treatment	9	2787.4	309.712	1.96	2.456281	NS
Error	18	2839.5	157.7509			
Total	29					

SE(m) ± 7.25 CD at 5% 21.55

ANOVA 7: (2nd observation 20/11/2019)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	1662.1	831.0583	3.49	3.554557	NS
Treatment	9	5813.6	645.9528	2.71	2.456281	S
Error	18	4285.0	238.0583			
Total	29					

SE(m) ± 8.90 CD at 5% 26.46

ANOVA 8: (3rd observation 20/12/2019)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	968.2	484.1083	2.93	3.554557	NS
Treatment	9	7696.1	855.1194	5.17	2.456281	S
Error	18	2974.9	165.275			
Total	29					

SE(m) ± 7.42 CD at 5% 22.05

ANOVA 9: (4thobservation 29/01/2020)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	1603.5	801.7333	3.13	3.554557	NS
Treatment	9	8038.8	893.2046	3.48	2.456281	S
Error	18	4615.5	256.4185			
Total	29					

SE(m) ± 9.24 CD at 5% 27.46

ANOVA 10: (5th observation 01/03/2020)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	1563.3	781.6583	2.99	3.554557	NS
Treatment	9	8026.2	891.7963	3.41	2.456281	S
Error	18	4710.2	261.6769			
Total	29					

SE(m) ± 9.33 CD at 5% 27.74

Effect of lac insect on stem thickness of *C. cajan*

ANOVA 11: (1st observation 18/10/19)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	1.1	0.567656	6.68	3.554557	S
Treatment	9	4.0	0.446851	5.26	2.456281	S
Error	18	1.5	0.084936			
Total	29					

SE(m) ± 0.17 CD at 5% 0.50

ANOVA 12: (2nd observation 20/11/19)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	2.3	1.127836	10.51	3.554557	S
Treatment	9	5.6	0.623478	5.81	2.456281	S
Error	18	1.9	0.107273			
Total	29					

SE(m) ± 0.19 CD at 5% 0.56

ANOVA 13: (3rd observation 27/12/19)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	1.0	0.519876	2.85	3.554557	NS
Treatment	9	7.8	0.862518	4.72	2.456281	S
Error	18	3.3	0.182596			
Total	29					

SE(m) ± 0.25 CD at 5% 0.73

ANOVA 14: (4th observation 25/01/20)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.9	0.451133	1.98	3.554557	NS
Treatment	9	8.5	0.944743	4.14	2.456281	S
Error	18	4.1	0.227961			
Total	29					

SE(m) ± 0.28 CD at 5% 0.82

ANOVA 15: (5th observation 25/02/20)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.7	0.372602	2.07	3.554557	NS
Treatment	9	11.5	1.282328	7.12	2.456281	S
Error	18	3.2	0.180095			
Total	29					

SE(m) ± 0.25 CD at 5% 0.73

Effect of lac insect on primary branches thickness of *C. cajan*

ANOVA 16: (1st observation 18/10/19)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.2	0.11041	7.64	3.554557	S
Treatment	9	0.4	0.046496	3.22	2.456281	S
Error	18	0.3	0.014461			
Total	29					

SE(m) ± 0.07 CD at 5% 0.21

ANOVA 17: (2nd observation 20/11/19)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.1	0.074552	3.42	3.554557	NS
Treatment	9	0.6	0.066685	3.06	2.456281	S
Error	18	0.4	0.021792			
Total	29					

SE(m) ± 0.09 CD at 5% 0.25

ANOVA 18: (3rd observation 27/12/19)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.2	0.1086	2.07	3.554557	NS
Treatment	9	1.0	0.112274	2.14	2.456281	NS
Error	18	0.9	0.052552			
Total	29					

SE(m) ± 0.13 CD at 5% 0.39

ANOVA 19: (4th observation 25/01/20)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.3	0.146131	2.05	3.554557	NS
Treatment	9	1.2	0.134452	1.89	2.456281	NS
Error	18	1.3	0.071291			
Total	29					

SE(m) ± 0.15 CD at 5% 0.46

ANOVA 20: (5th observation 25/02/20)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.3	0.148241	2.04	3.554557	NS
Treatment	9	1.2	0.138091	1.90	2.456281	NS
Error	18	1.3	0.072807			
Total	29					

SE(m) ± 0.16 CD at 5% 0.46

Effect of lac insect on secondary branches thickness of *C. cajan*

ANOVA 21: (1st observation 18/10/19)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.3	0.158613	6.64	3.5545571	S
Treatment	9	0.5	0.051686	2.16	2.4562811	NS
Error	18	0.4	0.023884			
Total	29					

SE(m) ± 0.09 CD at 5% 0.27

ANOVA 22: (2nd observation 20/11/19)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.3	0.145834	6.77	3.554557	S
Treatment	9	1.0	0.116655	5.42	2.456281	S
Error	18	0.4	0.021527			
Total	29					

SE(m) ± 0.08 CD at 5% 0.2

ANOVA 23: (3rd observation 27/12/19)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.2	0.093855	3.86	3.554557	S
Treatment	9	0.9	0.100153	4.12	2.456281	S
Error	18	0.4	0.024304			
Total	29					

SE(m) ± 0.09 CD at 5% 0.27

ANOVA 24: (4th observation 25/01/20)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.2	0.109241	3.21	3.554557	NS
Treatment	9	0.9	0.099964	2.94	2.456281	S
Error	18	0.6	0.034036			
Total	29					

SE(m) ± 0.11 CD at 5% 0.32

ANOVA 25: (5th observation 25/02/20)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.2	0.122665	3.34	3.554557	NS
Treatment	9	0.9	0.101552	2.77	2.456281	S
Error	18	0.7	0.036687			
Total	29					

SE(m) ± 0.11 CD at 5% 0.33

ANOVA 26: Mean weight of 100 seeds during 1st picking with lac insect

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.6	0.303087	1.08	3.738892	NS
Treatment	7	124.2	17.73802	63.08	2.764199	S
Error	14	3.9	0.281198			
Total	23					

SE(m) ± 0.31 CD at 5% 0.93

ANOVA 27: Mean weight of 100 seeds during 1st picking without lac insect

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.0	0.003617	0.10	3.738892	NS
Treatment	7	148.0	21.14763	597.27	2.764199	S
Error	14	0.5	0.035407			
Total	23					

SE(m) ± 0.11 CD at 5% 0.33

ANOVA 28: Mean weight of 100 seeds during 2nd picking with lac insect

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	1.3	0.656191	2.27	3.554557	NS
Treatment	9	164.5	18.27254	63.18	2.456281	S
Error	18	5.2	0.289214			
Total	29					

SE(m) ± 0.31 CD at 5% 0.92

ANOVA 29: Mean weight of 100 seeds during 2nd picking without lac insect

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.1	0.041743	1.16	3.554557	NS
Treatment	9	175.4	19.48899	543.78	2.456281	S
Error	18	0.6	0.03584			
Total	29					

SE(m) ± 0.11 CD at 5% 0.32

ANOVA 30: Mean number of pods per plant during 1st picking

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	73376.1	36688.04	1.37	3.738892	NS
Treatment	7	8840584.0	1262941	47.10	2.764199	S
Error	14	375384.3	26813.16			
Total	23					

SE(m) ± 94.54 CD at 5% 286.76

ANOVA 31: Mean number of pods per plant during 2nd picking

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	1064127.3	532063.6	1.98	3.554557	NS
Treatment	9	170815876	18979542	70.47	2.456281	S
Error	18	4847593.2	269310.7			
Total	29					

SE(m) ± 299.62 CD at 5% 890.21

ANOVA 32: Mean weight of pods per plant during 1st picking)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	32698.4	16349.2	1.19	3.738892	NS
Treatment	7	3332479.2	476068.5	34.60	2.764199	S
Error	14	192607.8	13757.7			
Total	23					

SE(m) ± 67.72 CD at 5% 205.41

ANOVA 33: Mean weight of pods per plant during 2nd picking)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	227185.4	113592.7	1.46	3.554557	NS
Treatment	9	31709541	3523282	45.26	2.456281	S
Error	18	1401238.5	77846.58			
Total	29					

SE(m) ± 161.09 CD at 5% 478.61

ANOVA 34: Mean weight of seed per plant during 1st picking

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	13797.1	6898.573	1.58	3.738892	NS
Treatment	7	475223.6	67889.08	15.56	2.764199	S
Error	14	61077.5	4362.68			
Total	23					

SE(m) ± 38.13 CD at 5% 115.18

ANOVA 35: Mean weight of seed per plant during 2nd picking)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	8484.5	4242.225	0.60	3.554557	NS
Treatment	9	1689266.6	187696.3	26.48	2.456281	S
Error	18	127607.1	7089.281			
Total	29					

SE(m) ± 48.61 CD at 5% 144.43

Mean yield of lac crop per plant on *C. cajan*

ANOVA 36: Mean stick lac length (cm)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	19471.8	9735.925	3.81	3.554557	S
Treatment	9	708453.8	78717.09	30.81	2.456281	S
Error	18	45988.0	2554.888			
Total	29					

SE(m) ± 29.18 CD at 5 % 86.7

ANOVA 37: Mean lac yield (g)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	634.6	317.275	2.03	3.554557	NS
Treatment	9	187418.4	20824.27	133.48	2.456281	S
Error	18	2808.1	156.0065			
Total	29					

SE(m) ± 7.21 CD at 5% 21.43

ANOVA 38: Mean weight of 100 lac cell (g)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.0	0.005281	0.31	3.554557	NS
Treatment	9	2.2	0.242017	14.05	2.456281	S
Error	18	0.3	0.017229			
Total	29					

SE(m) ± 0.08 CD at 5% 0.23

ANOVA 39: Mean weight of lac/2.5 cm^2 slot

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	0.0	0.004323	0.27	3.554557	NS
Treatment	9	1.6	0.177837	11.19	2.456281	S
Error	18	0.3	0.015894			
Total	29					

SE(m) ± 0.07 CD at 5% 0.22

ANOVA 40: Mean weight of fuel wood per plant (g)

SV	DF	SS	MSS	FCAL	FTAB 5%	5%
Replication	2	2.1	1.03283	3.77	3.554557	S
Treatment	9	35.7	3.963111	14.46	2.456281	S
Error	18	4.9	0.274017			
Total	29					

SE(m) ± 0.07 CD at 5% 0.22

CURRICULUM VITAE

Name of the author : Ankit Khichi

Permanent address : Village Doulatpur, Tehsil Icchawar District Sehore M. P.

Date of Birth : 01 March 1994

The author of this thesis Ankit Khichi, s/o Mr. Umashankar Khichi and Mrs. Lokmani Khichi, was born on 1st March 1994 in District Sehore of Madhya Pradesh. He joined the below institutions and successfully completed the degree of M.Sc. (Ag.) during the year 2019-20 with 6.83 OGPA out of 10-point scale.

Institutions	Courses	Year
JNKVV, Jabalpur	M.Sc. (Ag.)	2020
RVSKVV, Gwalior	B.Sc. (Ag.)	2018
School of Excellence Sehore	12th	2012
School of Excellence Sehore	10th	2010

For the partial fulfillment of the Master's degree programme, he was allotted a field research experiment entitled "**Study on the performance of *Rangeeni* lac insect (*Kerria lacca* Kerr.) on tall and long duration genotypes of *Cajanus cajan* (L.) Millsp**." which was successfully completed by him and being submitted in the form of the present thesis.