Research Journal of Agricultural Sciences
Volume 15; Issue 06 (Nov–Dec 2024); pp 1299–1304

Full Length Research Article

ISSN: 0976-1675 (P)
ISSN: 2249-4538 (E)

Impact of Nutrient Management of Host Tree of *Kerria lacca* on Lac Cell Weight

Sangita Basrani*[1], Moni Thomas[2] and Sadhana Kesharwani[3]

[1, 3] Department of Zoology, Government M. H. College of Science and Home Science, Jabalpur - 482 004, Madhya Pradesh, India
[2] Institute of Agri-Business Management, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur - 482 004, Madhya Pradesh, India

Received: 21 Oct 2024; Revised accepted: 02 Dec 2024

Abstract

Nutrient management of host plants of lac insects is an important operation for increasing lac production. The mean weight of lac cell is an important parameter to evaluate the resin production by an individual lac insect. In the two-year (2021-22 and 2022-23) field trial with different combinations of NPK, both basal and foliar applications were carried out in lac grower's field during *katki* cropon *Butea monosperma*. The results revealed that the mean weight (g) of 100 lac cells varied from T_8(3.06g)-Control to T_6 (5.35g)-NPK basal application + three NPK foliar applications. All treatments had significantly higher mean weight (g) of 100 lac cells over T_8(3.06g). However, the mean weight (g) of 100 lac cells in treatments T_1(5.29g), T_5(5.27g), T_2(5.20g), T_3(5.18g) and T_6(5.35g) were at par with each other.

***Key words*:** Nutrition, Lac cell, Lac production, Dry weight, *Butea monosperma*

Plant growth and development depend substantially on the mineral nutrients available in the soil [1]. Plants are immobile [2] and often face difficulties in obtaining an adequate supply of nutrients for their basic cellular processes [3]. Plant growth and crop yield is significantly dependent on the availability of essential nutrients, preferably in well-balanced ratios [4]. Some of those nutrients, known as macronutrients, though, are required in relatively large amounts [5]. Among these macronutrients, Nitrogen (N), Phosphorus (P), and Potassium (K) are three important nutrients that are often added as fertilizers in present crop production [6]. Nitrogen (N), as a macro-element is essential for plant growth and maturation. A deficiency of nutrients results in decreased plant productivity and health [7]. Nitrogen deficiency reduces plant productivity by limiting photosynthesis, shrinking leaf area, and shortening the lifespan of green foliage [8]. Insufficient nitrogen supply reduces cell division and expansion rates [9], hinders photosynthesis, slows leaf production, suppresses tillering [10], and lowers yield [11]. Deficiency of phosphorus causes decline in plants' photosynthetic capacity and growth [12] while potassium deficiency in plants constitutes abiotic stress that triggers a variety of responses leads to reduced growth and productivity [13].

Plant nutrition profoundly influences a plant's susceptibility to insect pests [14]. The availability of nitrogen as a plant nutrient often restricts the performance of phytophagous insects [15]. Nutrients influence plant physiology and chemistry, which in turn affects how attractive or resistant the plant is to herbivorous (phytophagous) insects. Among the various nutrients, nitrogen is particularly important due to its role in the synthesis of amino acids, proteins, and secondary metabolites, which are fundamental to both plant growth and defense. When nitrogen is abundant, plants typically exhibit increased growth rates and higher levels of foliar nitrogen content. This can enhance the nutritional quality of the plant for insect herbivores, potentially improving their performance, reproduction, and population growth. For example, insects feeding on nitrogen-rich plants may experience faster development and greater fecundity due to the higher availability of proteins and other nitrogen-containing compounds essential for their metabolism. For phloem-feeding hemipterans, amino acids in the plant's phloem sap represent their main source of dietary nitrogen [16]. Plants fertilized with potassium alone or in combination with others were significantly infested with moderate numbers of *Bemesia tabaci* [17]. Significantly higher infestation of *Myzus persicae euphorbiae* recorded in plants receiving phosphorus [18].

Indian lac insect, *Kerria lacca* belongs to a distinct group of phyto-succivorous insects that feeds on sugar-rich phloem sap [19-21]. It thrives well only on specific plant species known as lac hosts [22]. Lac insect remains sedentary throughout its life. It does not move once lac insects has penetrated its stylet into the host tissues [23]. The effect of amino acids becomes more pronounce in lac insect due to its sedentary nature [24]. It produces a resinous secretion known as lac [25-26]. It is a natural biodegradable product with diverse applications in commerce and industry [27]. Its production offers substantial potential for generating employment in forest and sub-forest areas, providing opportunities for both men and women [28]. There is a relationship between the insect's nutrition from the host plant and lac insect's secretion [29]. Resin production by *K. lacca* is dependent on quality and quantity of phloem sap of its host [30]. The phloem sap is closely linked to the nutrient status of the plant.

***Correspondence to:** Sangita Basrani, E-mail: sangitabasrani0@gmail.com

Citation: Basrani S, Thomas M, Kesharwani S. 2024. Impact of nutrient management of host tree of *Kerria lacca* on lac cell weight. *Res. Jr. Agril. Sci.* 15(6): 1299-1304.

India is a leading lac producer [31]in the world with the average production of 18,385 tons per year during the last two decades [32]. In India, Chhattisgarh state leads in lac production followed by Jharkhand [33] and Madhya Pradesh [34]. Currently lac is commercially produced on host trees viz. *Butea monosperma*, *Zizyphus mauritiana* and *Schlecheria oleosa*, that naturally occurs in forests, wasteland and field bund [35-36].

Butea monosperma is one of the major lac host plants for *rangeeni* strain of lac insect [37]. About 50 percent of lac produced in India is obtained from the *rangeeni* strain of lac insect [38]. *Butea monosperma* is a hardy tree, thrives in challenging environments like drought-prone, saline, and water-logged soils [39]. It is widely distributed across India [40] including degraded areas. It benefits disadvantaged rural communities, particularly in semi-arid regions. Despite its accessibility, traditional lac production methods often lead to sub-optimal yields. Improved management practices have been needed for *B. monosperma* to enhance lac production, especially in areas promoting natural re-vegetation of degraded land.

MATERIALS AND METHODS

The present two-year study was conducted during the years 2021-22 and 2022-23 in the Village Mediaras to evaluate effect of foliar and basal application of NPK on *B. monosperma* plants for *katki* lac production. The study was planned under RBD, with three replications (Table 1).

Table 1 Details of nutrient application

S. No.	Treatments details
T_1:	NPK basal application + no NPK foliar application
T_2:	One NPK foliar application + no NPK basal application
T_3:	NPK basal application + one NPK foliar application
T_4:	Two NPK foliar applications + no NPK basal application
T_5:	NPK basal application + two NPK foliar applications
T_6:	NPK basal application + three NPK foliar applications
T_7:	Three NPK foliar applications + no NPK basal application
T_8:	No NPK foliar applications+ no NPK basal application

Basal fertilizer application

The process of basal application of fertilizer was done in the month of June during the both years (2021 and 2022). A circular trench around the main trunk of *B. monosperma* with a distance of 3 feet away from the trunk was made by clearing the debris. The basal fertilizer, consisting of 0.5 kg of urea (N), 1 kg of SSP (P), and 1 kg of MoP (K) as per treatment, was mixed well and evenly applied in the trench, followed by covering it with soil. It was naturally irrigated with rain water.

Broodlac inoculation (BLI)

Healthy broodlac, ranging from 200g to 400g, was used for each *B. monosperma* tree, The broodlac quantity used depended upon size [41-43], [36], availability of number and length of succulent branches [30], [44-46] of host tree. It was inoculated on June 30, 2021, and July 7, 2022.

Shifting

The broodlac bundles were carefully shifted to different branches on the same tree 7 to 8 days after inoculation [43]. This was done to ensure efficient use of the broodlac and sufficient spread of lac insects [41], [47].

Phunki removal

The crawling immature lac insects from broodlac settle on the tree within three weeks of its inoculation. Broodlac without larvae is referred to as *phunki* essentially sticklac [35]. *Phunki* usually contains predators. It was removed 21 days after the inoculation of broodlac. In this process, raw lac is also recovered from the *phunki* while removing the predators [41], [48].

Spraying of chemicals

a. *Equipment and items*

The spraying operations were carried out using a power sprayer. The recommended Personal protection essentials (PPE) used consisted of hand gloves, face masks, goggles and soap.

b. *Preparation of spray solutions*

The insecticide solutions were prepared by adding 1g of Cartap hydrochloride (contact insecticide) per litre of water. The spray solution was prepared by brisk stirring the solution to avoid clogging of the nozzle. The NPK (19:19:19) foliar solution was also prepared by mixing 3g of it per litre of water in the power sprayer tank, followed by brisk stirring with a piece of stick.

c. *Spraying*

Foliar application of insecticide and NPK solution were done separately using power sprayer equipped with long lance so as to cover foliage uniformly.

d. *Spraying schedule*

The first spray of the pesticides was conducted after 34 days of BLI in year 2021 and 30 days after BLI in year 2022. The second spray of the pesticides was conducted after 67 days of BLI in year 2021 and 59 days after BLI in year 2022. First foliar application was conducted 15 days before BLI in year 2021 and 22 days before BLI in year 2022. Second foliar application conducted 40 days after BLI in year 2021 and 44 days after BLI in year 2022. Third foliar application was conducted 71 days after BLI in year 2021 and 72 days after BLI in year 2022.

Details of observations

Pre harvest observations

a. *Larval settlement count*

Lac insects were counted within a space measuring 2.5 cm² (with dimensions of 2.5 cm in length and 1.0 cm in width) on the branch [41].

b. *Marking of slot*

Thirty days after the Broodlac Inoculation (BLI), branches with a substantial lac insect settlement were chosen for the marking of slots. Once a lac insect inserts its stylet into the phloem, it becomes sedentary. A slot 1 cm wide and 2.5 cm long was marked on the bark of the branch bearing a significant lac insect settlement. Six such slots, each measuring 2.5 cm², were made on three branches of the earmarked tree i.e. 2 slots/branch. Later, a thread was stretched between the index fingers of both hands, and the lac settlement adjacent to the boundaries of the slot was carefully removed to distinguish the slot from the rest of the lac settlement on the branch [42].

c. *Digital recording*

Lac insect settlements within the slot were digitally photographed using a Digital Single Lens Reflex (DSLR) Canon 90 D camera equipped with an 18-135 mm micro lens. The camera was set to manual mode with ISO 100 and a shutter speed of 160-200 to ensure the best quality images. Multiple pictures of the slot were taken for clarity, and the best shot was selected [48].

d. *Digital counting*

The digital images captured with the DSLR camera were transferred to a laptop or computer using a pen drive. These images were then opened using the Paint 3D program in Microsoft Office 2010 (MS Office 2010).

To facilitate counting, the image on the computer screen was enlarged. The Brush tool in the Paint 3D program's Tool bar (from the Toolbar in the computer) was selected, followed by choosing the desired thickness of the Calligraphy pen, ranging from 1 bx to 18 x, and selecting the contrast colour for the brush tool. By placing the cursor on each individual lac insect within the image of the slot and clicking the left mouse button, a dot of the selected thickness and color was placed on the insect. This process was repeated until all the lac insects in the slot had a dot. The number of dots was counted and recorded, and the image was saved in a designated folder after renaming it for future reference [48].

Post harvest observation

Harvesting of sticklac

At maturity, the sticklac was harvested on 28th Oct 2021 and 2022 for estimation of lac yield.

Scraping of raw lac

After harvesting of sticklac its scraping was done in between 5th and 6th November 2021 and 2022.

RESULTS AND DISCUSSION

Mean dry weight(g) of 100 lac cells

First year (2021-22)

Each female lac insect is represented by a lac cell that it secretes over the body to protect itself. The secretion of resin as a protective covering is a continuous process. It increases with the age of lac insects and the nutrient status of the host tree. As lac cell grows in size, it coalesces with the neighbouring lac cell. Thus, a continuous lac encrustation is formed on the host twig. This is referred as sticklac. The mean dry weight(g) of 100 lac cells varied from 3.12g (T_8) to 5.27g (T_2). All treatments had significantly higher mean dry weight of 100 lac cells over the control (T_8). However, mean weight (g)of 100 lac cells in treatments T_1 (5.20g) - NPK basal application, T_2(5.27g) -one NPK foliar application, T_3 (5.14g) - NPK basal application + one NPK foliar application, T_4 (4.84g) - two NPK foliar applications, T_6 (4.89g) - NPK basal application +three foliar applications and T_5 (4.76g)- NPK basal application + two NPK foliar applications were at par with each other.

Percent increase in mean dry weight of 100 lac cells over the least

Percent increase in mean dry weight of 100 lac cells over the least (T_8) in different treatments ranged from 68.91 to 22.97 percent. It was highest (68.91%) in treatment T_2 followed by T_1 (66.67%), T_3(64.74%), T_6(56.73%), T_4(55.13%), T_5 (52.55%), T_7 (38.78%) and T_8 (22.97%).

Second year (2022-23)

The mean dry weight of 100 lac cells varied from T_8 (3.00g) to T_6 (5.82g). Even in the second year all treatments had a significantly higher mean dry weight of 100 lac cells over the Control (T_8). However, mean dry weight of 100 lac cells in treatments T_6 (5.82g)- NPK basal application +three foliar applications, T_5 (5.77g)-NPK basal application + two NPK foliar applications, T_1 (5.38g) - NPK basal application, T_3 (5.21g) NPK basal application + one NPK foliar application, T_2 (5.12g)- one NPK foliar application, T_7 (4.95g)- three NPK foliar and T_4 (4.38)- Two NPK foliar applications were at par with each other.

Percent increase in mean dry weight of 100 lac cells over the least

Percent increase in mean dry weight of 100 lac cells over the least (T_8) was maximum (94%) in treatment T_6 followed by T_5 (92.33%), T_1 (79.33%), T_3 (73.78%), T_2 (70.67%), T_7 (65%) and T_4 (46.00%).

Pooled data

The two-year pooled data on the mean weight (g) of 100 lac cells varied from T_8 (3.06g) to T_6 (5.35g). All treatments had significantly higher mean weight (g) of 100 lac cells over T_8 (3.06g). However, the mean weight of 100 lac cells in treatments T_1 (5.29g), T_5 (5.27g), T_2 (5.20g), T_3 (5.18g), and T_6 (5.35g) were at par with each other.

Percent increase in mean dry weight(g) of 100 lac cells over the least

Percent increase in mean dry weight (g) of 100 lac cells over the least (T_8) was highest 74.84 percent in treatment T_6 followed by T_1 (72.88%), T_5 (72.22%), T_2 (69.93%), T_3 (69.28%), T_7 (51.63%), and T_4 (50.65%). The analysis of 100 lac cell weight reveals an impact of nutrient accessibility and availability to lac insects. The mean dry weight (g) of 100 lac cells is analyzed to estimate the lac production by individual female lac insect. The weight of 100 lac cell is similar to 100 seed weight of any cultivated crop [48]. Like 100 seed weight of any crop, 100 lac cell weight decides quality and quantity of the lac crop [49].

In the first year, the mean dry weights 100 lac cells in treatments T_1 (5.20g), T_2 (5.27g), T_3 (5.14g), T_4 (4.84g), T_6 (4.89g) and T_5 (4.76g) were at par with each other, indicating that both basal and foliar applications of NPK can effectively enhance lac cell weight. The highest mean weight of 100 lac cells observed in T_2 (5.27g) suggests that a single foliar application may be particularly effective in promoting health status of *B. monosperma* that leads to increased resin production by lac insects. Foliar application of NPK and Fe + Zn increased seed weight in chickpea [50]. Foliar fertilization improved nutrient uptake efficiency in *K. lacca* leading to enhanced 100 lac cell weight [30], [43], [51].

The mean dry weight of 100 lac cells was generally higher in the second year across all treatments. This improvement over the first-year results suggests a cumulative effect of sustained nutrient application on weight of 100 lac cells. It ranged from T_8 (3.06g)-Control to T_6 (5.82g)- NPK basal application + three foliar applications. Treatments T_6 (5.82g) and T_5 (5.77g) showed the highest mean dry weights, indicating that multiple foliar applications, when combined with a basal application, yield more benefits over time. Other treatments, including T_1 (5.38g), T_3 (5.21g), and T_2 (5.12g), also performed well, with results significantly similar to treatments T_6, T_5 and T_4. Basal and foliar application of nutrients increased 100 lac cells weight in *Cajanus cajan* [36].

In the two-year pooled data, the mean weight of 100 lac cells was highest in treatment T_6 (5.35 g)- NPK basal application + three NPK foliar applications followed by T_1 (5.29 g) and T_5 (5.27g). This could be due to improved nutrient availability and uptake by the host plant, leading to better growth and development of the lac insect, ultimately resulting in increased weight of lac cell. The nutritional content of phloem sap, which can be influenced by soil fertility and tree health, directly affects the growth rate and health of the lac insects [35]. Adequate nutrients lead to better cell development and potentially heavier cell weight, which could correlate with healthier and more productive insects. The amount of resin produced by *K. lacca* depends on the host plant and the nutrient levels of those plants [20]. Honeydew secretion by brown plant hopper showed a positive relationship with nitrogen, total free sugars, and soluble protein levels [52].

Table 2 Mean dry weight (g) of 100 lac cells

Treatments	Mean dry weight (g) of 100 lac cells					
	Year 2021-22		Year 2022-23		Pooled data (Year 2021-22 and 2022-23)	
Details	Mean dry weight (g) of 100 lac cells	Percent (%) increase in mean dry weight over the least	Mean dry weight (g) of 100 lac cells	Percent (%) increase in mean dry weight over the least	Mean dry weight (g) of 100 lac cells	Percent (%) increase in mean dry weight over least
T_1: NPK basal application	5.20	66.67	5.38	79.33	5.29	72.88
T_2: One NPK foliar application	5.27	68.91	5.12	70.67	5.20	69.93
T_3: NPK basal application + one NPK foliar application	5.14	64.74	5.21	73.67	5.18	69.28
T_4: Two NPK foliar applications	4.84	55.13	4.38	46	4.61	50.65
T_5: NPK basal application +two NPK foliar applications	4.76	52.56	5.77	92.33	5.27	72.22
T_6: NPK basal application +three foliar applications	4.89	56.73	5.82	94	5.35	74.84
T_7: Three NPK foliar applications	4.33	38.78	4.95	65	4.64	51.63
T_8: No NPK basal application and no NPK foliar application	3.12	--	3.00	--	3.06	--
SEm±	0.24		0.33		.19	
CD 5%	0.73		1.00		0.58	

Significant at 5% level

Previous studies have reported that the mean weight (g) of 100 lac cells varied from 2.24g to 2.54g [41], 1.79g to 3.42g [53], 5.54g to 6.90g [20], 5.18g to 6.30g [54], 3.82g to 5.18g [45], 3.03g to 3.68g [43], 4.66g to 6.33g [50] and 4.95g to 8.21g [30].

CONCLUSION

The study highlights the fact that nutrient management of the host plants leads to higher resin production by the lac insects. Both NPK (nitrogen, phosphorus and potassium) foliar and basal application improve plant health. Lac insects feed on phloem sap of host plant that subsequently increases the quality and quantity of resin produced by lac insects. The outcome recommends the nutrient management of host trees of lac insects.

Acknowledgement

The authors express their gratitude to Shri Ram Niranjan Patel, Shri Narmada Patel and Shri Rohit Pasi of Mediaras village for their support and cooperation.

LITERATURE CITED

1. Kudoyarova GR, Dodd IC, Veselov DS, Rothwell SA, Veselov SY. 2015. Common and specific responses to availability of mineral nutrients and water. *Jr. Exp. Botany* 66(8): 2133-2144.

2.Gull A, Lone AA, Wani NUI. 2019. Biotic and abiotic stresses in plants. *In*: (Eds) de Oliveira AB. Abiotic and Biotic Stress in Plants. IntechOpen.

3. Morgan JB, Connolly EL. 2013. Plant-soil interactions: Nutrient uptake. *Nature Education Knowledge* 4(8): 2.

4. Hafiz FB, von Tucher S, Rozhon W. 2022. Plant nutrition: Physiological and metabolic responses, molecular mechanisms and chromatin modifications. *Int. Jr. Mol. Science* 23(8): 4084.

5. Finkl CW Jr. 1979. Macronutrients. *In*: (Eds) Finkl, C.W. Jr. *The Encyclopedia of Soil Science*. New York: Van Nostrand Reinhold. pp 274-276.

6. Kulcheski FR, Côrrea R, Gomes IA, de Lima JC, Margis R. 2015. NPK macronutrients and microRNA homeostasis. *Front Plant Science* 6: 451.

7.McCauley A, Jones C, Jacobsen J. 2011. *Plant Nutrient Functions and Deficiency and Toxicity Symptoms*. Nutrient Management Module No. 9. Montana State University Extension Publications**.**

8.Mu X, Chen Y. 2021.The physiological response of photosynthesis to nitrogen deficiency. *Plant Physiology and Biochemistry* 158: 76-82.

9. Roggatz U,Mcdonald AJS, Stadenberg I, Schurr U. 1999. Effects of nitrogen deprivation on cell division and expansion in leaves of *Ricinus communis* L. *Plant, Cell and Environment* 22: 81-89.

10. Gerik TJ, Oosterhuis DM, Torbert HA. 1998. Managing cotton nitrogen supply. *Advances in Agronomy* 64: 115-147.

11. Zhao D, Reddy KR, Kakani VG, Read JJ, Koti S. 2007. Canopy reflectance in cotton for growth assessment and prediction of lint yield. *European Journal of Agronomy* 26: 335-344.
12. Neocleous D, Savvas D. 2019. The effects of phosphorus supply limitation on photosynthesis, biomass production, nutritional quality, and mineral nutrition in lettuce grown in a recirculating nutrient solution. *Scientia Horticulturae* 252: 379-387.
13. Hafsi C, Debez A, Abdelly C. 2014. Potassium deficiency in plants: effects and signaling cascades. *Acta Physiol. Plantarum* 36: 1055-1070.
14. Singh V, Sood AK. 2017. Plant nutrition: A tool for the management of hemipteran insect-pests- A review. *Agriculture Review* 38: 260-270.
15. Douglas AE. 2006. Phloem-sap feeding by animals: problems and solutions. *Journal of Experimental Botany* 57: 747-754.
16. Douglas AE. 1993. The nutritional quality of phloem sap utilized by natural aphid populations. *Ecological Entomology* 18(1): 31-38.
17. El-Rafie KK.1999. Effect of different rates of (N, P, K) fertilizers on *Bemisia tabaci* (Genn.) infestation on tomato and its effect on the yield. *Egyptian Journal of Agricultural Research* 77(3): 1067-1073.
18. Omar HIH, Haydar MF, Afifi FML.1993. Effect of N P K and their combinations as soil fertilizers on tomato infestation with certain insects. *Egyptian Journal of Agricultural Research* 71(1): 195-205.
19. Ahmad A, Kaushik S, Ramamurthy VV, Lakhanpaul S, Ramani R, Sharma KK, Vidyarthi AS. 2012. Mouthparts and stylet penetration of the lac insect *Kerria lacca* (Kerr) (Hemiptera:Tachardiidae). *Arthropod Structure and Development* 41(5): 435-441.
20. Shah TH, Thomas M, Bhandari R. 2014.Impact of nutrient management in *Zizyphus mauritiana* (Lamb.) on the survivability of lac insect and the yield of *Aghani* crop of *Kusmi* lac. *India Journal of Entomology and Zoology Studies* 2(5): 160-163.
21. Shamim G, Pandey DM, Sharma KK, Ramani R. 2016. Genes Involved in the biosynthesis of lac dye constituents in Indian lac insect, *Kerria lacca* (Kerr). *Jr. Entomol. Res. Society* 8: 7-17.
22. Kumar, KK, Ramani R, Sharma KK. 2002. *Recent Advances in Lac Culture*. ILRI, Namkum, Ranchi. pp 290.
23. Anjana G, Thomas M, Patel SK, Kurmi S, Pahalwan DK, Bhan M, Bajpai A, Singh AK. 2023. Impact of irrigation levels and plant density of annual lac insect host plant *Cajanus cajan* (L.) Millsp. on the survival of *Kerria lacca* Kerr. *Biological Forum – An International Journal* 15(10): 554-561.
24. Khichi A, Thomas M, Kakade S, Patil DB, Raut V, Tripathi N, Saxena AK, Upadhyay A, Sharma HL. 2021. Survival of lac insects on Pigeon pea genotypes. *International Journal of Current Microbiology and Applied Sciences* 10(2): 1465-1475.
25. Sharma KK. 2017. Lac insects and host plants. *In*: (Eds) Omkar. Industrial Entomology. Springer, Singapore. pp 157-180.
26. Kaushik SP, 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* 6: 32-38.
27. Singh D, Chandrakar MR, Gauraha AK, Choudhary VK, Kumar S. 2021. An economic analysis of lac: A case study of Radha self-help group of Kanker district. *The Pharma Innovation Journal* 10(8S): 363-366.
28. Gupta RK, Ganai SA, Bali K. 2020. Current status, critical gaps and way forward for lac production in J&K. *Journal of Entomology and Zoology Studies* 8(5): 1658-1661.
29. Kaushik S, Vashishtha A, Shweta S. 2020. Essential amino acid profiling of the four lac hosts belonging to genus *Flemingia*: its implications on lac productivity. *Physiology Mol. Biol Plants* 26: 1867-1874.
30 Kumar S, Thomas M, Lal N, Virendra, Markam VK. 2017. Effect of nutrition in Palas (*Butea monosperma* Lam.) on the survivability of lac insect. *The Pharma Innovation Journal* 6(8): 320-324.
31.Shah TH, Thomas M, Bhandari R. 2015. Lac production, constraints and management: A review. *International Journal of Current Research* 7(3): 13652-13659.
32. Thombare N, Kumar S, Kumari U, Sakare P, Yogi RK, Prasad N, Sharma KK. 2022.Shellac as a multifunctional biopolymer: A review on properties, applications and future potential. *Int. Jr. Biol. Macromology* 215: 203-223.
33. Khobragade D, Thomas M, Pachori R, Sharma JL, Shrivastava A. 2012. Farmer participatory trial on the predator management of Lac insect *K. lawwi* (Kerr) in Anuppur District, Madhya Pradesh. *Journal of Tropical Forestry* 28(1/2): 38-45.
34. Jaiswal AK, Pal G, Singh JP, Patel B. 2013. Growth analysis of lac production in Madhya Pradesh. *Indian Forester* 139(5): 448-452.
35. Dehariya N, Thomas M, Pateria, K, Solanki R. 2022. Survival of *Kerria lacca* (Kerr) on pigeon pea. *Journal of Entomology and Zoology Studies* 10(3): 141-144.
36. Kakade S, Patidar R, Vajpayee S, Thomas M, Tripathi N, Bhowmick A. 2020. Survival of lac insects *Kerria lacca* (Kerr.) on *Cajanus cajan* (L) Millsp. *Int. Jr. Curr. Microbiol. App. Science* 12: 173-182.
37. Kapur AP. 1962. The lac insect. *In* (Eds): A monograph on lac, B. Mukhopadhyay and M. S. Muthana. ILRI, Ranchi. pp 67.
38. Pal G, Jaiswal AK, Bhattacharya A. 2011. Lac statistics at a glance 2010. Technical Bulletin No. 01/2011, Indian Institute of Natural Resins and Gums, Ranchi. pp 1-24.
39. Fageria D, Rao DV. 2015. A Review on *Butea monosperma* (Lam.) kuntze: A great therapeutic valuable leguminous plant. *International Journal of Scientific and Research Publications* 5(6): 1-9.
40.Sindhia VR, Bairwa R. 2010. Plant review: *Butea monosperma*. *International Journal of Pharmaceutical and Clinical Research* 2(2): 90-94.
41. Janghel S. 2013. Study on comparative efficacy of insecticides in *Katki* crop for predator management on *Rangeeni* lac crop on *Zizyphus mauritiana* in Malara village, Seoni District. *M. Sc. (Agriculture) Thesis*, submitted in JNKVV. Jabalpur, M.P.
42. Namdev BK. 2014. Study on the performance of *Aghani* crop of *Kusmi* lac on nutrient managed *Zizyphus mauritiana* under heavy rainfall condition. *M. Sc. (Agriculture) Thesis*, submitted in JNKVV, Jabalpur, M.P.
43. Sharma H, Ghugal SG, Gurjar R, Thomas M, Rajawat BS. 2015. Performance of *Kerria lacca* (Kerr) in response to foliar application of nutrients on *Butea monosperma*. *An International Quarterly Journal of Environmental Sciences* 8: 355-359.
44. Sahu S. 2016. Survival and yield of *Rangeeni* Lac insect on *Buteamonosperma* (Lam) treated with different micronutrients and humic acid. *M. Sc. (Agriculture) Thesis*, submitted, JNKVV, Jabalpur, M.P.

45. Ghugal SG, Thomas M, Pachori R. 2015. Performance of *katki* lac on nutrient managed of *Butea monosperma* (Lam.) Taub. *Trends in Biosciences* 8(24): 6873-6877.
46. Thomas M, Sharma P, Vishwakarma N, Shukla R, Singh DK, Nayak S, Sharma DP. 2018. Environmental and economic benefits accrued by tribal women in Jabalpur district of Madhya Pradesh through *Rangeeni* lac production on *Buteamonosperma*. *Journal of Tropical Forestry* 34(3): 31-40.
47. Kunal R. 2013. Study on Predator surveillance and its management on *Rangeeni* lac in Barghat block district Seoni Madhya Pradesh. *M. Sc. (Agriculture) Thesis*, submitted in JNKVV, Jabalpur. M.P.
48. Vajpayee S, Patidar R, Kakade S, Thomas M, Tripathi N, Bhowmick AK, Gontia AS, Kulhare PS, Sharma HL. 2019. Effect of population density of *Kerria lacca* Kerr. on its growth and survival. *International Journal of Current Microbiology and Applied Sciences* 8(12): 912-924.
49. Shah TH, Mushtaq R, Thomas M. 2018. Impact of nutrient management in *Zizyphus mauritiana* (Lamb.) on the weight of lac cells. *Int. Jr. Adv. Res. Sci. Engineering* 7(4): 2030-2036.
50. Drostkar E, Talebi R, Kanouni H. 2016. Foliar application of Fe, Zn and NPK nano-fertilizers on seed yield and morphological traits in chickpea under rainfed condition. *Journal of Research in Ecology* 4(2): 221-228.
51. Gurjar R. 2016. Study on the effect of foliar application of nitrogen and PGR on *Butea monosperma* on *Katki* crop production. *M. Sc. (Agriculture) Thesis*, JNKVV, Jabalpur, M.P.
52. Rashid MM, Jahan M, Islam KS. 2016. Impact of nitrogen, phosphorus and potassium on brown planthopper and tolerance of its host rice plants. *Rice Science* 23(3): 119-131.
53. Patel B. 2013.Comparative performance of *Kusmi* and *Rangeeni* lac on Ber, *Zizyphus mauritiana* at Kanchana village Barghat Block, Seoni district, M. P. *M. Sc. (Agriculture) Thesis*, submitted in JNKVV, Jabalpur, M.P.
54. Namdev BK, Thomas M, Kurmi A, Thakur AS, Upadhyaya A. 2015. Impact of nutrient management of *Zizyphus mauritiana* (Lamb.) on the yield of *kusmi* lac. *The Bioscan* 10(3): 1219-1222.