International Journal of Environment and Climate Change

Volume 12, Issue 12, Page 1582-1599, 2022; Article no.IJECC.95664
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Threat to the Sustainable Production of Natural Resins: A Case of *Rangeeni* Strain of *Kerria lacca* (Kerr) in Eastern Plateau & Hills Region of South East Asia

R. K. Yogi [a*], Govind Pal [a], Alok Kumar [a], A. K. Singh [a], Nirmal Kumar [a] and K. K. Sharma [a]

[a] *Indian Council of Agricultural Research (ICAR), New Delhi, India.*

Authors' contributions

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

Article Information

DOI: 10.9734/IJECC/2022/v12i121601

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/95664

Policy Article

Received: 25/10/2022
Accepted: 30/12/2022
Published: 31/12/2022

ABSTRACT

The study conducted to examine the trends, growth and instability in the production of an insect-based natural resin in India. Study is designed with sampling and Focused Group Discussions (FGDs) based primary data as well as secondary data. District-level time-series data of Jharkhand state for 50 years from 1970-71 to 2019-20 was used. Time series analysis revealed the variation in lac production levels in different levels of geo coordinates. Compound Annual Growth Rate (CAGR) was worked out by fitting the exponential function. The instability indices worked out by using the method suggested by Cuddy and Dell. The growth in lac production and export of lac-based value-added products has decelerated in the post-liberalization period, while yield growth has accelerated.

**Corresponding author: E-mail: yogindri@gmail.com;*

The overall decline in the production level of *rangeeni* crop ranged from -5.54% in Western Plateau Sub Zone V to -6.98% in South Eastern Plateau Sub Zone VI. Utilization of the existing natural endowment of *Butea monosperma* in major *rangeeni* lac-producing districts in Western Plateau Sub Zone V could be a promising strategy to minimize the variation in the production of *rangeeni* crop. A paradigm shifts from *rangeeni* lac cultivation during previous decades coupled with climate change issues may be another possible reason for the regional disparity in the level of *rangeeni* lac production.

The overall scenario in Jharkhand state depicts the alarming situation for *katki* crop (Rainy season *rangeeni* crop) having the highest instability index (49.69), particularly with significant negative growth rates from 2000 to 2020. The magnitude of decline for *katki* crop was found highest and most significant during the 2001-2010 period. Although, the production of *rangeeni* strain was affected adversely in Jharkhand (-21.60%) during the Ninth Five Year Plan coupled with shifting from *rangeeni* to *kusmi* lac cultivation due to boosting through capacity building and skill development programs which influenced the awareness and knowledge level of the stakeholders. However, COVID-19 could break the momentum, and functionaries including the institutions and facilitators shifted to manage the disrupted supply chains during 2019-20 and 2020-21. Post COVID-19 scenario, emerged with new ICT-enabled interventions with greater scope for extension and awareness programs. However, there is a huge technological gap in the existing lac industry with poor automation and dependency on local labor. Policy interventions including market initiatives like Minimum Support Prices (MSP), *Van Dhan Vikas Kendras* (VDVKs); and Institutional initiatives like FPOs, SHGs, JLGs, *etc*. may play a key role in strengthening the sector. New host plants like *Flemingia semialata* may be promoted to reduce instability indices in the long run.

Keywords: Growth; instability index; non-wood forest products; time series analysis.

1. INTRODUCTION

Non-Wood Forest Products (NWFPs) play a major role in the livelihood of tribal farmers' incomes mainly due to their presence in the vicinity of the tribal community habitation and greater economic value. In Jharkhand, forest dwellers inoculate tiny insects on natural host trees for cultivation to meet the cash requirement during the lean periods. Tree species in the agro-forestry system are very important and vital for lac cultivation. It reflects the choice of farmers and in some sense demand of the market. Rich biodiversity across the Agro-forestry Systems of India supports about 49.2 crores of *palas* (*Butea monosperma),* 4.5 crores of *ber* (*Ziziphus mauritiana)*, and about 3.7 crores of *Kusum (Schleichera oleosa)* as the major lac host trees which comprises about 3% of the total number of available trees [1].

Lac insects are the sole animal species that produce natural resin. Out of 29 lac insect species found worldwide, 24 species are found in India [2]. India is the largest supplier of animal-based naturally secreted resin in the World. The Indian lac insect, *Kerria lacca* (Kerr) is industrially important because of its resin and pigment synthesizing capacity. Lac insects are phytophagous, sedentary almost throughout life, and depend on phloem sap which is a nutritionally imbalanced diet [3]. Their life stages are morphologically and physiologically highly diverse. Besides, their resin production potential also varies with different stages; crawlers and adult males do not secrete resin whereas, settlers and adult females after fertilization secrete resin albeit in different quantities [4]. This resin and pigment as a raw material meet more than 60% of the global demand for lac and its value-added products. The products of lac insects (lac resin, lac dye, and lac wax) find humongous applications in different industries including food, pharmaceutical, textile, surface coating, cosmetics, electrical industries, *etc*. [5]. From the beginning of the 21st century, due to increasing demand for natural products, a paradigm shift in the scope and applications of shellac has been witnessed, especially in green electronics, 3D printing, stealth technology, intelligent sensors, food and pharmaceutical industries [6]. Understanding the production and trade scenario is highly essential to devise future strategies for the sustainable production of natural resins for industrial application. In this context, it is imperative to examine the time series production data. The study examined the growth, instability index, and structural change in production as well as the overseas trade scenario of lac and its value-added products from India. Time-series data for 50 years from 1970-71 to 2019-20 was used [7].

This study explores the comparative analysis including decadal and quinquennial for the production of various strains of natural resin and export of value-added products to estimate the compound annual growth rates and instability indices for the period of 1970-71 to 2019-20. The models considered in the analysis are linear, logarithmic model, quadratic, compound, and power model. Durbin Watson test, Shapiro-Wilk's test, and park's test have been used for testing error assumptions. Based on the significance of the parametric coefficient, residual diagnostics, and the model fit statistics, the best fit model has been selected for the estimation of the growth rate. Instability is an important characteristic of agriculture in general and tribal agricultural practices including NWFP production/collection. It is caused by several factors-natural (*i.e.* abrupt changes in rainfall and temperature as well as species of lac hosts) and man-made (*i.e.* domestic & overseas demand, technological change, quantity, and quality of inputs including *brood lac*, pesticides, tools, *etc*). Widespread use of modern inputs such as improved seeds, agrochemicals and irrigation, and agronomic practices can potentially reduce instability in agricultural growth caused by changes in weather conditions, insect pests, and diseases [8]. Lac production is known to be affected by weather conditions like rainfall, temperature, the occurrence of hail, the frost as well as the incidence of pests [9].

Production is also affected by unstable demand due to the availability of alternate resins and fluctuating price [10]. In a study conducted in 1993, the result showed that the country registered a negative growth rate (3.55%) and instability in lac production to the extent of 42% during 1960-61 to 1989-90 [11]. Significant variation in growth rate and instability was observed from state to state and crop to crop. This study focus on two main questions: Has lac production growth in Jharkhand been accompanied by an increase in instability? Does the magnitude of instability vary across crops and regions, and what are the reasons behind it?

2. RESEARCH METHODOLOGY

The Eastern Plateau & Hills Region of India comprising 63 districts of six states including Jharkhand Chhattisgarh, Odisha, Madhya Pradesh, Maharashtra, and West Bengal contributes more than 95% of lac production in India [12]. This Agro climatic region with natural resource endowment and suitable climatic conditions enabled the community to supply lac-based quality natural products for domestic as well as the international market for a long time. It is evident from the export of lac and its value-added products from India during 20th and 21st Century, the peak level supply of 42368 tons in 1936-37 to the lowest level of 4361.30 tons only in 2012-13, but with the highest foreign exchange earnings of US$ 88.23 million in the history of international trade of this natural resin of animal origin. Current lac production estimates revealed that only less than 10% of lac host trees are being utilized for lac cultivation. It is assumed that some bottlenecks are hampering the growth of the lac sector [13,14]. As the Jharkhand state was identified for the study as it has about 50% share in total lac production in India. Agro-Climatic Zone (ACZ) namely Eastern Plateau & Hills Region-VII is characterized by Rainfed agriculture, Moisture stress, drought and Soil acidity, Iron toxicity, low SRRs, non-availability of electricity, high population growth, poor road, poor Input delivery, and communication infrastructure. In this context, lac cultivation becomes an important means of livelihood security among the tribal communities. The identified state of Jharkhand comprised three Agro-climatic sub-zones briefed in Appendix 1.

The study is mainly based on the primary data maintained as the database at NRG Information Cell, ICAR-IINRG Ranchi. Secondary data on the export of lac and its value-added products from India have been collected from the Directorate General of Commercial Intelligence and Statistics (DGCI&S), Kolkata, Ministry of Commerce & Industry, DGFT, and Indiastat.com. The data have been collected for 50 years spanning from 1970-71 to 2019-20. A series of Focus Group Discussions (FGDs) were also conducted among the stakeholders for better understanding the bottlenecks at grassroots levels. Statistical tools like growth rate and percentages were used for analysis. The Compound Annual Growth Rate (CAGR) in the production of lac was worked out by fitting the exponential function given below (Equation 1):

$$Y = ab^t \qquad \text{Equation 1}$$

where,

Y = The dependent variable (export)
a = Constant term
b = Regression coefficient
t = Time variable in years

The equation can be rewritten in the logarithmic form as follows (Equation 2)

$$\log Yt = \log a + t \log b \quad \text{Equation 2}$$

where,

Y_t = production of lac in t^{th} year
We can, thus, calculate the compound growth rates (r) as under (Equation 3)

$$r = \text{Antilog}(\log b - 1) * 100 \quad \text{Equation 3}$$

where,

r = Compound growth rate per annum (%)
b = Regression coefficient

The coefficient of variation (CV) often contains the trend component and thus overestimates the level of instability in time series data characterized by long-term trends. To overcome this problem, this study used the instability index given by Cuddy and Dell in 1978 which corrects the co-efficient of variation which is used as a measure of variability in time-series data [15-18]. The instability index was estimated by using the equation given below in equation *4*:

$$\text{Instablity Index} = CV\sqrt{1 - R^2} \quad \text{Equation 4}$$

where,

CV = simple estimate of the coefficient of variation in %,
R^2 = is the coefficient of determination of the trend equation adjusted for the number of degrees of freedom.

The future lac production scenario is projected based on the linear trend equation of time series data. Trend equation is given as under in equation 5:

$$Y = a + bt \quad \text{Equation 5}$$

where in,

'Y' is lac production and 't' is the time.

To determine whether the difference in instability (CV) between sub-periods is statistically significant or not, we follow Anderson and Hazell [19], where a standard normal Z-statistic is estimated as illustrated in equation *6*:

$$Z - \text{Statistics} = \frac{(CV_2 - CV_1)}{D} \quad \text{Equation 6}$$

where,

CV_1 and CV_2 are the coefficients of variations in lac production at the district and state levels, respectively. D is defined as equation 7:

$$D = \frac{\sqrt{\left(\frac{1+2c^2}{2}\right)\left(\frac{1}{n^1}+\frac{1}{n^2}\right)}}{CV} \quad \text{Equation 7}$$

where,

CV is the coefficient of variation in All India lac production over the time
CV_1 and CV_2 are the coefficients of variations in lac production at the district and state levels, respectively.

The number of observations for the state as well as district levels is indicated as n_1 and n_2, respectively. We have approximated c by CV_1 following Anderson and Hazell.

3. RESULTS

Recent trends in the sector: According to Census 2011, a total of 3.3 crore population of the state comprises 76% of the rural population. About 26% populations belong to the tribal community and about 80 lakhs (91%) of the tribal inhabit rural areas. In the state, more than 75% population residing in rural areas is the target group and out of this about 31% are tribal [20,2]). An empirical exploration of socioeconomic determinants in the state by Singh, et al. [22] and the World Bank Report [23] revealed the magnitude of gaps. About 20 to 28% of sampled households were possessed host trees but not involved in lac cultivation and about 35 to 59% of households are using less than 50% of the available host trees [24]. Anthropological studies about the tribal indicate that their needs are comparatively lesser and differ in terms of choice [25]. Migration problem is also observed in these areas [26]. Consequently, the adoption rate is low and generally they are not early adopters [27]. Be that as it may, Corbridge's work should be read as a structural account of the Jharkhand movement's lack of political traction over the years rather than as evidence for the historical dissolution of core *Adivasi* concerns relating to *'Jal, Jungle, Zameen* (water, forests, and land). Corbridge is careful to point out that the reservations 'has not brought a tribal middle class into existence; rather it has been captured by a pre-existing tribal elite', which is predominantly male and many of whom originate in urban areas [28]. The interplay of economic potential and socio-political vulnerability in

Jharkhand has already seen dramatic developments [29]. Islam et al. [30], and Kumar & Choudhury [31] highlighted the livelihood contributions of forest resources to the tribal communities of Jharkhand. Magry et al. [32] in their study in Jharkhand found lac being mostly a subsidiary occupation however providing much-needed cash income in low agriculture activity seasons. A priority based policy intervention advocated well by Yogi et al. [33].

Based on a survey in the local weekly markets of different lac-producing districts, the estimated national production of sticklac during 2019-20 was approximately 18,944 tons comprising *rangeeni* (6050 tons) and *kusmi* (12894 tons) sticklac. Among the lac-growing states, Jharkhand state ranks 1st (54.60%) followed by Chhattisgarh (18.37%), Madhya Pradesh (13.03%), West Bengal (5.57%), Maharashtra (4.50%), and Odisha (3.55%). These six states contribute more than 99 % of the total lac production in India. Among the different cropping season crops, *aghani* crop was ranked 1st with a contribution of 36.48 % followed by *jethwi* (31.58 %), *baisakhi* (17.58 %), and *katki* (14.36 %) in total lac production. In comparison to the average production during 2010-11 to 2019-20, the current year (2019-20) production of *ranggeni* crop declined by 9.24% while the production of *kusmi* crop enhanced by 23.11%, respectively. The increase in production was comprised of 13.64 % and 32.68 % for the *jethwi* and *aghani* crops, respectively. However, a decrease of 13.14% and 3.96% was observed in the case of *baisakhi* and *katki* crops, respectively. Overall, the total lac production for the year 2019-20 has increased by about 3.28 % in comparison to the average production. All India's annual lac production ranged from 15,000 to 20,000 during 1970-71 to 2019-20 with a peak level of 23,000 tons in 1972-73 and the lowest level of 9,000 tons in 2010-11. Similarly, Jharkhand state contributed about 7000 to 12000 tons annually during 1970-71 to 2019-20 with a peak level of 16,000 tons in 1973-74 and the lowest level of 4,000 tons in 2010-11. The variation in the production of lac at the National as well as state level shows temporal impact coupled with the biotic and abiotic stress conditions. Natural enemies of lac insects include pathogens, parasites, and predators. Based on the Focus Group Discussions (FGDs), it has been indicated that about 30% yield losses can be avoided by checking the growth of the microorganisms. Predators (*Eublema amabilis and Psudohypatopa pulverea)* and parasites are the major natural enemies of lac insects causing about 30-40% crop loss on average [34-36]. *Chrysopa spp.* is a sporadic pest and sometimes causes significant mortality [37], in which *Chrysopa lecciperda and Chrysopa medestes* are the most prevalent in the lac ecosystem which causes considerable damage, especially to the winter season (*aghani*) *kusmi* lac crop [38]. Studies on the extent and nature of damage caused by parasitoids pertain mostly to extent of parasitization, and the seasonal and relative abundance of parasites associated with lac insects [39- 41]. Abiotic factors including climate and the extent of forward and backward linkages influenced lac production in India. Significant fall in lac production during 2010-11 was due to climatic factors and the declining trend from 2014-15 to 2017-18 was due to poor forward and backward linkages.

Major lac-producing districts namely Ranchi, Khunti, Gumla, Simdega, West Singhbum, and Palamu showed less variance compared to the minor lac-producing districts of Jharkhand state. Statistical analysis revealed a significant variation over time across minor lac-producing districts namely Bokaro, Chatra, Dhanbad, Deoghar, Dumka, Giridih, East Singhbhum, Garhwa, Hazaribag, Jamtara, Latehar, Lohardaga, and Saraikela Kharsanwa. Overall, state-level, as well as national-level lac production, was sustained over the period of 1970-71 to 2019-20 (Table 1). Onwards 1990-91, there was a significant enhancement in the export unit value of the lac and its value-added products in comparison to the Consumer Price Index (CPI). It indicates the technological breakthrough in the processing and value-addition industry which improved the earnings of foreign exchange reserves significantly.

Growth Analysis: A detailed time series analysis revealed that the production level of *rangeeni* strain at the national as well as regional levels declined over time (Table *2*). In Central and North Eastern Plateau Sub *Zone IV* production level of *baisakhi* crop (Summer season *rangeeni* crop) improved over time in Dhanbad (1.77%), Dumka (3.29%), Giridih (5.43%), and Jamtara (0.89%) districts. However, the production level of lac in Bokaro (-15.83%), Deoghar (-6.30%), Hazaribagh (-16.44%), and Ranchi (-6.89%) including Khunti declined. The District wise Compound Annual Growth Rate (CAGR) of *baisakhi* crop of Indian Lac (*Kerria lacca* Kerr) during 1970-71 to 2020-21 is illustrated in Fig.1.

Similarly, the production level of *katki* crop of *rangeeni* lac (rainy season crop) improved over time in Dhanbad (17.12%), Deoghar (2.90%), Dumka (9.25%), Giridih (2.82%), and Jamtara (3.04%) districts. However, the production level of *katki* lac in Bokaro (-4.93%), Hazaribagh (-17.52%), and Ranchi (-3.92%) including Khunti declined. Overall, the production level of *rangeeni* strain improved over the time in Dhanbad (7.10%), Dumka (11.04%), Giridih (5.52%) and Jamtara (1.61%) districts. However, the production level of lac in Bokaro (-10.33%), Deoghar (-2.88%), Hazaribagh (-15.24%) and Ranchi (-6.06%) including Khunti declined. Godda, Koderma, Pakur, Ramgarh & Sahebganj districts were minor lac-producing areas in this Zone. Few district-level data were missing and extrapolated.

The District wise Compound Annual Growth Rate (CAGR) of *katki* crop of Indian Lac (*Kerria lacca* Kerr) during 1970-71 to 2020-21 is illustrated in Fig. *2*.

In Western Plateau, Sub Zone V production level of *Baisakhi* crop (Summer season *rangeeni* crop) improved over time in Chatra (1.84%), Garhwa (7.64%), Gumla (8.22%) Latehar (17.50) and Simdega (17.17%) districts. However, the level of lac production in Lohardaga (-7.12%) and Palamau (-9.97%) declined. Similarly, the production level of *Katki* crop of *rangeeni* lac (rainy season crop) improved over time in Chatra (17.64%), Garhwa (11.21%), Gumla (8.33%), Latehar (17.32), and Simdega (17.17%) districts. However, the production level of *katki* lac in Lohardaga (-3.88%) and Palamau (-5.83%) declined. Overall, the production level of *rangeeni* strain improved over time in Chatra (6.22%), Garhwa (8.03%), Gumla (9.31%), Latehar (18.64), and Simdega (19.86%) districts. However, the production level of lac in Lohardaga (-2.84%) and Palamau (-8.51%) declined. The District wise Compound Annual Growth Rate (CAGR) of *rangeeni* crop of Indian Lac (*Kerria lacca* Kerr) during 1970-71 to 2020-21 is illustrated in Fig. 3.

In South Eastern Plateau Sub Zone VI production level of *Baisakhi* crop (Summer season *rangeeni* crop) improved over time in Saraikela (6.20%) and West Singhbhum (8.42%) districts. However, the level of lac production in East Singhbhum (-29.56%) declined. Other areas of this zone have shown an increasing trend over time. Similarly, the production level of *Katki* crop of *rangeeni* lac (rainy season crop) improved over time in Saraikela (21.45%) and West Singhbhum (6.59%) districts. However, the production level of *katki* lac in East Singhbhum (-23.19%) declined. Overall, the production level of *rangeeni* strain improved over time in Saraikela (8.38%) and West Singhbhum (7.96%), and other minor areas (9.27%) districts. However, the level of lac production in East Singhbhum (-24.58%) declined significantly.

4. DISCUSSION

As depicted in Table 2, the magnitude of the decline in the production level of the summer season crop of *rangeeni* lac was found higher in South Eastern Plateau Sub Zone VI (-7.62%) comparatively to the Western Plateau Sub Zone V (-7.11%). It was comparatively lower in the Central and North Eastern Plateau Sub *Zone IV* (-6.49%). Similarly, a decline in the production level of rainy season *rangeeni* crops was also found higher in South Eastern Plateau Sub Zone VI (-5.55%) compared to the Central and North Eastern Plateau Sub *Zone IV* (-3.53%). It was comparatively lower in the Western Plateau Sub Zone V (-2.62%). An overall decline in the production level of *rangeeni* crops was also found higher in South Eastern Plateau Sub Zone VI (-6.98%) comparatively to the Central and North Eastern Plateau Sub *Zone IV* (-5.67%). It was comparatively lower in the Western Plateau Sub Zone V (-5.54%) as this zone comprises major *rangeeni* lac-producing districts utilizing the natural endowment of *Butea monosperma*. The density of the alternate lac host tree *Ziziphus mauritiana* was comparatively lower in the Western Plateau Sub Zone V. A paradigm shifts from *rangeeni* to *kusmi lac* cultivation during previous decades coupled with climate change issues may be the possible reason for the regional disparity in the level of *rangeeni* lac production

A detailed time series analysis revealed that the Quinquennial trend of CAGR level in average production of *Baisakhi* crop (Summer season *rangeeni* crop) at the national as well as regional level showed fluctuation ranging from -52.14% to 63.85% the over the time of 50 years (Table 3). The transition phase (1990–1992) of the policy framework of the Indian economy coupled with biotic and abiotic factors affected the average production of *rangeeni strain* adversely in Central and North Eastern Plateau Sub Zone IV (-49.91%) and South Eastern Plateau Sub Zone VI (-21.60%). Consequently, it affected the production level of *rangeeni* strain adversely in the Jharkhand state (-29.51%) as well as the national level (-19.59%).

Table 1. District-wise average production of Indian Lac (*Kerria lacca* Kerr.) during 1970-71 to 2019-20 (Decadal trend)

Name of the District /State / Country	1970-71 to 1979-80	1980-81 to 1989-90	1990-91 to 1999-00	2000-01 to 2009-10	2010-11 to 2019-20	't' statistics
I. Central and North Eastern Plateau Sub Zone IV	**799.49**	**571.78**	**433.76**	**321.69**	**377.18**	**5.24**
Bokaro	29.10	3.40	4.60	24.50	37.50	2.61
Dhanbad	3.40	5.90	11.90	220.00	34.50	1.19**
Deoghar	2.10	2.20	2.60	15.00	7.00	2.08*
Dumka	0.20	0.10	1.70	60.50	54.20	1.50**
Giridih	19.00	29.60	21.70	248.50	61.00	1.55**
Hazaribag	410.70	138.80	87.10	102.15	33.10	2.08*
Jamtara	1.20	1.00	4.00	120.00	18.60	1.13**
Ranchi	5930.20	4393.20	3336.50	1782.85	2771.50	4.58
II. Western Plateau Sub Zone V	**553.31**	**441.69**	**451.56**	**567.39**	**581.53**	**15.50**
Chatra	5.20	12.50	23.50	161.00	63.50	1.65**
Garhwa	96.30	2.50	64.60	226.90	34.00	1.96**
Gumla	124.20	523.90	698.80	725.30	1531.30	2.81
Latehar	22.50	0.00	6.50	238.20	77.30	1.39**
Lohardaga	22.40	0.00	4.50	113.00	27.40	1.46**
Palamu	3416.80	2552.90	2363.00	1326.60	174.20	3.15
Simdega	185.80	0.00	0.00	1180.70	2163.00	1.48**
Khunti	0.00	0.00	0.00	0.00	1321.00	0.89**
Others	3.80	1.70	4.10	27.40	77.00	1.42**
III. South Eastern Plateau Sub Zone VI	**718.33**	**962.07**	**987.17**	**378.27**	**291.07**	**4.13**
E. Singhbhum	2027.10	1712.20	1367.20	44.70	7.20	2.18
S. Kharsanwa	17.00	49.20	27.50	241.50	79.00	1.80**
W. Singhbhum	110.90	1124.80	1566.80	848.60	787.00	3.34
Jharkhand	12427.90	10553.90	9596.60	7707.40	9359.30	11.46
India	20351.00	16538.60	15833.70	19544.90	17139.15	18.22
Export unit value (₹)	13.49	32.58	85.65	181.27	495.46	1.64**
CPI ($)	52.39	104.64	149.93	193.61	237.12	4.07

Double asterisk (**) indicates that computed 't' statistics is significant at 1 % level of significance while a single asterisk (*) indicates the value is significant at 5 % level of significance

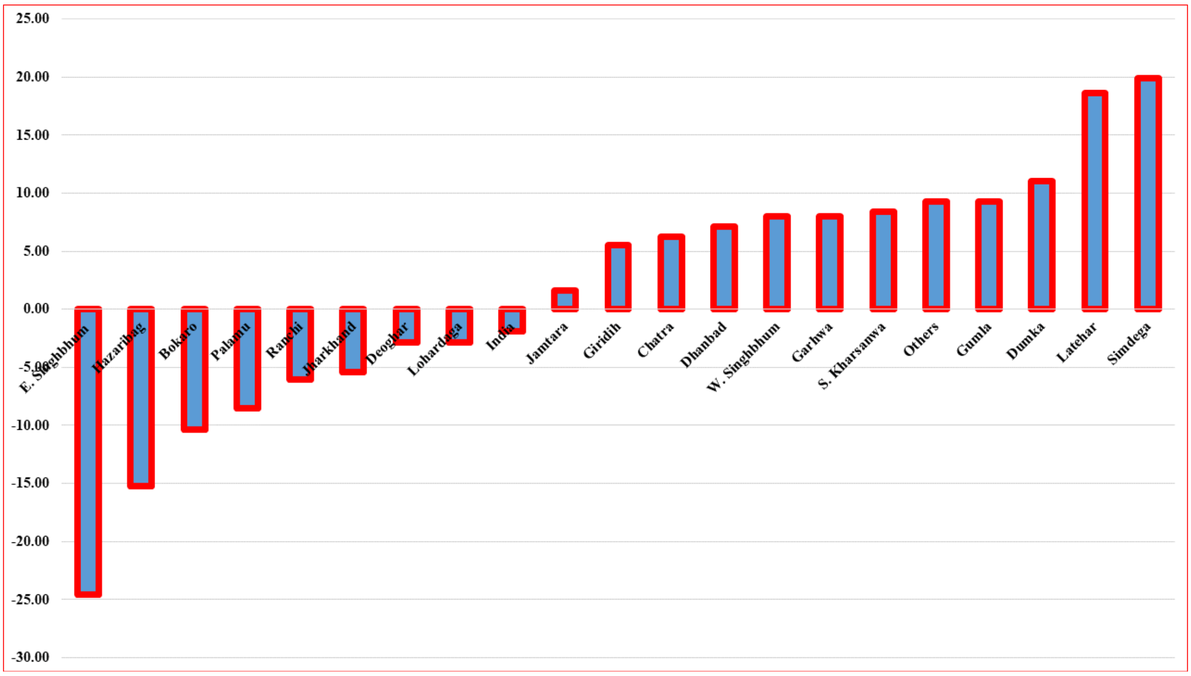

Fig. 1. District-wise Compound Annual Growth Rate (CAGR) of *baisakhi* crop of Indian Lac (*Kerria lacca* Kerr) during 1970-71 to 2020-21

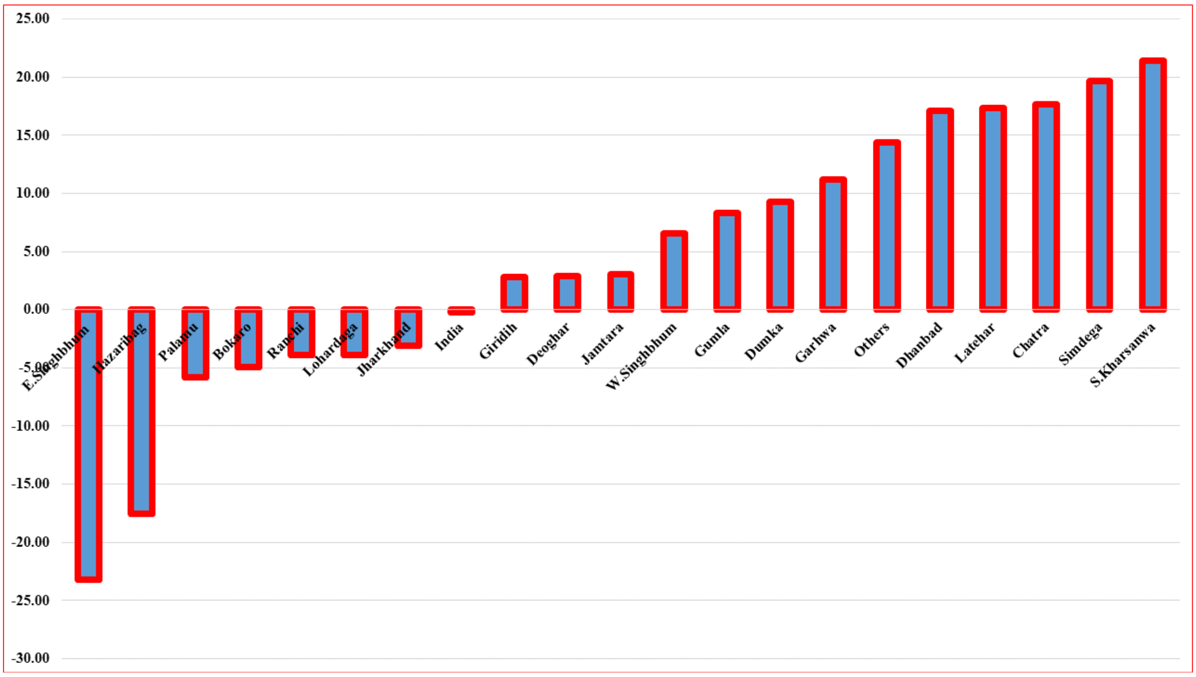

Fig. 2. District-wise compound annual growth rate (CAGR) of *katki* crop of Indian Lac (*Kerria lacca* Kerr.) during 1970-71 to 2020-21

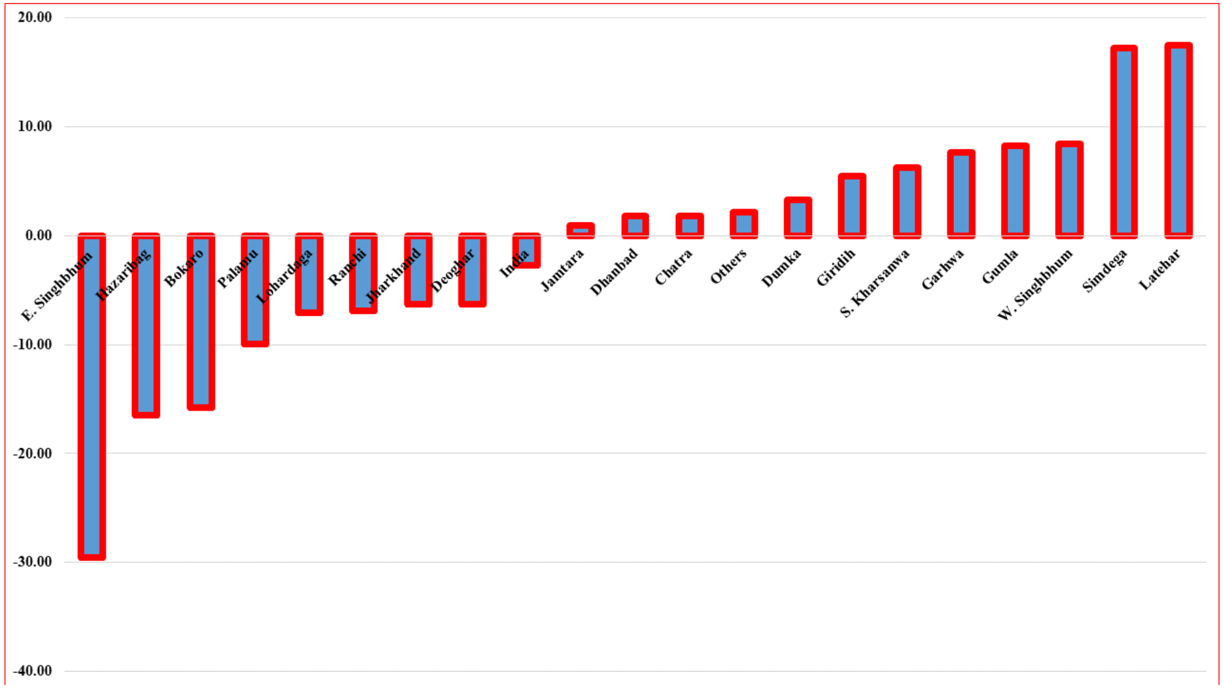

Fig. 3. District-wise compound annual growth rate (CAGR) of *rangeeni* strain of Indian Lac (*Kerria lacca* Kerr.) during 1970-71 to 2020-21

Table 2. Compound annual growth rate (CAGR) of different crops of *rangeeni* strains of Indian Lac (1970-71 to 2020-21)

Name of the District/State/Country	*Baisakhi*	*Katki*	*Rangeeni* (Baisakhi+Katki)
I. Central and North Eastern Plateau Sub Zone IV	**-6.49**	**-3.53**	**-5.67**
Bokaro	-15.83	-4.93	-10.33
Dhanbad	1.77	17.12	7.10
Deoghar	-6.30	2.90	-2.88
Dumka	3.29	9.25	11.04
Giridih	5.43	2.82	5.52
Hazaribag	-16.44	-17.52	-15.24
Jamtara	0.89	3.04	1.61
Ranchi	-6.89	-3.92	-6.06
II. Western Plateau Sub Zone V	**-7.11**	**-2.62**	**-5.54**
Chatra	1.84	17.64	6.22
Garhwa	7.64	11.21	8.03
Gumla	8.22	8.33	9.31
Latehar	17.50	17.32	18.64
Lohardaga	-7.12	-3.88	-2.84
Palamu	-9.97	-5.83	-8.51
Simdega	17.17	19.66	19.86
III. South Eastern Plateau Sub Zone VI	**-7.62**	**-5.55**	**-6.98**
East Singhbhum	-29.56	-23.19	-24.58
Saraikela Kharsanwa	6.20	21.45	8.38
West Singhbhum	8.42	6.59	7.96
Others	2.12	14.36	9.27
Jharkhand	**-6.34**	**-3.11**	**-5.38**
India	**-2.71**	**-0.19**	**-1.90**

Table 3. District-wise compound annual growth rate (CAGR) of *rangeeni* strain of Indian Lac (*Kerria lacca* Kerr.) during 1970-71 to 2019-20 (Quinquennial trend)

Name of the District/State/ Country	Fourth Five Year Plan (1969 – 1974)	Fifth Five Year Plan (1974 – 1979)	Sixth Five Year Plan (1980 – 1985)	Seventh Five Year Plan (1985 – 1990)	Annual Plan (1990 – 1992)	Eighth Five Year Plan (1992 - 1997)	Ninth Five Year Plan (1997 – 2002)	Tenth Five Year Plan (2002 – 2007)	Eleventh Five Year Plan (2007 – 2012)	Twelfth Five Year Plan (2012 – 2017)	Annual Plan (2017 – 2020)
	1969-70 to 1973-74	1974-75 to 1978-79	1980-81 to 1984-85	1985-86 to 1989-90	1990-91 to 1991-92	1992-93 to 1996-97	1997-98 to 2001-02	2002-03 to 2006-07	2007-08 to 20011-12	2012-13 to 2016-17	2017-18 to 2019-20
Central and North Eastern Plateau Sub Zone IV											
Baisakhi crop	32.33	-9.26	-20.13	0.54	-50.34	30.08	-14.46	-20.79	6.52	-20.51	14.76
Katki crop	11.29	-3.94	-4.51	14.42	-48.73	5.84	-27.97	26.77	-16.19	-23.84	-2.11
Rangeeni strain	29.80	-7.61	-16.28	5.59	-49.91	19.92	-17.62	-1.21	-4.34	-21.84	8.84
Western Plateau Sub Zone V											
Baisakhi crop	12.26	-23.71	-20.26	-14.67	-11.10	0.79	-11.45	-32.07	-15.82	-31.74	14.10
Katki crop	-1.88	-20.59	-4.45	-8.44	63.85	26.65	-19.44	-12.12	-29.68	-28.43	-6.29
Rangeeni strain	8.75	-21.66	-17.10	-12.82	4.73	10.86	-13.05	-23.36	-24.09	-29.57	2.20
South Eastern Plateau Sub Zone VI											
Baisakhi crop	28.28	-23.92	-2.26	-5.41	-12.00	-14.32	-34.11	-52.14	5.09	-27.50	50.00
Katki crop	-17.20	-10.06	15.75	-6.58	-36.74	2.19	-39.34	-37.21	-18.56	-36.70	15.47
Rangeeni strain	16.08	-20.11	1.92	-6.80	-21.28	-10.14	-35.68	-42.92	-6.13	-29.25	41.42
Jharkhand											
Baisakhi crop	24.80	-16.51	-17.33	-6.84	-31.17	2.56	-19.72	-29.93	-0.32	-21.18	23.54
Katki crop	-2.70	-11.08	0.06	-0.22	-25.34	11.84	-28.01	-4.47	-22.08	-22.72	0.90
Rangeeni strain	19.52	-14.56	-13.44	-4.70	-29.51	5.58	-21.60	-18.17	-11.63	-21.81	14.29
India											
Baisakhi crop	10.24	-15.20	-15.19	-6.20	-22.63	5.90	-1.39	-13.09	-16.68	-12.36	11.42
Katki crop	-9.07	-11.98	-4.99	-0.24	-12.30	14.55	2.11	9.68	-21.68	0.52	-1.47
Rangeeni strain	5.34	-13.92	-12.42	-4.30	-19.59	8.72	0.04	-3.49	-18.82	-7.03	5.03

*Note: Undefined or nil values of district level CAGR excluded. *Due to inadequate data during the Rolling Plan Period (1978 – 1980) of 1978-79 to 1979-80 excluded*

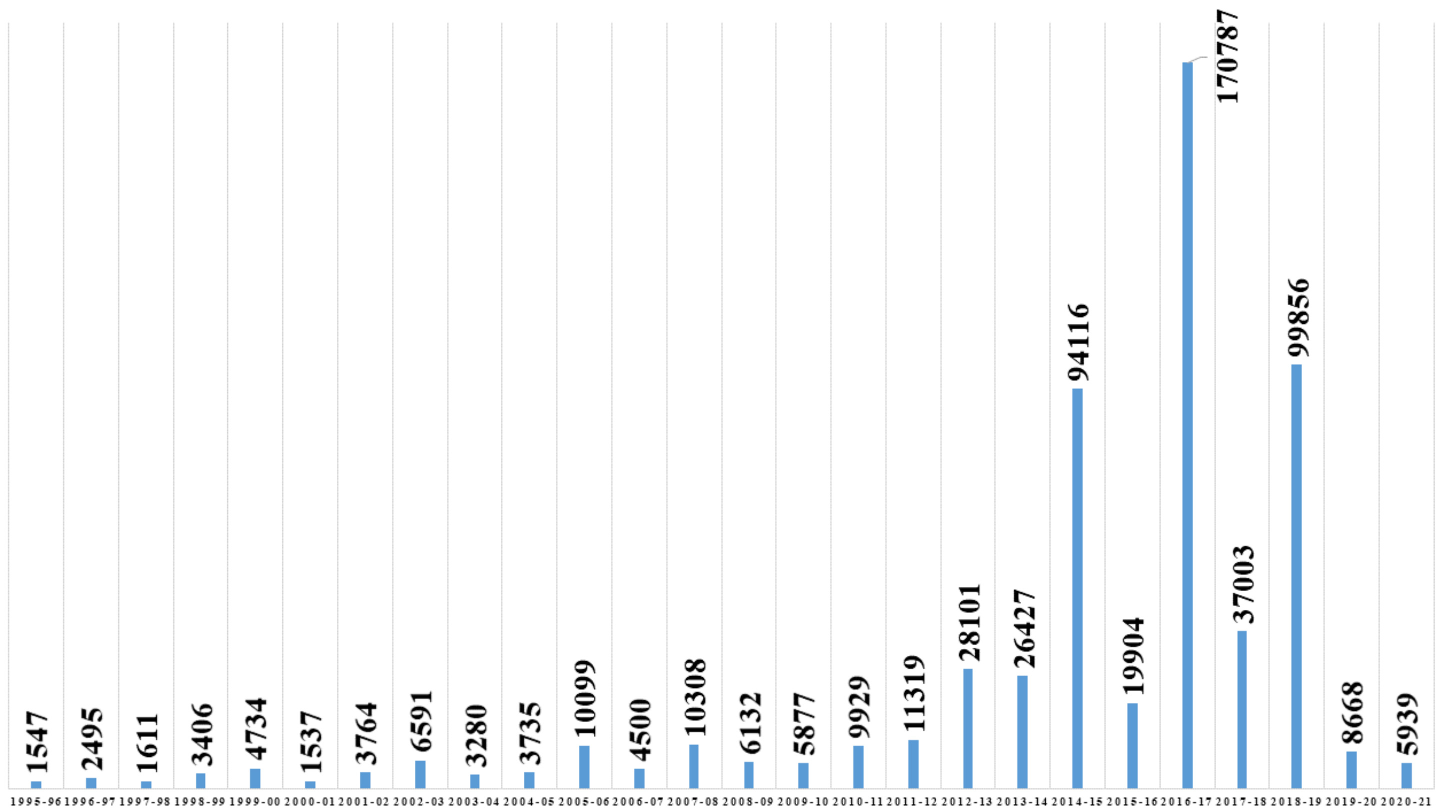

Fig. 4. Year-wise outreach of the institutional framework through capacity building and skill development program during 1995-96 to 2020-21

Table 4. District-wise compound annual growth rate (CAGR) and instability indices of baisakhi crop of indian lac (*Kerria lacca* Kerr) during 1970-71 to 2019-20 (Decadal trend)

Name of the District / State / Country	Decade 1970s 1970-71 to 1979-80	Decade 1980s 1980-81 to 1989-90	Decade 1990s 1990-91 to 1999-00	Decade 2000s 2000-01 to 2009-10	Decade 2010s 2010-11 to 2019-20	Instability Indices 1970-71 to 2019-20	Z Statistics In the Zones & in State over the National
Central and North Eastern Plateau Sub Zone IV							
***Baisakhi* crop**	-0.52	-11.40	-5.55	-24.08	-5.88	47.05	6.38
***Katki* crop**	3.00	4.03	-1.61	-11.08	-12.73	52.15	3.00
***Rangeeni* strain**	0.21	-8.31	-4.17	-19.41	-8.38	37.08	5.46
Western Plateau Sub Zone V							
***Baisakhi* crop**	-3.88	-7.49	3.64	-23.05	-15.12	44.83	4.53
***Katki* crop**	-1.11	5.82	2.12	-7.83	-15.90	64.65	4.42
***Rangeeni* strain**	-2.81	-4.81	4.01	-17.38	-15.58	42.17	3.72
South Eastern Plateau Sub Zone VI							
***Baisakhi* crop**	-7.24	-0.60	-12.47	-30.83	-8.98	70.99	7.59
***Katki* crop**	-10.54	19.27	-2.48	-23.74	-15.84	77.38	7.94
***Rangeeni* strain**	-7.68	4.16	-8.21	-27.12	-11.30	63.09	7.70
All Jharkhand							
***Baisakhi* crop**	-2.66	-7.98	-2.74	-24.28	-6.23	37.79	4.49
***Katki* crop**	-1.28	9.06	-0.67	-10.58	-11.22	49.69	2.19**
***Rangeeni* strain**	-2.08	-4.50	-2.02	-19.21	-8.37	32.12	3.47
All India							
***Baisakhi* crop**	-3.87	-4.75	-1.81	-6.08	-3.25	26.10	-
***Katki* crop**	-4.59	6.43	0.26	-3.61	1.81	36.62	-
***Rangeeni* strain**	-3.88	-2.08	-1.13	-4.74	-1.10	23.78	-

Notes: The values of Z are computed between the Zones & in State over the National. Double asterisk (**) indicates that computed Z is significant at 1 percent level of significance while a single asterisk (*) indicates the value is significant at 5 percent level of significance

However, the highest decline of -52.14% in the production level of *Baisakhi* crop (Summer season *rangeeni* crop) was observed in South Eastern Plateau Sub Zone VI during Tenth Five Year Plan (2002–2007). The Fourth Five Year Plan (1969 – 1974) remained a favorable period for lac production in comparison to Fifth Five Year Plan (1974–1979), Sixth Five Year Plan (1980 – 1985), and Seventh Five Year Plan (1985 – 1990). During the annual plan (1990–1992), the highest acceleration of 63.85% has been observed for the *katki* crop (rainy season *rangeeni* crop). Subsequently, the average production of *rangeeni strain* again revived during Eighth Five Year Plan (1992 -1997) at the national as well as regional levels. Although, the production of *rangeeni strain* was affected adversely in Jharkhand (-21.60%) during the Ninth Five Year Plan (1997 – 2002). Further, the scenario changed speedily through shifting from *rangeeni* lac cultivation on *ber (Ziziphus mauritiana)* substituted by the *kusmi strain* due to its quality premium as well as high productivity. Onward of 1999-2000, the outreach through capacity building and skill development programs increased substantially from 4000 to more than one lakh in the Twelfth Five Year Plan (2012 – 2017) and succeeding years which influenced the awareness and knowledge level of the stakeholders (Fig. 4).

Consequently, a paradigm shifts from *rangeeni* to *kusmi* crop flipped the situation over the period. However, COVID-19 broke the momentum, and functionaries shifted to manage the disrupted supply chains during 2019-20 and 2020-21. Post COVID-19 scenario, emerged with new ICT-enabled interventions with greater scope for extension and awareness programs.

Instability Analysis: A detailed time series analysis revealed that instability in the production of *Baisakhi* crop (Summer season *rangeeni* crop) at the national, as well as regional level, showed fluctuation ranging from 60 to120 over the time of 50 years (Table 4). The average production of *rangeeni* strain was affected adversely in South Eastern Plateau Sub Zone VI with high instability index (63.09) comparatively to Western Plateau Sub Zone V (42.17) followed by Central and North Eastern Plateau Sub Zone IV (37.08). The overall scenario in Jharkhand state depicts the alarming situation for *katki* crop (Rainy season *rangeeni* crop) having the highest instability index (49.69), particularly with significant negative growth rates from 2000 to 2020. The magnitude of decline for *katki* crop was found highest and most significant during the 2001-2010 period. The weather data (Temperature, humidity, and rainfall) based analysis of the last 28 years for the DMS geo coordinates (Latitude: 23° 20' 51.97" N Longitude: 85° 20' 18.82" E) revealed an increase in annual mean temperature of 0.23 degree Celsius, decrease in mean RH of 6.2% and decrease in rainfall of 64.6mm. An increased gap between the mean maximum and minimum temperature was reported in a study conducted by Mohanasundaram et al. [42 & 43]. A paradigm shifts of lac growers from *rangeeni* to *kusmi* strain (both *Kerria* species) was observed in recent years due to the failure of *rangeeni* crops [44]. Jaiswal and co-workers [45] also reported a state-wise shift in *kusmi* lac production was also witnessed. The highest shift was evident in Jharkhand followed by Chhattisgarh and West Bengal. It indicates the impact of climate change and also supports weather data-based studies in the region.

5. CONCLUSIONS

Time series analysis revealed the variation in lac production levels in different levels of geo coordinates. Abiotic factors including climate and the extent of forward and backward linkages aroused as the major factors influencing the lac production in India. Although natural enemies of lac insects include pathogens, parasites and predators also affect lac production adversely. Feedback through FGDs revealed that about 30% yield losses can be avoided by checking the growth of the microorganisms by adopting brood lac treatment and other pest management practices.

The overall decline in the production level of *rangeeni* crops ranged from -5.54% in Western Plateau Sub Zone V to -6.98% in South Eastern Plateau Sub Zone VI. Utilization of the existing natural endowment of *Butea monosperma* in major *rangeeni* lac-producing districts in Western Plateau Sub Zone V could be a promising strategy to minimize the variation in the production of *rangeeni* crops. A paradigm shifts from *rangeeni* lac cultivation during previous decades coupled with climate change issues may be another possible reason for the regional disparity in the level of *rangeeni* lac production.

The overall scenario in Jharkhand state depicts the alarming situation for *katki* crop (Rainy season *rangeeni* crop) having the highest instability index (49.69), particularly with significant negative growth rates from 2000 to 2020. The magnitude of decline for *katki* crop was found the highest and significant during the 2001-2010 period. Although, the production of *rangeeni* strain was affected adversely in Jharkhand (-21.60%) during the Ninth Five Year Plan coupled with shifting from *rangeeni* to *kusmi* lac cultivation due to boosting through capacity building and skill development programs which influenced the awareness and knowledge level of the stakeholders. However, COVID-19 could break the momentum, and functionaries including the institutions and facilitators shifted to manage the disrupted supply chains during 2019-20 and 2020-21. Post COVID-19 scenario, emerged with new ICT-enabled interventions with greater scope for extension and awareness programs. However, a huge technological gap in the existing lac industry with poor automation and dependency on local labor. Policy interventions including Minimum Support Price (MSP), *Van Dhan Vikas Kendras* (Forest Resource Development Centers), SHGs (Self Help Groups), JLGs (Joint Liability Groups), *etc*. may play a key role in strengthening the sector.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Government of India. State of Forest Report 2021. Ministry of Environment, Forest and Climate Change, Dehradun, Uttarakhand, India; 2022.
2. García MM, Denno BD, Miller DR, Miller GL, Ben-Dov Y, Hardy NB. Scale net: A literature-based model of scale insect biology and systematics. Database; 2016. Available:https://doi.org/10.1093/database/bav118.
3. Thamilarasi K, Ekbal Sajiya, Kumari Kanchan, Lohot Vaibhav D, Mohanasundaram Arumugam, Sharma K Kewal. Unraveling bacterial diversity of the Indian lac insect *Kerria lacca* Kerr using next generation sequencing. International Journal of Tropical Insect Science; 2022. Available:https://doi.org/10.1007/s42690-022-00758-x
4. Thamilarasi K, Sharma KK. Interaction of lac insects with microbes. In: Kumar A, Kumar N, Chand H (ed). Commercial Entomology. New India Publishing Agency, New Delhi, India (ISBN- 978–93–87973–87–9). 2019;129–140.
5. Siddiqui SA. Lac-The versatile natural resin. Natural Product Radiance. 2004; 3(5):332–337.
6. Thombare Nandkishore, Kumar Saurav, Kumari Usha, Sakare Priyanka, Yogi Raj Kumar, Prasad Niranjan, Sharma Kewal Krishan. Shellac as a multifunctional biopolymer: A review on properties, applications and future potential. International Journal of Biological Macromolecules. 2022;215 (2022):203–223.
7. Yogi RK, Kumar Nirmal, Sharma KK. Lac, plant resins and gums statistics 2020: At a Glance. ICAR-Indian Institute of Natural Resins and Gums, Ranchi (Jharkhand), India. 2022; Bulletin (Technical) No. 2 /2022. (i-x)/01-102.
8. Hazell PBR. Instability in Indian food grain production. Research Report 30, International Food Policy Research Institute, Washington, D. C; 1982.
9. Srivastava, DC, Mehra BP. Studies on the abundance of various insects associated with the Indian lac insect, *Kerria lacca* (Kerr). Indian Journal of Ecology. 1984; 7:96-104.
10. Saha SK, Jaiswal AK. Modeling sticklac lac production in India-An uni and multivariate regression approach. Ann. Agric. Res. 1992;14(1):149-153.
11. Saha SK, Jaiswal AK. Growth and instability in lac production in India. Ann. Agric. Res. 1993;14(2):45-51.
12. Yogi RK, Kumar Alok, Singh AK. Lac, plant resins and gums statistics 2017: At a Glance. ICAR-Indian Institute of Natural Resins and Gums, Ranchi (Jharkhand), India. 2020; Bulletin (Technical) No. 05/2020:01-78.
13. Yogi RK, Kumar Nirmal Sharma KK. Lac, plant resins and gums statistics 2019: At a Glance. ICAR-Indian Institute of Natural Resins and Gums, Ranchi (Jharkhand), India. (ISSN No.IS-2454-8782) 2021; Bulletin (Technical) No. 3/2021. 01-82.
14. Ramani R, Kumar SB, Bhatt P, Variar M, Arunachalam A. Jharkhand agri-development vision. ICAR-IINRG, Ranchi. 2015;80.
15. Cuddy, Dell. Measuring the Instability of Time Series Data. Oxford. Bulletin of Economics and Statistics, 1978;40(1):79-85.

16. Weber A, Sievers M. Observations on the geography of wheat production instability. Quarterly Journal of International Agriculture. 1985;24(3):201-211.
17. Singh AJ, D Byerlee. Relative Variability in wheat yields across countries and over time. Journal of Agricultural Economics. 1990;41(1):21-32.
18. UK Deb, Bose GK, Dey MM. Growth and variability in sugarcane production in Bangladesh. The Asian Economic Review. 1999;41(1):152-165.
19. Anderson JR, Hazell PBR. (Eds.). Variability in grain yields: implications for agricultural research and policy in developing countries. The Johns Hopkins University Press, Baltimore, and London; 1989.
20. Jaiswal AK, Kumar KK, Pal G. Effect of holding size on the utilization on conventional lac host trees in Ranchi district (Jharkhand). Journal of Non-Timber Forest Products. 2006;13(1):47-50.
21. Yogi RK, Jaiswal AK, Sharma KK. Enabling Rural Households of *Chotanagpur* Plateau Region of Jharkhand for Doubling Farm Income. Jharkhand Journal of Development and Management Studies. 2017;15 (1):7179-7195.
22. Singh KM, Singh RKP, Meena MS, Kumar A, Jha AK, Kumar A. Rural poverty in Jharkhand: an empirical exploration of socioeconomic determinants. 2012; Online at
Available:http://mpra.ub.uni-muenchen.de/44811/ MPRA: Paper No. 44811.
23. World Bank. Jharkhand: addressing the challenges of inclusive development. Report No. 36437-In Poverty Reduction and Economic Management. India Country Management Unit, South; 2007.
24. Yogi RK, Jaiswal AK. Socio-economic characteristics of lac growers and host trees utilization pattern: A comparative study. International Journal of Usufructs Management. 2014;15(2):37-46.
25. Ekka P. Jharkhand tribals, are they really a minority? Economic and Political Weekly. 2000;35(52 & 53):4610-4612.
26. Maharatna A, Chikte R. Demography of tribal population in Jharkhand 1951-1991. Economic and Political Weekly. 2004; 39 (46 &47): 5053-5062.
27. Xaxa Virginius. Protective Discrimination: Why Scheduled Tribes lag behind Scheduled Castes. Economic and Political Weekly. 2001;36(29).
28. Corbridge S. The Ideology of Tribal Economy and Society: Politics of Jharkhand, c.1950-1980', Modern Asian Studies, 22:1-41. Reprinted (2003) in R. D. Munda and S. B. Mullick, The Jharkhand Movement: Indigenous Peoples' Struggle for Autonomy in India, Chaibasa: Bindrai Institute for Research Study and Action (in association with Transaction Publishers and International Work Group for Indigenous Affairs). 1988;131-170.
29. Aaron SJ. Contrarian Lives: Christians and contemporary protest in Jharkhand. Asia Research Centre, Working Paper 18; 2007.
30. Islam AU, Quli SMS, Rai R, Sofi PA. Livelihood contributions of forest resources to the tribal communities of Jharkhand. Indian Journal of Fundamental and Applied Life Sciences. 2013;3(2):131-144.
31. Kumar S, A Choudhury. Enhancement of livelihood activities through non-timber forest products: a study in Jharkhand's Ranchi and Simdega districts. Jharkhand Journal of Development and Management Studies 2016;14 (1):6919-6930.
32. Magry MA, Narula SA, Anwar Raheel. Scope of lac as enterprise development in Jharkhand. Indian Journal of Economics and Development. 2017;13(2): 387-392.
DOI: 10.5958/2322-0430.2017.00193.7
33. Yogi RK, Singh AK, Kumar Nirmal, Sharma KK. Assessing Minimum Support Price for Non-Wood Forest Products (NWFPs): A Priority based Policy Intervention in India. *Multilogic in* Science Journal. 2018;8(Issue special C):261-267.
34. Glower, RM. Lac cultivation of India; 1937.
35. Narayanan, ES. Pest of lac in India. In: B Mukhopapadhyay and MS Muthana, (eds), A Monograph on lac. Indian Lac Research Institute, Ranchi (India). 1962;90-133.
36. Malhotra CP, Katiyar RN. Control of *Eublemma amabilis* Moore, a serious predator of the lac insect *Kerria lacca* (Kerr.): Screening of insecticide for their safety to lac insect. Indian Journals of Entomology1975; 37:385-396
37. Sharma KK, Jaiswal AK. Biotic factors affecting the productivity of lac insects. In: Kumar, KK, Ramani, R and Sharma, KK (Eds.). Recent advances in lac culture. Indian Lac Research Institute, Namkum, Ranchi, Jharkhand, India. 2002;290.
38. Mohanasundaram Arumugam, Sharma Kewal Krishan, Naiyar Naaz. Lac insect,

natural enemies and their management. In book: Commercial Entomology Publisher: New India Publishing Agency, New Delhi. 2019;111-128.

39. Sharma KK, Jaiswal AK, Bhattacharya A, Mishra YD, Sushil SN. Emergence profile and relative abundance of parasitoids associated with Indian lac insect, *Kerria lacca* (Kerr). Indian Journal of Ecology. 1997;24:17-22.
40. Srivastava DC, NS Chauhan, TPS Teotia. Seasonal abundance of insects associated with the Indian lac insect, *Kerria lacca*, Indian Journal of Ecology. 1984;11: 37-42.
41. Srivastava DC, NS Chauhan. A critical appraisal of the estimates of parasitic losses in lac. Indian Shellac. 1984;(1 and 2):24(Sept.- Dec.).
42. Mohanasundaram A, M Monobrullah. Crop mortality due to heavy parasitization. ICAR IINRG Newsletter. 2014;18(2):3.
43. Mohanasundaram A, M Monobrullah, Sharma KK, Anees K, Singh RK, Meena SC, Verma Shweta. Climate change: Effect of weather parameters on production of summer season crop of *rangeeni* strain of Indian Lac insect, *Kerria lacca* (Kerr) at Ranchi, Jharkhand. Journal of Agrometeorology. 2014;16(1):108-113.
44. Yogi RK, Singh RK, Bhattacharya A, Jaiswal AK, Kumar Alok. Current Scenario and New Policy Interventions in the Lac Sector. Jharkhand Journal of Development and Management Studies. 2016;14(1):6903-6917.
45. Jaiswal AK, Sharmila Roy, Sushil SN. A paradigm shift of quality Lac production in India. Indian Forester. 2020;146 (7):47-652.
DOI:10.36808/if/2020/v146i7/154261

Appendix 1. Agro-climatic sub zones

Agro-climatic sub zones	Characteristics	Name of the districts (Numbers)
Central and North Eastern Plateau Sub *Zone IV*	Erratic and uneven distribution of rainfall ii. Coarse textured soils, crust formation on the soil surface iii. Low water retention capacity of the soil iv. Lack of safe disposal of runoff and drying of tanks.	Bokaro, Deoghar, Dhanbad, Dumka, Giridih, Godda, Jamtara, Khunti, Koderma, Hazaribagh, Pakur, Ramgarh, Ranchi & Sahebganj (14)
Western Plateau *Sub Zone V*	Erratic/ uneven distribution of rainfall ii. Low water retentive capacity of the soil.	Chatra, Garhwa, Gumla, Latehar, Lohardaga, Palamau and Simdega (7).
South Eastern Plateau *Sub Zone VI*	Uneven distribution of rainfall ii. Low water holding capacity, eroded soils iii. Shallow soil depth iv. Poor soil fertility.	East Singhbhum, Saraikela and West Singhbhum (3)

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/95664