

**Policy Article****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****Abstract**

The study examined the growth, instability, and trends in the production of an insect-based natural resin in India. 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. Abiotic factors including climate and the extent of forward and backward linkages aroused as the major factors. Although natural enemies of lac insects include pathogens, parasites and predators also affect production adversely. About 30% yield losses can be avoided by checking the growth of the microorganisms by adopting broodlac treatment and other pest management practices. 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. 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

**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*) major lac host trees which comprises about 3% of the total number of available trees (Forest Survey of India, 2017).

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 (Garcia *et al.* 2016). 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 (Thamilarasi *et al.* 2022). 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 (Thamilarasi and Sharma 2019). 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.* (Siddiqui 2004). 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 (Thombare *et al.* 2022). 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.

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.*). Hazell (1982) argues that 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. 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 (Mehra and Srivastav 1976).

Production is also affected by unstable demand due to the availability of alternate resins and fluctuating price (Saha and Jaiswal 1992). Saha and Jaiswal (1993) studied the trend during 1960-61 to 1989-90, the result showed that the country registered a negative growth rate (3.55%) and instability

in lac production to the extent of 42%. Significant variation in growth rate and instability was observed from state to state and crop to crop. We 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?

**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 (Yogi *et al.* 2020). 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 20<sup>th</sup> and 21<sup>st</sup> 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 (Yogi *et al* 2019 and Ramani *et al* 2015). 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. Statistical tools like growth rate and percentages were used for analysis as shown in. The Compound Annual Growth Rate (CAGR) in the export of lac was worked out by fitting the exponential function given below (Equation **Error! Reference source not found.**):

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

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 **Error! Reference source not found.**)

$$\log Y_t = \log a + t \log b$$

.....**Equation 2**

where,

$Y_t$  = production of lac in  $t^{th}$  year

We can, thus, calculate the compound growth rates (r) as under (Equation **Error! Reference source not found.**)

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

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 (1978) which corrects the co-efficient of variation which is used as a measure of variability in time-series data (e.g., Weber and Sievers, 1985; Singh and Byerlee, 1990; Deb et al., 1999). The instability index was estimated by using the equation given below in equation **Error! Reference source not found.:**

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

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 **Error! Reference source not found.:**

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

wherein,

‘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 (1989), where a standard normal Z-statistic is estimated as illustrated in equation **Error! Reference source not found.**:

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

where,

CV<sub>1</sub> and CV<sub>2</sub> are the coefficients of variations in lac production at the district and state levels, respectively. D is defined as equation **Error! Reference source not found.**:

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

where,

CV is the coefficient of variation in All India lac production over the time

CV<sub>1</sub> and CV<sub>2</sub> 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<sub>1</sub> and n<sub>2</sub>, respectively. We have approximated c by CV<sub>1</sub> following Anderson and Hazell (1987).

### RESULTS

**Lac production:** 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 1<sup>st</sup> (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 1<sup>st</sup> 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.

**Socioeconomic background of the lac growing communities:** 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 (Jaiswal *et al* 2006; Yogi *et al.* 2015; Yogi *et al.* 2017). An empirical exploration of socioeconomic determinants in the state by Singh, *et al* (2012) and the World Bank Report (2007) 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 (Yogi *et al.* 2014). Anthropological studies about the tribal indicate that their needs are comparatively lesser and differ in terms of choice (Ekka, P. 2000). Migration problem is also observed in these areas (Maharatna and Chikte 2004). Consequently, the adoption rate is low and generally they are not early adopters (Xaxa 2001). 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 (Corbridge 2000). The interplay of economic potential and socio-political vulnerability in Jharkhand has already seen dramatic developments (Aaron 2007). Islam *et al* (2013), and Kumar & Choudhury (2016) highlighted the livelihood contributions of forest resources to the tribal communities of Jharkhand. Magry *et al* (2017) in their study in Jharkhand found lac being mostly a subsidiary occupation however providing much-needed cash income in low agriculture activity seasons.

#### **Average production of *rangeeni* strains of Indian Lac in Jharkhand**

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. It has been indicated that about 30% yield losses can be avoided by checking the growth of the microorganisms. Predators (*Eublema amabilis* and *Pseudohypatopa pulverea*) and parasites are the major natural enemies of lac insects causing about 30-40% crop loss on average (Glover 1937, Naraynan 1962, Malhotra and Katiyar 1975). *Chrysopa spp.* is a sporadic pest and sometimes causes significant mortality (Sharma and Jaiswal, 2002), 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 (Mohanasundaram *et al.*; 2019). 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 (Sharma *et al.*, 1997; Srivastava *et al.*, 1984; Srivastava and Chauhan, 1984; Srivastava and Mehra, 1984). 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 Singhbhum, 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 (**Error! Reference source not found.**). 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.

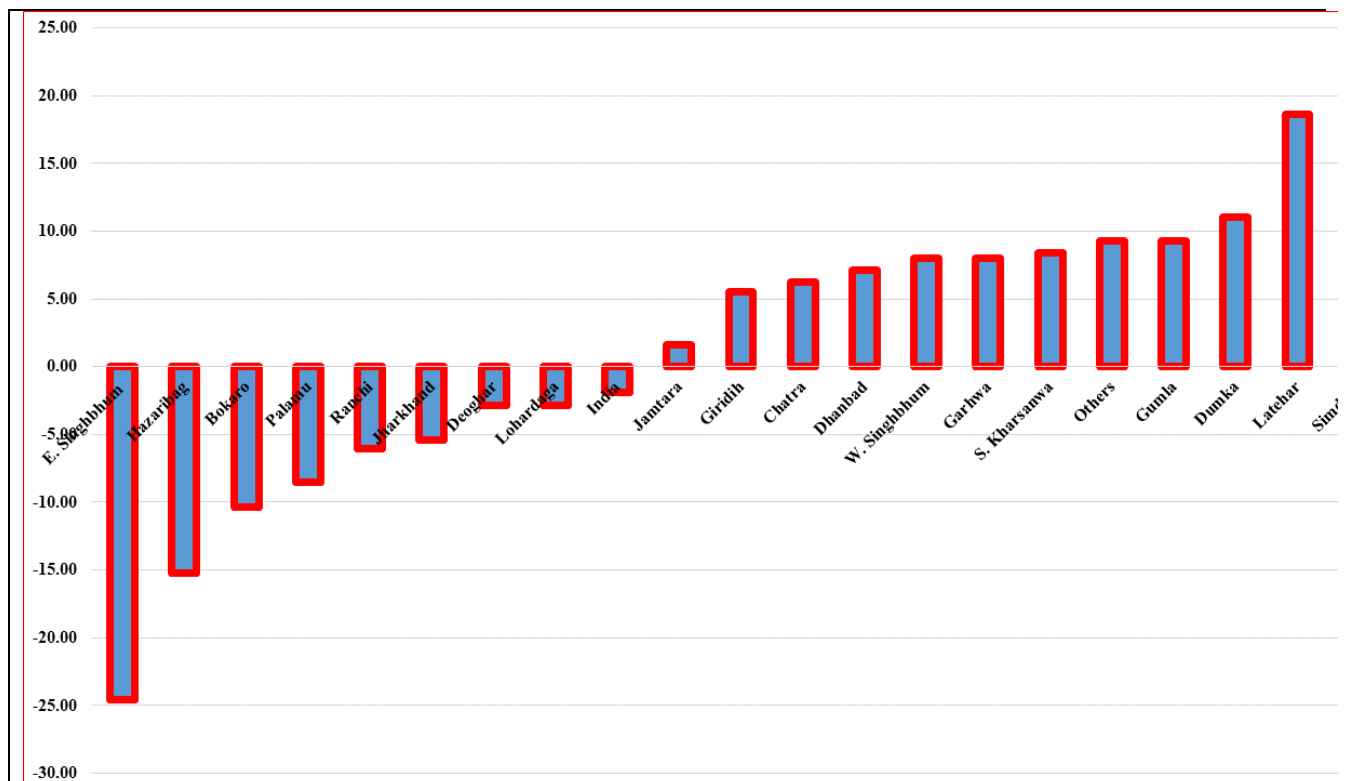
**Table 1 District-wise average production of Indian Lac (*Kerria lacca* Kerr.) during 1970-71 to 2019-20 (Decadal trend)**

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
<b>I. Central and North Eastern Plateau Sub Zone IV</b>	<b>799.49</b>	<b>571.78</b>	<b>433.76</b>	<b>321.69</b>	<b>377.18</b>	<b>5.24</b>
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
<b>II. Western Plateau Sub Zone V</b>	<b>553.31</b>	<b>441.69</b>	<b>451.56</b>	<b>567.39</b>	<b>581.53</b>	<b>15.50</b>
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**
<b>III. South Eastern Plateau Sub Zone VI</b>	<b>718.33</b>	<b>962.07</b>	<b>987.17</b>	<b>378.27</b>	<b>291.07</b>	<b>4.13</b>
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.

### Compound Annual Growth Rate (CAGR) of different crops of *rangeeni* strains of Indian Lac

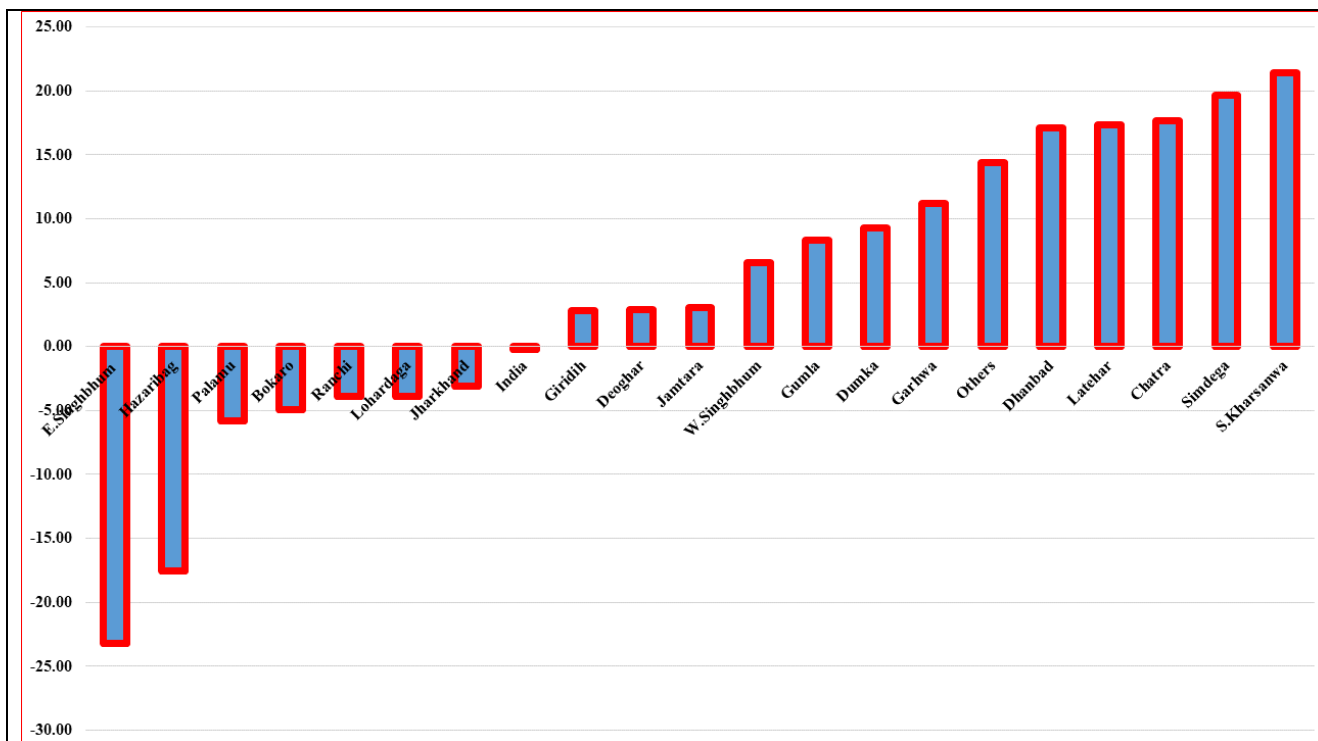
A detailed time series analysis revealed that the production level of *rangeeni* strain at the national as well as regional levels declined over time (Table 2). In Central and North Eastern Plateau Sub Zone IV production level of *baisakhi* crop (Summer season *rangeeni* crop) improved over time in Dhanbad (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 Figure 1.



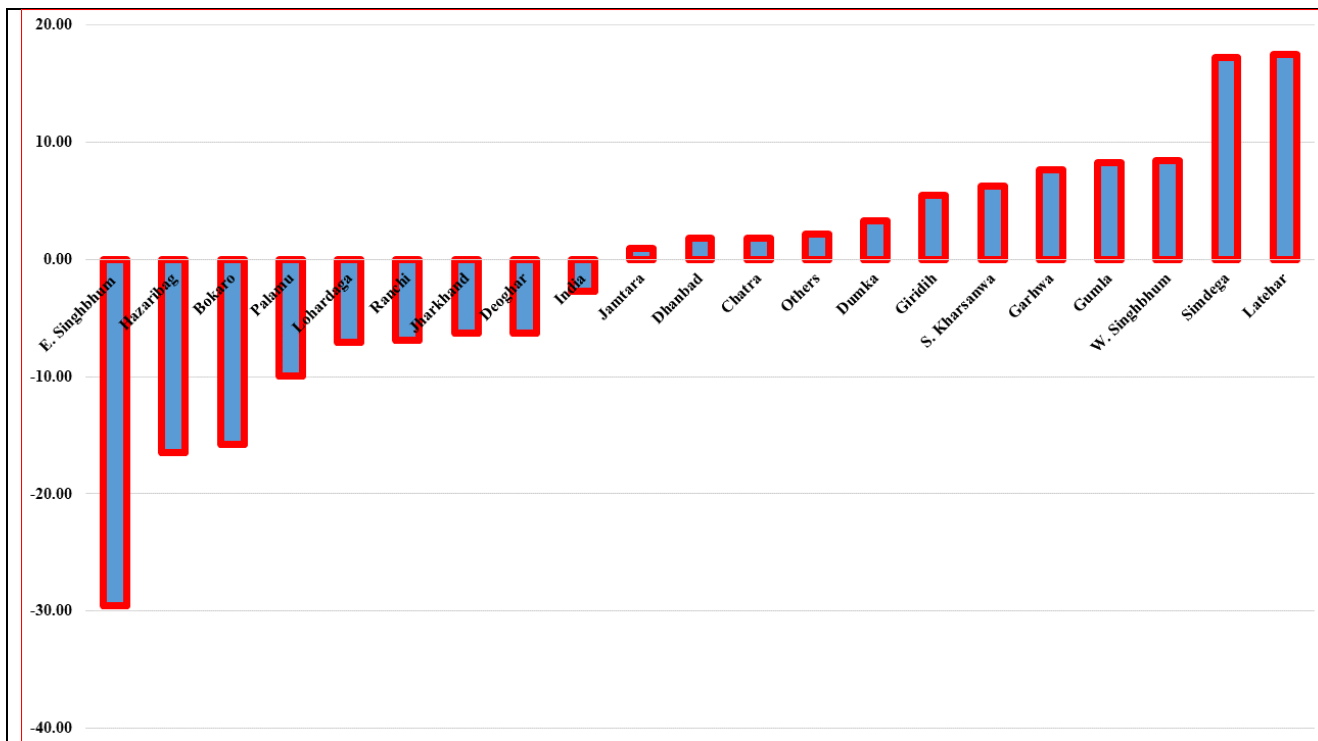
**Figure 1 District-wise Compound Annual Growth Rate (CAGR) of *baisakhi* crop of Indian Lac (*Kerria lacca* Kerr) during 1970-71 to 2020-21**

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 Figure 2.



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



**Figure 3 District-wise Compound Annual Growth Rate (CAGR) of *rangeeni* strain of Indian Lac (*Kerria lacca* Kerr.) during 1970-71 to 2020-21**

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 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 **Error! Reference source not found.**

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.

**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	<i>Baisakhi</i>	<i>Katki</i>	<i>Rangeeni</i> ( <i>Baisakhi</i> + <i>Katki</i> )
<b>I. Central and North Eastern Plateau Sub Zone IV</b>	<b>-6.49</b>	<b>-3.53</b>	<b>-5.67</b>
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
<b>II. Western Plateau Sub Zone V</b>	<b>-7.11</b>	<b>-2.62</b>	<b>-5.54</b>
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
<b>III. South Eastern Plateau Sub Zone VI</b>	<b>-7.62</b>	<b>-5.55</b>	<b>-6.98</b>
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
<b>Jharkhand</b>	<b>-6.34</b>	<b>-3.11</b>	<b>-5.38</b>
<b>India</b>	<b>-2.71</b>	<b>-0.19</b>	<b>-1.90</b>

## 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%).

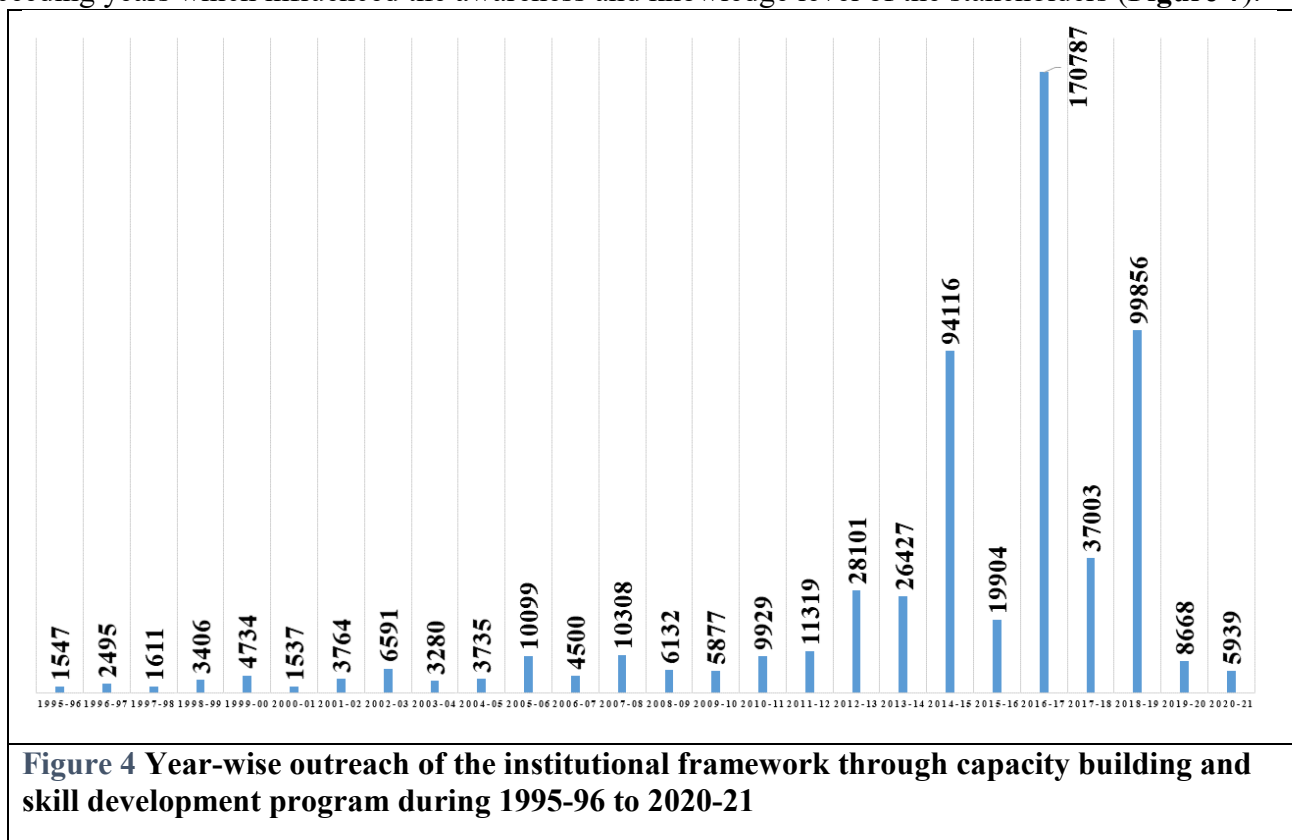
**Table 3 District-wise compound annual growth rate (CAGR) of *rangeeni* strain of Indian Lac (*Kerria lacca* Kerr.) during 1970-71 to 2019-20 (Quinquennial trend)**

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 2011-12	2012-13 to 2016-17	2017-18 to 2019-20
<b>Central and North Eastern Plateau Sub Zone IV</b>											
<i>Baisakhi</i> crop	32.33	-9.26	-20.13	0.54	-50.34	30.08	-14.46	-20.79	6.52	-20.51	14.76
<i>Katki</i> crop	11.29	-3.94	-4.51	14.42	-48.73	5.84	-27.97	26.77	-16.19	-23.84	-2.11
<i>Rangeeni</i> strain	29.80	-7.61	-16.28	5.59	-49.91	19.92	-17.62	-1.21	-4.34	-21.84	8.84
<b>Western Plateau Sub Zone V</b>											
<i>Baisakhi</i> crop	12.26	-23.71	-20.26	-14.67	-11.10	0.79	-11.45	-32.07	-15.82	-31.74	14.10
<i>Katki</i> crop	-1.88	-20.59	-4.45	-8.44	63.85	26.65	-19.44	-12.12	-29.68	-28.43	-6.29
<i>Rangeeni</i> strain	8.75	-21.66	-17.10	-12.82	4.73	10.86	-13.05	-23.36	-24.09	-29.57	2.20
<b>South Eastern Plateau Sub Zone VI</b>											
<i>Baisakhi</i> crop	28.28	-23.92	-2.26	-5.41	-12.00	-14.32	-34.11	-52.14	5.09	-27.50	50.00
<i>Katki</i> crop	-17.20	-10.06	15.75	-6.58	-36.74	2.19	-39.34	-37.21	-18.56	-36.70	15.47
<i>Rangeeni</i> strain	16.08	-20.11	1.92	-6.80	-21.28	-10.14	-35.68	-42.92	-6.13	-29.25	41.42
<b>Jharkhand</b>											
<i>Baisakhi</i> crop	24.80	-16.51	-17.33	-6.84	-31.17	2.56	-19.72	-29.93	-0.32	-21.18	23.54
<i>Katki</i> crop	-2.70	-11.08	0.06	-0.22	-25.34	11.84	-28.01	-4.47	-22.08	-22.72	0.90
<i>Rangeeni</i> strain	19.52	-14.56	-13.44	-4.70	-29.51	5.58	-21.60	-18.17	-11.63	-21.81	14.29
<b>India</b>											
<i>Baisakhi</i> crop	10.24	-15.20	-15.19	-6.20	-22.63	5.90	-1.39	-13.09	-16.68	-12.36	11.42
<i>Katki</i> crop	-9.07	-11.98	-4.99	-0.24	-12.30	14.55	2.11	9.68	-21.68	0.52	-1.47
<i>Rangeeni</i> 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.

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 (**Figure 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.

**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	Decade 1980s	Decade 1990s	Decade 2000s	Decade 2010s	Instability Indices	Z Statistics
	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		
<b>Central and North Eastern Plateau Sub Zone IV</b>							
<i>Baisakhi</i> crop	-0.52	-11.40	-5.55	-24.08	-5.88	47.05	6.38
<i>Katki</i> crop	3.00	4.03	-1.61	-11.08	-12.73	52.15	3.00
<i>Rangeeni</i> strain	0.21	-8.31	-4.17	-19.41	-8.38	37.08	5.46
<b>Western Plateau Sub Zone V</b>							
<i>Baisakhi</i> crop	-3.88	-7.49	3.64	-23.05	-15.12	44.83	4.53
<i>Katki</i> crop	-1.11	5.82	2.12	-7.83	-15.90	64.65	4.42
<i>Rangeeni</i> strain	-2.81	-4.81	4.01	-17.38	-15.58	42.17	3.72

South Eastern Plateau Sub Zone VI							
<b>Baisakhi crop</b>	-7.24	-0.60	-12.47	-30.83	-8.98	70.99	7.59
<b>Katki crop</b>	-10.54	19.27	-2.48	-23.74	-15.84	77.38	7.94
<b>Rangeeni strain</b>	-7.68	4.16	-8.21	-27.12	-11.30	63.09	7.70
All Jharkhand							
<b>Baisakhi crop</b>	-2.66	-7.98	-2.74	-24.28	-6.23	37.79	4.49
<b>Katki crop</b>	-1.28	9.06	-0.67	-10.58	-11.22	49.69	2.19**
<b>Rangeeni strain</b>	-2.08	-4.50	-2.02	-19.21	-8.37	32.12	3.47
All India							
<b>Baisakhi crop</b>	-3.87	-4.75	-1.81	-6.08	-3.25	26.10	-
<b>Katki crop</b>	-4.59	6.43	0.26	-3.61	1.81	36.62	-
<b>Rangeeni strain</b>	-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.

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 to 120 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* (2014). 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 (Yogi *et al*, 2016). Jaiswal and co-workers (2020) 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.

### CONCLUSIONS

At present India is the leading lac-producing country in the World and has a lion's share in processing and value addition with the existing industrial infrastructure. 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. lac production in India. Although natural enemies of lac insects include pathogens, parasites and predators also affect lac production adversely. 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 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, 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.

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## 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)