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Impact of biotic and abiotic factors on lac production and peoples' livelihood improvement in India-An overview

S. Sarvade*
College of Agriculture, Balaghat, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh (482 004), India
R. K. Panse
College of Agriculture, Balaghat, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh (482 004), India
S.K. Rajak
College of Agriculture, Balaghat, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh (482 004), India
V. B. Upadhyay
College of Agriculture, Balaghat, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh (482 004), India

*Corresponding author. E-mail: somanath553@gmail.com

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Abstract:
In India, Madhya Pradesh is the third largest lac producing state after Chhattisgarh and Jharkhand, as they contribute 12, 16 and 60%, respectively in total country's lac production. Lac is produced in ten out of eleven agro-climatic zones of Madhya Pradesh. In total lac production of the state, *Baisakhi* (*Butea monosperma*, inoculated in October-November) crop contributes 76% followed by 19% by *Katki* (*Butea monosperma*, inoculated in June-July), 3% by *Aghani* (*Schleichera oleosa*, inoculated in June-July) and 2% by *Jethwi* (*Schleichera oleosa*, inoculated in January-February). Ranchi was leading lac producing district followed by Simdega, Gumla, Khunti of Jharkhand and Seoni district of Madhya Pradesh. Increasing summer temperature up to 45 ^{0}C, the country's lac production was declined from 20,050 tons in 2003-04 to 16978 tons in 2014-15. In case of biotic factors, *Tachardiaephagus tachardiae* and *Tetrastichus purpureus* are the most abundant lac associated parasites and *Eublemma amabilis* and *Pseudohypatopa pulverea* are the most destructive key predators of lac insects. By combating these hindrances, lac cultivation generated an employment for 16-160 man days. Lac cultivation produces maximum gross return (Rs. 9,77,600) from 100 Kusum host plants, and the highest Benefit-Cost (6.80) ratio was recorded for *Ber-kusumi (Ziziphus mauritiana- Schleichera oleosa)* crop in Ranchi, Jharkhand. In this context, the study finds out obstacles in lac production of India and suggests some control measures to improve lac producing peoples' livelihood.

Keywords: Employment generation and income generation, Lac production, *Laccifer lacca*, parasites, predators.

INTRODUCTION

Lac is a natural, biodegradable, non-toxic, odourless, tasteless, non-injurious to health and hard resinous protective secretion of tiny lac insect, *Kerria lacca* (Kerr.). *Coccus lacca* Kerr, *Chermes lacca* Roxburgh, *Carteria lacca* Signoret, *Lakshadia indica* Mahdihassan, *Tachardia lacca* Chamberlin and *Laccifer lacca* Cockerell are synonyms of the *Kerria lacca* (Kerr.). The bulk of commercial lac is produced by *Laccifer lacca* (Kerr) insect in India, which belongs to the family Lacciferidae, super family Coccoidea, suborder Homoptera and order Hemiptera. Out of the nine genera and 99 species of lac-insects reported from all over the world; 2 genera and 26 species were found in our country, representing 26.3% of the known lac-insect species diversity. But, much confusion prevails regarding their exact identity, and it is possible that many of them are only strains or varieties of *L. lacca*. National Lac Insect Germplasm Centre (NATLIGEC) of the Indian Institute of Natural Resins and Gums (IINRG) maintains 72 lines of lac-insects which include 14 cultivated, 35 natural populations, 22 cross bred/ inbred/ selected and one exotic line (IINRG, 2014).
Some species found in India, also occur in other countries. *L. albizziae* is found in Ceylon, whereas, *L. chinensis* is the chief source of commercial lac in Thailand. The *L. lacca* is found in Burma, Cambodia, Laos, North Vietnam, China, Formosa, Indonesia, Philippines, Malaya, Pakistan, Nepal, Sikkim and Bhutan (Jaiswal and Sharma, 2011).
On an average three hundred thousand insects

produce 1 Kg of lac resin. Two strains of the lac insect i.e. *Rangeeni* (*Butea monosperma; Ziziphus xylopyra*) and the *Kusumi* (*Schleichera oleosa; Ziziphus mauritiana; Acacia catechu*) were commonly recognized in India. Each strain completed its life cycle in six months, but the seasons of maturity differ considerably. Thus in the case of *Rangeeni* strain, *Katki* crop (*Butea monosperma*, inoculated in June-July) is harvested in October-November and *Baisakhi* crop (*Butea monosperma*, inoculated in October-November) is obtained in June-July. Usually as a general practice, *Baisakhi* crop is harvested earlier in April or May as *Ari* i.e., in immature state of development. Similarly, in the case of *Kusumi* strain, *Aghani* crop (*Schleichera oleosa*, inoculated in June-July) is harvested in January-February and *Jethwi* crop (*Schleichera oleosa*, inoculated in January-February) is obtained in June-July. The present study was aimed to determine the impact of biotic and abiotic factors on the production of lac on different host plants.

Lac production: Lac insects can be nurtured on more than 400 plant species. Whereas, around hundred plants species have been recorded in India, on which lac insets grow for large scale lac production. The host plants for cultivation/raising of *Rangeeni* and *Kusumi* strains of lac insect is given in Table 1. Palas and ber were widely grown for raising *Rangeeni* crop, whereas kusum host plant for *Kusumi* crop. The list of lac host plants is given in Table 2 by accessing publications/ reports of researchers from different parts of India.

Lac production of India was 16978 tonnes in 2014-15, where 32.31 % was contributed by *Aghani,* 26.36% by *Jethwi*, 23.57% by *Baisakhi*, and 17.76 % by *Katki* crop (Yogi *et al.,* 2017). The Jharkhand state alone contributes around 60% in India's total lac production, so it is known as 'Lac State of India'. Chhattisgarh and Madhya Pradesh are the second and third largest lac producing states, respectively. Their contribution was 16 and 12 % in India's lac production during 2013-14. Maharashtra contributes around 6% and also 6% by rest of the states of India (Fig. 1).

Bokaro, Dhanbad, Giridih, Khunti, Ranchi, Simdega and West Singhbhum are the lac producing districts of Jharkhand, whereas Seoni and Balaghat are the main lac producing districts of Madhya Pradesh. In case of Madhya Pradesh, lac is produced in ten out of its eleven agro-climatic zones. Jaitahari, Keshwahi, Kotma, Venkatnagar areas of Anuppur; Baihar, Katangi, Lalbarra, Lamta, Langi, Parashwada, Waraseoni areas of Balaghat; Damoa area of Chhindwara; Bazak, Bhanupur, Karanjia, Ramnagar, Rampur areas of Dindori; Bankhedi, Babai, Daggrai, Darawpadaw, Hapa, Jonahata, Kekra, Lokamti, Pipariya areas of Hoshangabad; Bichhia, Chabbi, Ghughari, Kalpi, Mahegaon, Mavai, Nainpur, Narainganj, Navas-Bablia areas of Mandla; Chichli, Godarwara, Kalakhar, Kalyanpur, Nayakheda, Salechauka areas of Narshinghpur; Barghat, Ghansore, Kahani, Kanewara, Keolari, Khamaria, Khari areas of Seoni; Burhar, Jaitpur, Sohagpur areas of Shahdol are the main lac producing areas of different districts/clusters of Madhya Pradesh (Table 3).

Baisakhi strain contributes 76% followed by 19% by *Katki*, 3% by *Aghani* and 2% by *Jethwi* in total lac production of Madhya Pradesh (Fig. 3). Among these districts, Seoni contribute about 48% of the total stick lac production in Madhya Pradesh (Table 4) and it stands at 5th position in India after Ranchi, Simdega, Gumla and Khunti districts of Jharkhand (Fig. 2). The majority of the lac producing districts are predominantly tribal, have high rainfall (100 to 140 cm) with soil varying from shallow medium black, medium deep black to mixed red and black (Yogi *et al.,* 2017). Among all the lac producing districts of Madhya Pradesh, only five districts i.e. Balaghat, Chhindwada, Hoshangabad, Mandla and Seoni have market places. Whereas, Indore and Hoshangabad only have lac processing units (Table 5).

Lac production in India from the year 2003-04 to 2014-15 showed reducing trend. Lowest production recorded in the year of 2010-11 and highest production in 2013-014. In case of Madhya Pradesh, lowest lac production was also reported in 2010-11, whereas highest in 2007-8 (Fig. 4). This may be due to fluctuations in climatic factors, however the impact of climatic parameters on lac production was undistinguishable. Some researchers reported that temperature is the most important climatic factor affecting lac production (Mishra *et al.,* 1999a, 1999b; Bhagat and Mishra, 2002; Sharma, 2007; Thomas, 2010), whereas Pal *et al.* (2009; 2011) reported that the high summer temperature is the main cause of annual national lac production.

Factors affecting lac insects: Lac crop is vulnerable to both biotic and abiotic stress conditions (Bhagat and Mishra, 2002; Jaiswal *et al*., 2008). Environment of an agro-ecosystem is largely governed by interactions between abiotic and biotic components. The abiotic stress factors alter the effects of biotic stresses and are most harmful when occur in combination (Mittler, 2006).

Abiotic: Climate of India has undergone significant changes showing increasing trends in annual temperature with an average of 0.56^{0}C rise over last 100 years (IPCC, 2007; Rao *et al*., 2009; Anonymous, 2010). The production of lac is greatly influenced by the climatic factors, like temperature, rainfall, humidity, wind etc, (Nicholson, 1925; Bhagat and Mishra, 2002). The temperature is the most important climatic factor affecting lac production (Mishra *et al*., 1999a, 1999b; Bhagat and Mishra, 2002; Sharma, 2007; Thomas, 2010). The annual national lac production declined from

Table 1. Host plants for the cultivation of two lac insect strains in India.

Strain	Host plants
Rangeeni	Palas/dhak (*Butea monosperma*), Ber (*Ziziphus mauritiana*), Ghont/kat-ber (*Ziziphus xylopyra*), Porho/khunia/jahrphali (*Ficus cunia*), Barh/bargad/banyan (*Ficus benghalensis*), Peepal (*Ficus religiosa*), Arhar (*Cajanus cajan*), Tapria siris (*Albizia lucida*), Panjan/sandan (*Ougeinia oojeinensis*), khair (*Acacia catechu*) for ari, Pansaura (*Grewia serrulata* DC.)
Kusumi	Kusum (*Schleichera oleosa*), Khair (*Acacia catechu*), Ber (*Ziziphus mauritiana*)

(Source: Chattopadhyay, 2011; Yogi *et al.,* 2017)

Table 2. Host plants for cultivation of lac insects in different states of India.

State	Important lac hosts reported	Source
All parts of India	*Butea monosperma, Ficus religiosa, F. glomerata, F. benghalensis, F. infectoria*	Sharma *et al.,* 1997; Shrivastava, 2007; Anonymous, 2010; Chattopadhyay, 2011; Paul *et al.,* 2013
West Bengal	*Ziziphus mauritiana, B. monosperma, Ficus spp., Samanea (Albizia) saman*	Sharma *et al.,* 2006; Anonymous, 2010; Chattopadhyay, 2011
Punjab	*Zizyphus mauritiana, A. nilotica, Ficus spp.*	Sharma *et al.,* 2006; Anonymous, 2010; Chattopadhyay, 2011
Jharkhand	*Butea monosperma, Schleichera oleosa, Ziziphus mauritiana, Flemingia semialata* Roxb., *Albizia lucida, Acacia catechu, Croton oblongifolius, Ficus* spp., *Protium serratum, Litchi chinensis, Mangifera indica, Santalum album, Thea chinensis*	Sharma *et al.,* 2006; Anonymous, 2010; Chattopadhyay, 2011; Paul *et al.,* 2013; Meena *et al.,* 2014; IINRG, 2014
Chhattisgarh	*Z. mauritiana, Z. xylopyra, Acacia catechu, B. monosperma, S. oleosa*	Sharma *et al.,* 2006; Anonymous, 2010; Chattopadhyay, 2011
Madhya Pradesh	*Schleichera oleosa, Ziziphus jujuba, Z. mauritiana* (Lamb.)	Anonymous, 2010; Chattopadhyay, 2011; Shah *et al.,* 2014;
Uttar Pradesh	*Z. zylopyra, A. nilotica, B. monosperma, Z.mauritiana*	Sharma *et al.,* 2006; Anonymous, 2010; Chattopadhyay, 2011
Orissa	*Schleichera oleosa, Z. mauritiana*	Sharma *et al.,* 2006; Anonymous, 2010; Chattopadhyay, 2011
Karnataka	*Schleichera oleosa, Acacia spp., Ficus spp., Shorea talura*	Sharma *et al.,* 2006; Anonymous, 2010; Chattopadhyay, 2011
Tamil Nadu	*Schleichera oleosa, Shorea talura, A. nilotica, B. monosperma, Z. mauritiana*	Sharma *et al.,* 2006; Anonymous, 2010; Chattopadhyay, 2011
Rajasthan	*Acacia nilotica, B. monosperma, Ficus spp., Z. mauritiana, Albizia saman*	Sharma *et al.,* 2006; Paul *et al.,* 2013; IINRG, 2014
Gujarat	*Acacia nilotica, A. catechu, B. monosperma, Z. mauritiana, Albizia saman*	Sharma *et al.,* 2006; Paul *et al.,* 2013; IINRG, 2014
Assam	*Ficus cunia, Ficus rumphii, Cajanus cajan, Albizia lucida, Grewia* spp., *Leea* spp., *Moghania macrophylla, Kydia calycina; Flemingia macrophylla*	Sharma *et al.,* 2006; Chattopadhyay, 2011
Maharashtra	*Acacia catechu, A. nilotica, B. monosperma, S. oleosa, Z. mauritiana*	Sharma *et al.,* 2006;
Andhra Pradesh	*B. monosperma, Albizia saman, Peltophorum ferrugenium*	Sharma *et al.,* 2006;

20,050 tons in 2003-04 (Pal *et al*., 2009) to 16,978 tons in 2014- 15 (Yogi *et al.,* 2017) due to high summer temperatures (Pal *et al*., 2009). Meteorological factors play an important role in the population fluctuation of sucking insect pests (Gogoi and Dutta, 2000; Murugan and Uthamasamy, 2001; Panickar and Patel, 2001). High rainfall during the month of July influences lac insect settlement (Patel *et al.,* 1997). Changes in rainfall patterns, frequent droughts and floods, increased intensity and frequency of cold waves, outbreaks of insect pests and diseases area affecting many biological systems profoundly (IPCC, 2007) and lac sub-sector is also affected equally.

Biotic: The lac insect during its whole life cycle spends only a few hours of active mobility and after that spends a complete sedentary life. Hence they are prone to be attacked by many insect predators and parasitoids, causing substantial damage to the lac crop qualitatively and quantitatively (Singh *et al*., 2011a). The predators of lac insect include both vertebrate and invertebrate species (Mohanta *et al.,* 2014; Shah *et al.,* 2015).

Vertebrate: The important vertebrate enemies are squirrels and rats. The damage caused by those enemies can be as serious as 50% brood sticks were damaged by them. Squirrels are active during the day time and the damage by them is more common under forest condition. Rats are active in night time and the damage usually occurs near about the villages.

Invertebrates: It has been estimated that on an

Table 3. Major lac producing areas and districts of Madhya Pradesh, India.

S. N.	Name of district	Major lac producing areas
1	Anuppur	Jaitahari, Keshwahi, Kotma, Venkatnagar
2	Balaghat	Baihar, Katangi, Lalbarra, Lamta, Langi, Parashwada, Waraseoni
3	Chhindawada	Damoa
4	Dindori	Bazak, Bhanupur, Karanjia, Ramnagar, Rampur
5	Hosangabad	Bankhedi, Babai, Daggrai, Darawpadaw, Hapa, Jonahata, Kekra, Lokamti,Pipariya
6	Mandla	Bichhia, Chabbi, Ghughari, Kalpi, Mahegaon, Mavai, Nainpur, Narainganj, Navas-Bablia
7	Narshinghpur	Chichli, Godarwara, Kalakhar, Kalyanpur, Nayakheda, Salechauka
8	Seoni	Barghat, Ghansore, Kahani, Kanewara, Keolari, Khamaria, Khari
9	Shahdol	Burhar, Jaitpur, Sohagpur

(Source: Yogi *et al.,* 2017)

Table 4. Stick lac production (in tons) scenario in main lac producing district of Madhya Pradesh 2013-14, India.

Name of district	Name of lac crops				Total production
	Baisakhi	Jethwi	Katki	Aghani	
Annuppur and Shahdol	5	2	2	1	10
Balaghat	700	5	180	5	890
Chhindwada	15	6	7	8	36
Dindori	45	8	7	5	65
Hoshangabad	15	8	5	5	33
Mandla	50	2	40	15	107
Narsinghpur	10	2	2	2	16
Seoni	1000	5	170	10	1185
Others	70	10	55	20	155
Total	**1910**	**48**	**468**	**71**	**2497**

(Source: Yogi *et al.,* 2017)

Table 5. Major lac markets and processing centres in Madhya Pradesh, India.

Sr. No.	District	Market place	Processing centre	Quantity processed (tons) in 2013-14
1	Balaghat	Waraseoni, Katangi, Lalbarra and Langi	-	
2	Chhindawada	Damoh	-	
3	Hoshangabad	Pipariya	-	
4	Mandla	Bichhia and Nainpur	-	
5	Seoni	Barghat, Keolari and Khari	-	
6	-	-	**Indore**: - For: Seedlac, Bleached lac)	56
			Hoshangabad (Bankedhi):- For Seedlac	18

(Source: Yogi *et al.,* 2017)

average, up to 30-40% of the lac cells are destroyed by invertebrate enemies. The enemy attack can be as serious as it results in failure of crop. These are two kinds of enemy insects:

Parasites: All the parasites so far reported on lac are insects. Parasite accounts for a damage of 5-l0%. Till date about 19 parasites of lac insect have been recorded in India. The list of predators of lac insects are given in Table 6. *Tachardiaephagus tachardiae* and *Tetrastichus purpureus* were the most abundant lac associated parasites (Sharma, 2017). They lay eggs in lac cells, grubs (larvae) hatching out and feed on the lac insect.

Sharma *et al*., (2007) studied super parasitism in *K. lacca,* its implications on fecundity and resin producing efficiency. Parasitoids of lac insect were affect adversely on the resin yield and the fecundity of the insects, particularly during rainy seasons. The average reduction in resin production due to parasitism varied between 17.25-39.80 % in *Rangeeni* and 25.24-37.91 % in *Kusmi*. According to Narayanan (1962) super parasitism can occur but typically one parasite larva occurs in single scale. The parasitoids have life cycle of about one month, compared to 4-9 months for *K. lacca. Tachardiaephagus tachardiae, Aprostocetus purpureus, Coccophagus tschirchii* have 10-12 generation on commercial lac in a year, compared to 9 generation for *Paraechthrodryinus clavicornis* Cameron, an encyrtid, that can be either a primary or secondary parasitoids. *T. tachardiae* and *A. purpureus* are the most abundant lac associated parasitoids belongs to the order hymenoptera (Chattopadhyay, 2011).

Table 6. List of lac insect parasites with their family.

S. N.	Name of the parasites	Family
1	*Anicetus dodonia*	Encyrtidae
2	*Atropates hautefeuille*	Encyrtidae
3	*Aphrastobracon flavipennis*	Encyrtidae
4	*Bracon greeni*	Encyrtidae
5	*Campyloneurus indicus*	Encyrtidae
6	*Coccophaqus tchirchii*	Aphelinidae
7	*Erencyrtus dewitzi*	Encyrtidae
8	*Eupelmus tachardiae*	Eupelmidae
9	*Eurymyiocnema aphelinoides*	Aphelinidae
10	*Lyka lacca*	Encyrtidae
11	*Marietta javensis*	Aphelinidae
12	*Parageniaspis indicus*	Encyrtidae
13	*Parechthrodryinus clavicornis*	Encyrtidae
14	*Protyndarichus submettalicus*	Encyrtidae
15	*Tachardiaephagus tachardiae*	Encyrtidae
16	*Teachardiobius nigricans*	Encyrtidae
17	*Aprostocetus(Tetrastichus) purpureus*	Eulophidae

(Source: Sharma, 2017)

Table 7. List of lac insect predators with their family.

S.N.	Name of predator	Family
1	*Eublemma amabilis*	Noctuidae
2	*E. coccidiphaga*	Noctuidae
3	*E. cretacea*	Noctuidae
4	*E. scitula*	Noctuidae
5	*Pseudohypatopa pulverea*	Blastobasidae
6	*Catablemma sumbavensis*	Blastobasidae
7	*Cryptoblabes ephestialis*	Blastobasidae
8	*Phroderces falcatella*	Cosmoptery-gidae
9	*Lacciferophaga yunnanea*	Momphidae
10	*Chrysopa madestes* Neuroptera	Chrysopidae
11	*C. lacciperda*	Chrysopidae
12	*Berginus maindroni*	Mycetopha-gidae
13	*Silvanus iyeri*	Cucujidae
14	*Tribolium ferrugineum*	Tenebrionidae
15	*Phyllodromia humbertiana*	Blattellidae
16	*Ischonoptera fulvastrata*	Blattellidae

(Source: Mohanta *et. al.,* 2014; Sharma, 2017)

Table 8. Employment generation from lac cultivation in untrained lac-growers and trained lac-growers.

Particulars'	Palas (50 hosts)	Beri (50 hosts)	Kusumi(10 hosts)	Total M.D.
	Man-days			
Human labour (Untrained lac-growers)	24.8	47.2	41.2	113.2
(H.L.)Trained lac-growers	34.2	69.5	50.0	153.7

(Source: Pal, 2009)

Table 9. Employment generation from lac cultivation.

Particulars'	Palas (100 hosts)	Ber-Rangeeni (100)	Ber-Kusumi (100)	Kusum (40 hosts)
	Man-days			
Male	28-55	39-67	87	108-147
Female	17-35	77-110	58	85-160

(Source: Jaiswal *et al.,* 2011; 2013)

Table 10. Economic benefits from lac cultivation.

Particulars'	Kususm (100)	Palas (100)	Ber-Rangeeni (100)	Ber-kusumi (40)
Gross return (Rs)	9,77,600	1,25,000	4,20,000	8,55,000
Cost (Rs)	1,87,954	29,399	97,471.5	1,09,642
Net return (Rs)	7,89,646	95,601	3,22,529	7,45,358
B:C ratio	4.20	3.25	3.31	6.80

(Source: Jaiswal *et al.,* 2011; 2013)

Table 11. Income generation from lac cultivation in untrained lac-growers and trained lac-growers.

Host Plant	Particular	Untrained Lac-growers (Rs.)	Trained Lac-growers (Rs.)	Increase by trained lac -growers (%)
Palas(50)	*Cost of cultivation*	2566	3533	38
	Net return	4886	8169	67
	Input-output ratio	2.90	3.31	14
Ber (50)	*Cost of cultivation*	4674	7961	70
	Net return	9771	20914	114
	Input-output ratio	3.09	3.63	17
Kusum(10)	*Cost of cultivation*	6881	11042	60
	Net return	16284	33128	103
	Input-output ratio	3.37	4.0	19

(Source: Pal *et al.,* 2009)

Predators: The predators on the other hand, are more serious and may cause damage to the cells in a crop up to 30-35 %. About 20 predators have been reported from different parts of the country, which include vertebrates as well as insects. The list of predators of lac insects is given in Table 7. *Eublemma amabilis* and *Pseudohypatopa pulverea* were the most destructive key pests of lac in-

Table 12. Comparative study of net income derived from farm activities, non-farm activities and lac activities in Purulia district of West Bengal. (Source: Mandal and Sarkhel, 2014)

Farm Size Group	Net Income From Farm Activities (In Rs.)	Net Income From Non-Farm Activities (In Rs.)	Net Income From Lac Activities (In Rs.)	Total Income (In Rs.)
Marginal	3,78,282.50 (21.51%)	4,20,000 (23.88%)	9,60,158.50 (54.61%)	17,58,441.00
Small	8,32,385.00 (42.51%)	1,71,000.00 (8.73%)	9,54,597.30 (48.76%)	19,57,982.30
Medium	8,92,682.50 (38.29%)	1,43,000 (8.73%)	12,95,706.60 (55.58%)	23,31,389.10
Total	21,03,350.00 (38.29%)	7,34,000.00 (12.14%)	32,10,462.40 (53.08%)	60,47,812.40

(Figures within the parentheses indicate percentage to total income.)

sects but their incidence may vary from season to season, place to place and crop to crop (Chattopadhyay, 2011; Khopragade *et al.,* 2012; Sharma, 2017).

***Eublemma amabilis* Moore (Lepidoptera: Noctuidae):** It is widely distributed in all major lac growing regions of the country and is considered to be the most destructive predator of lac insect. The moth lays greyish white, round eggs, depressed in the centre and with beautiful sculpturing of the chorion. Eggs were laid singly. The first instar larva measures 0.51 to 0.54 mm in length. The newly hatched larva gets either through one of the openings or by tunnelling a hole through the encrustation. The attacked lac cell becomes hollow containing pink coloured discs of excreta and can be easily differentiated from the healthy cells. A single larva can destroy 40-60 lac insect cells during various instars before pupation.

Rahman *et al*. (2009) reported that the single larva of *E. amabilis* damages 42-50 mature lac cells before pupation and causes more injury to the *Kartki* crop than to the *Baishakhi* crop.

***Pseudohypatopa pulverea* Meyr *(Lepidoptera: Blastobasidae)*:** This predator is also widely distributed and found in all the lac growing areas of the country. Adult moth is blackish in colour and smaller in size than *E. amabilis*. Predator feeds on the live and dead lac insects and it found in large numbers in stored lac as well. Eggs of *P. pulverea* are oval in shape and laid singly on the lac insect. Newly hatched larva is about 1.35 mm in length. It feeds on the lac larvae and spins a loose web. A single predator has a capability to destroy 45 to 50 mature lac cells. It is considered to be very important, as it inflicts damage to the developing lac crop and also responsible for qualitative and quantitative deterioration of the stored lac.

Two lepidoptera predators i.e. *Eublemma ambilis* and *Pseudohypatopa pulverea* causes 30-40 % damage to lac crop (Glover, 1937; Mishra, 2002; Jaiswal *et al*., 2008; Singh *et al*., 2009). The monophagous predator (*E. amabilis*) of lac insect, causes damage to lac crop up to 20 to 25 % (Narayanan, 1962).

***Chrysopa spp.* (Neuroptera: Chrysopidae):** Larvae of the predator considered to be sporadic pest and prey upon various stages of the lac insect. Females lay eggs either on the lac encrustation, on leaves or any part of the host trees. Larvae emerge out from the egg shell with the aid of an "egg buster", climb down the stalk and start feeding immediately on the insect by inserting its long pair of mandibles.

The sporadic neuropteran (*Chrysopa* spp) is the most ubiquitous predator of the lac insect causing considerable loss, especially in the winter crops of *Kusmi*. A severe infestation by *Chrysopa* spp may lead to the loss of whole winter season crop, if not managed properly (Singh *et al*., 2011b). The first,

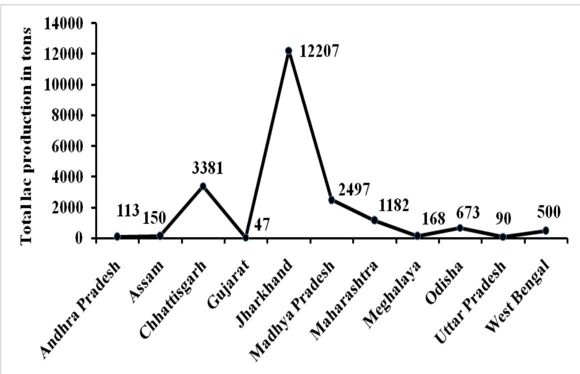

Fig. 1. *Status of lead lac producing states of India during 2013-14 (in tons) (Source: Yogi et al., 2017).*

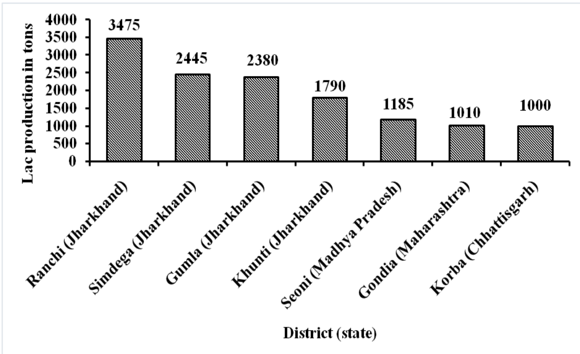

Fig. 2. *First seven high lac producing districts in different states of India (2013-14)(Source: Yogi et al., 2017)*

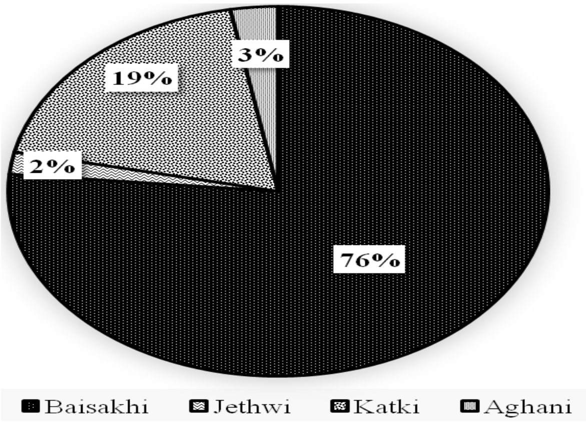

Fig. 3. *Strain wise contribution (%) in total lac production (2013-14). (Source: Yogi et al., 2017).*

second and third instar larvae of *Chrysopa madestes* can consume 20, 24 and 74 mature females of lac insect per day, respectively (Mehra, 1965, 1966).

Microbial flora associated with lac insects: Two types of micro-flora viz. bacteria and fungi are associated with the lac insects. Bacteria act as a lac hosts and they could be symbiotic or pathogenic. Besides insect enemies, lac crop yield suffers significantly due to other biotic agents particularly fungi. Fungal infection in lac culture causes severe losses of lac yield by i) Killing the lac insects through inhibiting respiration, ii) Hindering mating process, iii) Blocking larval emergence, iv) Affecting lac host efficiency.

Lac culture during rainy season is prone to fungal attack particularly when grown on Ber (*Ziziphus mauritiana*), Kusum (*Schleichera oleosa*). It may be due to their steady and spreading crown. Three species of fungi belonging to family Eurotiaceae and Aspergillaceae viz. *Aspergillus awamori, A. terricola* and *Penicillium citrinum* were reported to cause maximum loss in lac production. *A. awamori* and *P. citrinum* are black and greenish in colour, respectively. They were observed to make a continuous cover on lac insect and thereby blocking their breathing pores which leads to mortality of lac insects. A pathogenic fungus*, Pythium spp*. causes a heavy mortality of lac larvae which fail to enclose and dead in clusters within the female resinous cells.

Prevention and control of insect enemies

Preventive measures: Brood lac, free from parasite and predator should be used for inoculation. Self-inoculation of lac crops should be avoided as far as possible. Inoculated brood bundles should be kept on the host tree for a minimum period only. Phunki (empty brood lac sticks) should be removed from the inoculated trees within 2 – 3 weeks. All the collected lac from the tree and all phunki brood lac (after use as brood lac) should be scraped or fumigated at once. Cultivation of *Kusmi* strain of lac should be avoided in predominantly *Rangeeni* area and *vice versa*.

Mechanical control: Use of 60 synthetic mesh net (brood bag) to enclose brood lac for inoculation purposes. It can reduce infestation of enemy insects. The emerging lac larvae easily crawl out from the minute pores of the net and settle on the twigs of the lac host plants. Whereas the emerging adult predator enemies cannot move out of the brood bags and get entrapped within the net (Malhotra, 1983). This can check the egg laying by the predator moths on the new crop. C*hrysopa spp*. attacking *Kusmi* crop raised on Kusum (*S. oleosa*) during the months of August and September can be trapped by placing a light trap.

Cultural and physical management: Keeping the brood sticks inside a 60 mesh nylon net bag during inoculation traps parasitoids and predators, while allowing only lac crawlers to come out for settlement on new shoots (Malhotra, 1983). Khobragade *et al*., (2012) while conducting a farmer participatory trial on the predator of *K. lacca* management revealed two options for the man-

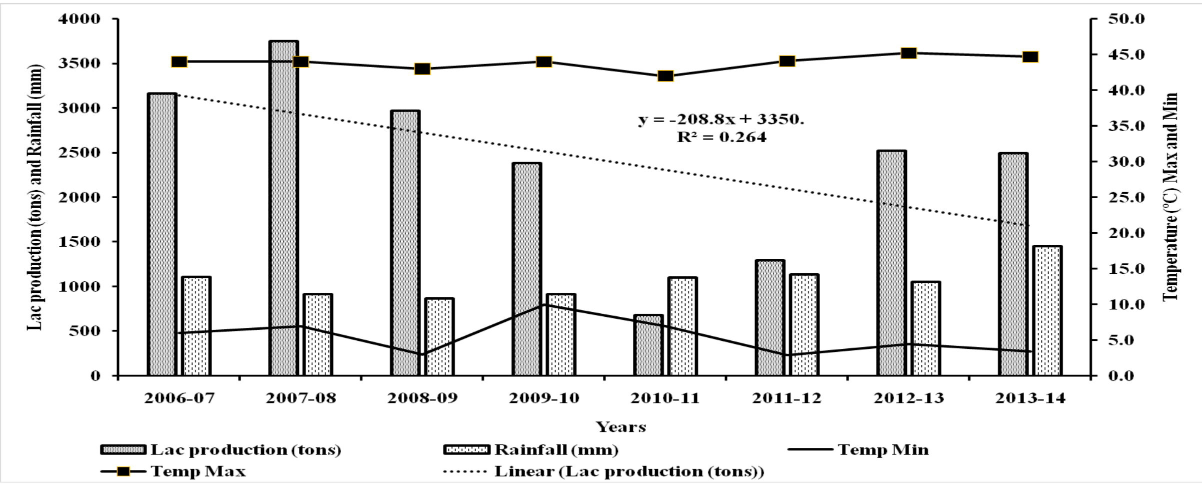

Fig. 4. *Lac production with relation to changing climatic conditions. (Source: Yogi et al., 2017; Pal, 2015; Anonymous, 2006, 2007, 2008, 2009, 2010, 2011, 2012 and 2013)*

agement of *E. amabilis*. Lac growers with poor investment capacity and those having their *B. monosperma* tree on the hilly and water scarce areas may opt for 60 mesh nylon net pouch for the management of *E. amabilis* in the lac crop. Whereas those with better financial status and the trees in plain area and sufficient water can opt for a combination of 60 mesh nylon pouches. Planting of *Cassia occidentalis* L. (Family: Leguminosae), a medicinal plant, on the periphery of a plot having *F. macrophylla* bushes resulted in significant reduction in the population of the two Lepidopteran lac insect predators viz. *E. amabilis* and *P. pulverea.* It resulted that the significant increase in brood lac yield.

Chemical control: Application of 0.05% Quinalphos at 30-35 days of the crop has been identified as the most effective dose of insecticide without any adverse effect on the economic attributes of the lac insect (Mishra *et al.,* 1996).

Gupta and Bhattacharya (2007) evaluated the toxicity of naturalyte compound against *Spilarctia oblique* and reported that Spinosad was more active after 48 hr of treatment. Fipronil (0.005 and 0.01%) and Indoxacarb (0.02%) were equally effective as they cause cent per cent larval mortality within 24 hr of treatment with both mode of application (topical application and residual exposure). Ethofenprox (0.02%) was most suitable for protecting lac crop at critical stages against *C. madestes* under field conditions (Jaiswal *et al*., 2007). Toxicity of ethofenprox against first instar larvae of *C. carnea* has been reported by Toda and Kashio (1997).

Microbial control: Use of bio- pesticide such as *Bacillus thuringiensis* at 30-35 days stage of crop was found to be effective microbial control measure for important enemy insects of lac. The suppression of lac predator was due to higher incidence of *Trichogramma chilonis* Ishi which is an egg parasitoid of Lepidopteran insects (Bhattacharaya *et al*., 2006).

Biological control: Two ants' viz. *Camponotus compresus* and *solenopsis geminate* rufa were the most important and promising for biological control of predator enemies of lac. Egg parasitoids viz. *Trichogramma pretiosum, T. chilonis, T. poliae, Trichogrammatoidea bactrae* and *Telenomus remus* have been found to be effective in management of lac predators. *E. amabilis* can be controlled by using natural enemies such as *Componotus compressus* and *Solenopsis geminata* (Rahman *et al*., 2009). Bhattacharya *et al.* (2006) carried out the field evaluation trail for management *of E. amabilis* with three species of the egg parasitoids (*T. achaea, T. exigum and T. ostrinae*). They revealed significant suppression of *E. amabilis* over the control by releasing 75 egg parasitoids per plant in *Kusmi* and *Rangeeni*. They are also equally affective to suppress the population of *E. amabilis* on lac crop raised on the bushy host plant, *F. macrophylla* (Bhattacharya *et al.,* 2007). The presence of ant fauna on lac colony reduced the predator of *E. amabilis* and *P. pulverea* population by 78.66 % (Kumar *et al*., 2007). Ant in the course of collecting and feeding honeydew secreted by lac colony destroyed the eggs of the predators. The extracted essential oils from *Cymbopogon citrates* (lemon grass), *C. martini* (Palmarosa) and *C. nardus* (Citronella) serve as an excellent repellents against *E. amabilis* and *P. pulverea* (Bhattacharya *et al.,* 2008).

(vii) Prevention and control of microbial flora associated with lac insects: Application of fungicides such as Bavistin (Carbendazim 0.05%) and Dithane M-45 (Mancozeb, 0.18%) by dipping the brood lac before inoculation and spraying on standing crop gives significantly better yield. Significant reduction (75% to 84%) in mortality of 2nd instar lac nymphs/ larvae was reported by the application of different concentration of Carbendazim and Aureofungin on *Kusmi* strain of lac insect.

Livelihood improvement

Employments Generation: The impact of training on lac grower's employment was studied by Pal (2009) during the years 2003-04 and 2004-05 in the Ranchi and West Singhbhum districts of Jharkhand. He reported that the increase in employment after training of lac growers in comparison to untrained lac-growers (Table 8). He further found that the employment generation in lac cultivation had increased by about 28.0 % on *palas,* 32.0 % on *ber* and 17.6 % on *kusum* for trained lac-growers. More than 60.0 % of the human labour used in lac cultivation was the family labour in all the three cases. Whereas, some lac growers do not go for engaging labour. Employment generation opportunities which were created and calculated as per field experience, market prices of produce and wage rates. As lac cultivation has very high potential for generating employment opportunity for both men and women, a work study was conducted by Jaiswal *et al.* (2011) and Jaiswal *et al.* (2013) on major lac host trees. They revealed that the lac cultivation generates an employment for 28-55 male and 17-35 female days on *Palas*, 39-67 male and 77-110 female days on *Ber-Rangeeni*, 87 male and 58 female days from *Ber-Kusumi*, 108-147 male and 85-160 female days on *Kusum*.

Income generation: Lac cultivation serves as a complementary and supplementary source of income for improving existing livelihood of the farmers in the states of Jharkhand, Chhattisgarh, Madhya Pradesh, Maharashtra, West Bengal, Odisha and other lac producing states of India. It is also an assured source of income during lean period of agricultural activities and providing additional source of income and cash flow to the marginal, small and large farmers, and sub-forest dwellers in the country. Lac cultivation is simple and required very low investment. It is eminently suited to the farmers living in the vicinity of the forests including women as it demands only their part time attention. With low cost inputs, it gives high returns which make it highly favourable with the farmers.

Income generation through lac cultivation in various host plant viz. Palas, Ber, and Kusum, maximum gross return (Rs. 9,77,600) was generated by 100 Kusum host plants. Whereas only 40 host plants of Ber-Kusumi crop have generate about Rs. 8,55,000 gross return (Table 10). The highest net return was recorded from 100 *Kususm* host plants followed by 40 *Ber-Kusumi* plants, 100 *Ber-Rangeeni* plants and 100 *Palas* plants. The highest output- input ratio (6.80) was found for *Ber-kusumi* crop (Jaiswal *et al.,* 2011; 2013).

The returns from lac cultivation on different host plants under trained and untrained lac-growers condition have been depicted in Table 11. The cost of cultivation and net returns increased in the case of trained lac-growers. The cost of cultivation was increased due to utilization of more labour and broodlac. The cost of cultivation was increased by 38 % in *Palas*, 70 % in *Ber* and 60 % in *Kusum*. While the increase in net return was by 67 %, 114 % and 103 % for *Palas, Ber* and *Kusum*, respectively. The B: C ratio was found to be higher in the case of trained than untrained lac-growers on all the three hosts. Regarding lac cultivation on different hosts, highest B: C ratio was found in *kusum*, followed by *ber* and *palas* (Pal *et al.,* 2009; Pal and Yog, 2014). Comparative study of net income derived from farm activities, non-farm activities and lac activities was conducted in Purulia district of West Bengal during 2009-10 (Mandal and Sarkhel, 2014). They revealed that the net income from lac activities contributed 54.61 % at marginal farmers, 48.76 % at small farmers and 55.58 % at medium farmers (Table 12).

Conclusion

The Jharkhand state of India alone contributes around 60% in total lac production, whereas, Chhatisgarh stands at second and Madhya Pradesh at third in lac producing states, contributing 16 and 12 %, respectively. *Rangeeni* and *kusami* lac were vulnerable to both biotic and abiotic stress conditions. The temperature is the most important climatic factor (abiotic) affecting lac production in India. Changes in rainfall patterns, frequent droughts and floods, increased intensity and frequency of cold waves are the other abiotic factors affecting profoundly lac sub-sector. Among the parasites, *Tachardiaephagus tachardiae* and *Tetrastichus purpureus* are the most abundant lac associated parasites, whereas *Eublemma amabilis* and *Pseudohypatopa pulverea* were the most destructive key predators. The reported losses in lac production due to different biotic and abiotic factors may be managed and minimized through applying different control measures. Lac cultivation serves as both a complementary and supplementary source of income to the existing livelihood options for the farmers in the states of Jharkhand, Chhattisgarh, Madhya Pradesh, Maharashtra, West Bengal, Odisha and other lac producing states of India. Lac cultivation generates an employment for 16-160 man days for different lac crops. Lac cultivation produces maximum gross return of Rs. 9, 77,600 from 100 Kusum host plants, whereas the highest (6.80) B:C ratio was recorded in *Ber-kusumi* crop in Ranchi, Jharkhand. Net income from lac activities contributes 54.61 % at marginal farmers' field, 48.76 % at small farmers' field and 55.58 % at medium farmers' field. The study creates awareness among the lac growing farmers and researchers towards the different obstacles comes while rearing lac insects and their control measures for increasing lac production.

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