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REVIEW ARTICLE

LAC PRODUCTION, CONSTRAINTS AND MANAGEMENT- A REVIEW

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ABSTRACT

Lac- a natural resin of wide industrial applications, is a secretion of Lac insect *Kerria lacca* Kerr belonging to the family Tachardiidae (Kerriidae) and order Hemiptera. Lac consists of resin, wax and dye, thus has a wide range of applications in food, pharmaceuticals, cosmetics, perfumes, varnishes, paints, polishes, adhesives, jewellery and textile dyes, since ancient times. India is the largest producer of Lac in the world with a production of 20,000 tons and 75 per cent of it is exported. Lac sector has a socio-economic importance as it employs 3-4 million people mostly forest dependant and tribals. Lac production promotes biodiversity and conserves host plants. Lac crop being vulnerable to both biotic and abiotic factors results in lowering of the yield. The present review of the work is to help understand earlier work done to generate information to increase the production.

INTRODUCTION

Lac- a natural resin of wide industrial applications, is a secretion of Lac insect *Kerria lacca* Kerr belonging to the family Tachardiidae (Kerriidae) and order Hemiptera. Lac consists of resin, wax and dye, thus has a wide range of applications in food, pharmaceuticals, cosmetics, perfumes, varnishes, paints, polishes, adhesives, jewellery and textile dyes, since ancient times. Lac is a cash crop of commercial importance providing an importance source of livelihood to millions of resource poor grower inhabiting tribal dominated forests and sub-forests regions of the country. The agricultural production continues to be constrained by a variety of biotic (e.g., pathogens, insects and weeds) and abiotic (e.g., drought, salinity, cold, frost and water-logging) factors that can significantly reduce the quantity and quality of crop production (Wang *et al*., 2013). Abiotic stress factors such as heat, cold, drought, salinity, and nutrient stress have a huge impact on world agriculture, as they reduce average yields by more than 50 per cent for most major crop plants (Wang *et al*., 2003). Analysis of lac production trends in India during past few years showed a decline in production which is attributed to the biotic stress as well as climatic patterns unfavorable for lac crop. The production of the lac is greatly affected by abiotic stress factors. The annual national lac production declined from 20,050 tons in 2003-04 (Pal *et al*., 2009) to 16,495 tons in 2009- 10 (Pal *et al*., 2011). Since the lac insect spends only few hours of active mobility and thereafter spends a complete sedentary life, they are prone to be attacked by many insect pests causing considerable loss to the lac crop. The average loss by the insect pests in lac culture is known to be far greater than what is usually witnessed in other agricultural crops. The loss caused to lac crop by the insect predators amounts to about 35-45 % annually. Keeping in view the severity of damage caused, the present review of the work is conducted to help understand earlier work done to generate information to increase the production.

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Lac insect

Lac is one of the most valuable gifts of nature to man, the only resin of animal origin secreted by a tiny scale insect, *K. lacca* belonging to the family Tachardiidae (Kerriidae), superfamily Coccoidea of the order Hemiptera (Pal, 2009; Mohanta *et al*., 2012). Family Kerridae consists of nine genera, while the number of species reported vary from 87 (Sharma and Ramani, 1999), 90 (Varshney, 2009) to 100 species (Ben-Dov and Lit, 1998). Two generas are found in India, while genus *Kerria* is commercially important as it has 19 species of industrial importance (Sharma and Ramani, 1999).

K. lacca, the most important and widely exploited insect for lac cultivation in India is represented by two strains or infra sub-specific forms, the *Rangeeni* and *Kusmi* strain, which differ by host preference, life cycle pattern, the quality and amount of lac produced (Kapur, 1962; Ramani, 2005). The *Kusmi* strain is grown on *Kusum* (*Schleichera oleosa*) while *Rangeeni* strain thrives on hosts other than *Kusum* (Sharma *et al*., 2006; Mohanta *et al*., 2012). In case of *Kusmi* strain, two crops are- *Jethwi* (harvested in June/July) and *Aghani* (in January/February) while in case of *Rangeeni,* two crops are- *Katki* (harvested in October/November) and *Baishakhi* (in May/June) (Chattopadhyay, 2011). The term lac seems to have been derived from the Sanskrit word *Laksha* meaning a hundred thousand (Ogle *et al*., 2006) and is suggestive of the large number of insects involved in its production. The description of the lac insect and its host plant– *Butea monosperma* (*Lakshataru*) is recorded in the *Atharva Veda*. It is also mentioned in the *Mahabharata* that *Kauravas* built the highly inflammable *lakhshagriha* or *Jadugriha* (Lac house) with a motive of physically eliminating *Pandavas* by setting the Lac palace on fire (Chattopadhyay, 2011). *K. lacca* completes its life cycle in four stages viz., egg, larva, pupa and adult. After mating, a female lac insect lay about 300-1000 fully developed eggs in her cell within the lac encrustation. Depending upon the physical conditions, emergence of larvae from the eggs takes place within a few hours from its laying. Crimson coloured larvae settling on the succulent twigs feed sap and moults thrice before pupation. The adult male lac insect lives for 3-4 days while the female lac insects lives longer and secretes lac and thus plays a major role in the production of Lac (Ogle *et al*., 2006).

Distribution of Lac insect

Lac insects are restricted to tropical and sub-tropical regions of the world, between the latitudes 40° N and 40° S in its distribution (Kapur, 1962). Only species belonging to the genus *Kerria* produce true lac. The commercially important lac insect species in various lac producing countries are different according to the local environment. *K. lacca*, represented by two infra-sub specific forms, viz., *Kusmi* and *Rangeeni,* is the commercial lac insect species in India (Kapur, 1962; Ramani, 2005) while it is *Kerria chinensis* in Thailand (Chen, 2005), *K. yunnanensis* in China (Chen *et al*., 1992) and *K. pusana* and *K. nepalensis* in Myanmar. However in Myanmar, *K. pusana* is widely promoted by the lac industry (Chen *et al*., 2011). The wild populations of *Kerria* are distributed throughout the length and breadth of India, except in the colder regions (Varshney, 1977).

Lac hosts

Lac insects are plant sap feeders (Sharma *et al*., 2006; Singh *et al*., 2009) therefore thrive well only on certain plant species known as lac hosts. More than 400 lac hosts have been observed throughout the world (Kapur, 1962; Varshney and Teotia, 1968; Varshney, 1968, 1985; Sharma *et al*., 1997). *Palash* (*B. monosperma*), *Ber* (*Zizyphus mauritiana*) and *Kusum* (*Schleichera oleosa*) are the most common hosts commercial for lac production in India (Roonwal, 1962; Pal, 2009; Mohanta *et al*., 2012), which are found in states of Jharkhand, Chhattisgarh, Madhya Pradesh, West Bengal, Maharashtra, besides a few others (Pal *et al*., 2011). The various lac host plants in China are *Dalbergia szemaoensis*, *D. obtusifolia*, *Ficus altissima* and *F. racemosa* (Chen *et al.,* 2010) while *Z. mauritiana*, *Samanea saman*, *B. monosperma*, *Acacia nilotica* and *A. catechu* are the major lac host plants in Bangladesh (Ferdousee *et al*., 2010).

Lac production

Lac makes a significant contribution to the foreign exchange earnings of the country. The most important role that Lac plays in the economic upliftment of a country is that roughly 3 to 4 million tribal people (Kumar, 2002), who constitute the socio-economically weakest link of Indian population, earn a subsidiary income from its cultivation (Chattopadhyay, 2011). Lac cultivation has a potential for generating employment for both men and women. Lac cultivation is being carried by all types of farmers *i.e.* marginal, small farmers and big farmers (Pal, 2009). During the year 2004-05, India earned a foreign exchange to the tune of Rs 165 crores from Lac (Pal *et al*., 2009).Lac production is confined to a few south, southeast and east Asian countries in the tropical forest region (Ramani *et al.*, 2007) while India is the leading lac producer, with an annual production of over 20,000 tons (Sharma *et al*., 2006; Ogle *et al*., 2006; Pal *et al*., 2009, 2011) and 75 per cent of it is exported to over hundred countries mainly in processed and semi-processed forms. The current production of lac in Bangladesh is around 700 tons per year (Mustafa, 2002). The Yunnan Province, located in the southwest of China, is the major lac producing area of the China (Chen and Yao, 2007) with a lac production of 3000 tons per year (Chen *et al.,* 2010). The lac production in India is mainly restricted to the states of Chhattisgarh, Jharkhand, Madhya Pradesh, West Bengal, Maharashtra, Orissa, besides a few others (Sharma *et al*., 2006; Pal *et al.*, 2011). Chhattisgarh state ranks first in the production of lac in India followed by Jharkhand (Khobragade *et al*., 2012). Madhya Pradesh is the third largest producer of lac in the country.

The total production of lac in Madhya Pradesh was 6500 mt during (2008-09) (Thomas, 2010). Jharkhand contributes around 39 per cent (Bharat, 2010) while West Bengal contributes nearly 7.5 per cent of total lac produced in India (Middya, 2010). The major lac producing districts in Madhya Pradesh are Balaghat, Seoni, Mandla, Chhindwara, Dindori, Narsingpur and Hoshangabad and they contribute about 80 per cent of the lac produced in the state (Thomas, 2010). The major lac producing districts of the West Bengal are Purulia, Bankura, West Medinipur, Malda and Murshidabad districts (Middya, 2010) while Ranchi, Simdega, Gumla, West Singhbhum, Palamau, Garhwa and Latehar are the major lac producing districts of Jharkhand (Bharat, 2010).

Constraints in lac production

Lac crop is vulnerable to both biotic and abiotic stress (Nicholson, 1925; Sharma *et al*., 1997; Bhagat and Mishra, 2002; Jaiswal *et al*., 2008). Agro-ecosystem environment 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), greatly influencing crop growth and productivity to the extent of 80 per cent (Oerke *et al*., 1994; Thielert, 2006).

Abiotic constraints

Lac insect agro-ecosystems have been highlighted for their conservation potential, but management to intensify lac production is reported to reduce biodiversity and may restrict ecosystem services (Chen *et al*., 2008). The Indian climate has undergone significant changes showing increasing trends in annual temperature with an average of 0.56^0C rise over last 100 years (IPCC., 2007; Rao *et al*., 2009; Anonymous, 2010). The rainfed zone of the country publicized significant negative trends in annual rainfall (De and Mukhopadhyay, 1998; Lal, 2003; Rao *et al*., 2009) while the semi arid regions of the country had maximum possibility of prevalence of droughts of varying magnitudes (20-30%), leading to sharp decline in water tables and crop failures (Lal, 2003; Samra, 2003; Rao *et al*., 2009). This is a worrying factor as most of the lac producing areas fall in the semi arid zones in the country. Environmental stress is a factor that reduces plant performance below that achieved under optimal conditions (Price, 1991). All plants encounter stress, because optimal conditions are rarely encountered in the field due to variations or fluctuations in environmental conditions. Several morphological and physiological changes may occur in plants under stress (Mattson and Haack, 1987). Under moisture stress, many plants show reduced leaf water, starch and carbohydrates and increased leaf nitrogen and soluble sugars (Miles *et al*., 1982; Mattson and Haack, 1987; English-Loeb *et al*., 1997). In contrast, low light levels can lead to reduced soluble sugars and increased leaf nitrogen and leaf water (Collinge and Louda, 1988; Attridge, 1990; Potter, 1992).

The morphological and physiological changes that occur in plants under stress may affect the performance of insect herbivores feeding on those plants (Mattson and Haack, 1987) but White (1969, 1993) suggested that plants under stress become more susceptible to insect herbivores, with the increase in insect performance driven by increases in leaf soluble nitrogen. The production of lac is greatly influenced by the climatogical factors, like temperature, rainfall, humidity, wind etc, (Nicholson, 1925; Bhagat and Mishra, 2002). The temperature is the most important climatogical factor affecting lac culture (Mishra *et al*., 1999a, b; Bhagat and Mishra, 2002; Sharma, 2007; Thomas, 2010). The annual national lac production declined from 20,050 tons in 2003-04 (Pal *et al*., 2009) to 16,495 tons in 2009- 10 (Pal *et al*., 2011) due to high summer temperatures. 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 profoundly many biological systems (IPCC., 2007) and lac sub-sector is also equally affected.

Biotic constraints

The lac insect during its life cycle spends only few hours of active mobility and thereafter spends a complete sedentary life and 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 biotic factors affecting lac insects include vertebrates, invertebrates and microbial fauna (Shaoji, 1993; Sharma *et al*., 2001, 2006). The vertebrates enemies include squirrels and rats (Thomas, 2004) and rats. The invertebrates enemies of lac insects are of two types viz., parasites and predators (Sharma *et al*., 1997). Twenty-two species of lac insect predators, 30 species of primary parasites, 45 species of secondary parasites (Das, 1990) and several fungal pathogens of lac insects as well as lac hosts besides several other fungal pathogens represent a rich biodiversity of lac ecosystem (Sharma *et al*., 2006).

Predators

The sporadic neuropteran predator *Chrysopa* spp, are the most ubiquitous predators in the lac ecosystems causing considerable loss, especially in the winter crops of *Kusmi* lac. 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, 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) in another study reported another species of neuropteran predator on lac crop, *C. lacciperda* whose average durations of first, second and third larvae instars were 3.8, 3.2 and 7.3 days, respectively. The first instar larvae of *Chrysoperla zastrowi arabica,* a new neuropteran predator reported by (Singh *et al*., 2011a) attack *Kusmi* lac culture soon after settlement of lac insect on tender shoots of *S. oleosa* host trees. About 150-200 adults of *C. zastrowi arabica* per *S. oleosa* tree were recorded on summer season *Kusmi* lac crop. The predation potential of this pest is very high with the larva feeding on 160-195 and 425-485 lac insects during second and third instar stages, respectively before pupation. Two lepidopteran predators *Eublemma ambilis* and *Pseudohypatopa pulverea* cause 30-40 per cent damage to lac crop (Glover, 1937; Mishra, 2002; Jaiswal *et al*., 2008; Singh *et al*., 2009). Narayanan (1962) reported *E. amabilis* as a monophagous predator of lac insects, causing damage to the tune of 20 to 25 per cent to lac crop. Malhotra and Katiyar (1975) too reported *E. amabilis* and *P. pulverea* as major pest normally causing 30 to 35 per cent damage to lac crop. The larvae of *E. amabilis* after hatching from the eggs on the surface of the lac colonies, lead a cryptic mode of life by burrowing and tunneling within the lac encrustation feeding exclusively on lac insects. This predator undergoes three overlapping generations in both summer and rainy season lac crop and moults ten times before pupating. Rahman *et al.* (2009) reported that the moth *E. amabilis* is very destructive to lac insect and lac encrustation. The moth is generally white-pinkish in colour and it lays grey-white and round eggs, depressed in the centre. The newly hatched larva enters the lac insect either through one of the opening in the cell or by tunneling a hole through the encrustation. A single larva damages 42-50 mature lac cells prior to pupation and causes more injury to the *Kartki* crop than to the *Baishakhi* crop.

Parasitoids

Sharma *et al*. (2007) studied superparasitism in *K. lacca* and its implications on fecundity and resin producing efficiency of its two strains. The parasitoids of lac insect cause severe damage to the crop affecting adversely the resin yield and the fecundity of the insects, particularly during rainy seasons. The average reduction in resin produced by a single female due to parasitism varied between 17.25-39.80 per cent in *Rangeeni* and 25.24-37.91 per cent in *Kusmi* strain. On the other hand the reduction in fecundity of lac insects ranged between 22.44-96.82 and 25.29-90.39 per cent in *Rangeeni* and *Kusmi* strains respectively. The result showed that as the number of parasitoids in each cell increased, there was a corresponding decrease in resin production and fecundity of the lac insects.
According to Narayanan (1962) superparasitism can occur but typically one parasitoid larva occurs in single scale. The parasitoids have life cycle of about one month in length, compared to 4-9 months, depending on scale strain and season, 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* belonging to the order hymenoptera are the most abundant lac associated parasitoids (Chattopadhyay, 2011). According to Varshney (1976) 28 parasitoids are recorded from lac scale species worldwide. The four braconid wasps listed are wrongly recorded as lac scale parasitoids but are actually parasitoids of some of the many predacious Lepidoptera that attack lac scales. The remaining 24 species are all chalcidoid wasps (Aphelinidae. Encyrtidae, Eulophidae, Eupelmidae and Pteromalidae. Most of these have been recorded from the commercial lac scale in India.

Sharma *et al.* (1997) reported fourteen species of parasitoids under 13 genera representing ten families were found associated with *K. lacca*. Of these, *A. purpureus* and *T. tachardiae* constituting about 55.82 per cent and 28.37 per cent, respectively of the total population of parasitoids, were among the most abundant. Among the beneficial fauna, only *Bracon greeni* Ashmaed was of some significance. Difference in relative abundance and emergence pattern on the basis of variety, host and the location were observed but the two strain of lac insect showed some differences in relative abundance of parasitoids. Subbarayudu and Maheswar (1998) in a study reported three parasitic species *A. purpureus, T. tachardia* and *C. tschirchii* on *Kusmi* lac. The parasites showed different patterns of peak emergence. Hayat *et al*. (2010) collected three new species of Encyrtidae from lac insects which were *Ooencyrtus thaiensis*, *O. paratachardinae*, and *Tachardiaephagus sarawakensis*. Two undetermined species, one each of *Cerapteroceroides* and *Cheiloneurus* were also recorded, but not described.

Management of abiotic constraints

Susceptibility of lac crops to higher temperature is widely acknowledged. Among the two lac strains- *Rangeeni* and *Kusmi*, former is more vulnerable and later is superior *Baishakhi* crop (October-May) of *Rangeeni* lac is the major contributor of lac production in India. High summer temperature and prolonged leaf loss of *Z. mauritiana* from February to April is severely affecting the *Baishakhi* crop in the country. *Z. mauritiana* also being a host of *Kusmi* strain of *K. lacca* offers an opportunity to overcome the impact of climate change on lac production in the country.

Management of biotic agents

Chemical management

Chemical pesticides like HCH/Chlordane recommended by Chaudhary (1983) and dichlorvos by Mishra *et al*. (1996) for the management of *Chrysopa* are no more recommended in India after their categorization as highly hazardous insecticides by WHO. The use of endosulfan presently in practice to control the lac insect predators has been banned in majority of the developed countries and in some parts of India due to its carcinogenic effect (Arora *et al*., 2009). 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. Insecticides fipronil (0.005 and 0.01%) and indoxacarb (0.02%) are 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%) is most suitable for protecting the lac crop at critical stage against *C. madestes* under field conditions without harming lac culture (Jaiswal *et al*., 2007). Toxicity of ethofenprox against first instar larvae of *C. carnea* has been reported by Toda and Kashio (1997). The safety of ethofenprox against lac insect culture has been established upto 0.04 per cent by field application (Jaiswal *et al*., 2004) and also by dipping broodlac Bhattacharya *et al*. (2005). Mishra *et al*. (1996) evaluated the efficacy of selected organophosphorus insecticides for the control of *C. madestes* and reported that dichlorvos at 0.03 per cent was most suitable for the control of the predator. Out of the four insecticides Endosulfan, Dichlorvos, Cartap hydrochloride and Ethofenprox recommended by Jaiswal *et al*. (2004), Cartap hydrochloride and Ethofenprox can be used for the management of lepidopteran (*E. amabilis* and *P. pulverea*) and the neuropteran (*Chrysopa* spp.) predators of *K. lacca*. Bhattacharya *et al.* (2005) evaluated Cartap hydrochloride (CHC), an insecticide having systemic and contact action, in lac ecosystem as a substitute for the currently used conventional insecticide endosulfan. Three doses of CHC (0.05, 0.075 and 0.1 per cent) tested against the predator *E. amabilis* infested on the 2nd instar larvae of lac insect (*K. lacca)* larvae reared on *B. monosperm*a during the rainy season proved safe to the lac insect and enabled effective control of *E. amabilis*. CHC at 0.05 per cent provided results at par with endosulfan in respect of reduction in the population of *E. amabilis* and consequent increase in lac crop yield.

Seven safer insecticides viz lambdacyhalothrin, carbosulfan, spinosad indoxacarb, fipronil, alphamethirn and ethofenprox against lac insect, evaluated for their bioefficacy against *C. lacciperda* by topical application and exposing the insect on residual film of insecticides results in cent per cent mortality of

C. lacciperda within 24 hr with both modes of treatment. The topical application of insecticides was found to be more efficient compared to exposure of insect on residual films (Singh *et al*., 2009, 2010). Diflubenzuron- a fifth generation insecticide with insect growth regulatory activity recorded by Coudriet and Seay (1979) has been reported to affect a number of lepidopterans. Bhattacharya *et al.* (1995) reported strong ovicidal action of Diflubenzoron (Dimilin 25 WP) against the eggs of *E. amabilis.*

Biological management

E. amabilis can be controlled by using its indigenous parasite *Bracon greeni* Ashmead (Negi *et al*., 1945) and with the help of natural enemies such as *Componotus compressus* and *Solenopsis geminata* (Rahman *et al*., 2009). *E. amabilis* and *P. pulverea* can be effectively controlled with the spray of *Bacillus thuringiensis* (Malhotra and Choudhary, 1968). Delfin, a commercial formulation of *B. thuringiensis* subspecies *kurstaki* recorded by Bhattacharya *et al.* (2008) is highly effective in dropping the incidence *of E. amabilis* and *P. pulverea* while significantly increases the yield of *K. lacca*. Three sprays of *B. thuringiensis* 0.051 per cent (commercial formulation Biolep) at an interval of 30 days after brood lac inoculation can be used for the successful control of both *E. amabilis* and *P. pulverea* in *Rangeeni* lac on *Ber* (Jaiswal *et al*., 2008).

The egg parasitoids *Trichogramma achaeae, T. exiguum, T. brasiliense, T. chilonis, T. poliae, T. ostrinae* and *T. pretiosum* can reduce the population of insect predators by more than 75 per cent and are highly effective against the eggs of *E amabilis* and *P. pulverea* (Bhattacharya *et al.,* 2008). Sushil *et al.,* (1995) found *T. pretiosum* as an efficient egg parasitoid of *E. amabilis* as it damaged 88.23 per cent eggs *E. amabilis* but the emergence of the parasitoid from the parasitized eggs was only 20.5 per cent. Bhattacharya *et al.* (2006) in a field evaluation trail for the management *of E. amabilis* with three species of the egg parasitoids (*T. achaea, T. exigum and T. ostrinae*) observed significant suppression of *E. amabilis* over the control with the release of 75 egg parasitoids per plant in *Kusmi* and *Rangeeni* lac biotypes. 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 per cent (Kumar *et al*., 2007). Ant in the course of collecting and feeding honeydew secreted by lac colony destroyed the eggs of the predators.

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 management of *K. lacca* revealed two options for the management of *E. amabilis* for different groups of lac growers. 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 while those with better financial status and the trees in plain area and sufficient water can opt for a combination of 60 mesh nylon pouches followed by a spray of endosulfan 30 days after the brood inoculation.

Planting of *Cassia occidentalis* L. (Family: Leguminosac), a medicinal plant, on the periphery of a plot having *F. macrophylla* bushes harbouring lac insects resulted in significant reduction in the population of the two Lepidopteran lac insect predators viz. *E. amabilis* and *P. pulverea* and result in significant increase in brood lac yield. 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). C*hrysopa spp*. attacking *Kusmi lac* crop raised on *Kusum* (*S. oleosa*) during the months of August and September can be trapped by placing a light trap in the field. 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).

Conclusion

K. lacca is a valuable insect of economical and ecological interest. Lac production is an economical activity among rainfed farmers and forest dependants in Central Indian region. *K. lacca* is prone to biotic and abiotic stress, thus affects the productivity, influencing the cash inflow of poor and marginal farmers. Biotic factors, predators and parasites cause heavy yield loss to the lac crop, requires to be managed sustainably. Management of biotic factors may be a combination of chemical, cultural and biological. This approach will reduce the cost as well as protect the environment. Manipulation of the host and location to combat climate change may be strategically plan, so that lac production is sustainable and economical.

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