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Broodlac Management in Lac Production: A Review

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Abstract

Broodlac is the key component of lac production. Thus, production and management of broodlac before and after its inoculation on host trees are very crucial. Predators and parasitoids on the broodlac have to be managed through cultural, biological and chemical approaches to avoid lac crop failures. Timely inoculation of brood, its shifting and removal from host trees are essential operations for successful lac production. This review focuses on broodlac management.

***Key words*:** Broodlac, Inoculation, Lac, Host trees, Resin

Lac is unique among natural resins because it is produced by an animal, specifically the lac insect *Kerria lacca*. These insects are indigenous to India and are well known for secreting a resin that has been harvested for centuries. This process is a remarkable example of symbiosis, as the lac insect relies on certain host plants for survival and reproduction, while the plant benefits from the relationship by receiving some protection from herbivores and competing plants due to the coating of resin. The only natural resin [1] that comes from animals is lac. *Kerria lacca* is an Indian lac insect that produces it [2-4]. It is a result of the intricate ecological relationship that exists between the lac insect and its host plant [5-6]. Commercially, *K. lacca* is reared on the naturally standing host trees like *Butea monosperma*, *Zizyphus mauritiana*, *Schleicheria oleosa* [7-8] as well as on *Z. xylophora* [9]. In India, lac insect genera are bivoltine having two distinct strains*:* *kusmi* and *rangeeni* [10]. The lac insect typically uses a variety of host trees, with some of the most common in India being *B. monosperma* (also known as the "flame of the forest"), *Z. mauritiana* (Indian jujube), and *Schleicheria oleosa* (kusum tree). These trees serve as both shelter and a food source for the insect. *Z. xylophora* is another notable host, although less widely used. To sustain commercial production, these insects are reared on these host trees under natural conditions. In India, lac insects have a unique breeding cycle and are classified into two distinct strains based on their lifecycle patterns: the kusmi and the rangeeni. Both strains are bivoltine, meaning they go through two life cycles per year, which allows for two distinct harvests annually. The kusmi strain generally prefers kusum trees, while the rangeeni strain is reared on other host trees like *B. monosperma* and *Z. mauritiana*.

The *kusmi* strain is grown on *kusum* (*S. oleosa*) and *Z. mauritiana* using *kusmi* brood [11]. The *rangeeni* strain thrives on host plants like *B. monosperma* [12-16] and *Z. mauritiana* [17-18] or both [19]. All the strain completes two cycles, yielding two crops per year. The *rangeeni* strain produces a summer crop (*baisakhi*) and a rainy crop (*katki*), while the *kusmi* strain produces *aghani*- winter crop and a *jethwi*- summer crop [20]. The immature *rangeeni* crop called *Ari*, is also harvested [21-22].

Millions of people make their living from the cultivation of lac and the tapping of natural resins and gums [23-25]. It also aids in the preservation of large tracts of forest. An essential part of the flora and fauna are lac insects and the biota they are linked with [26-27]. Lac-based businesses have the capacity to establish a solid basis for rural cottage industries [28]. Crop production and lac production can be readily combined to diversify land usage and boost revenue [29]. It is an assured source of income to mitigate during drought conditions [30]. It is a blend of traditional knowledge and modern methods that can work together to benefit both people and nature [31]. It provides high return [28**]** on minimum investment [32] and generates employment opportunities [23]. Lac production helps to prevent environmental damage and restore ecological balance [29].

Broodlac inoculation

The method of transferring *K. lacca* crawling larvae from brood lac to host tree branches is known as broodlac inoculation [33]. The inoculation or infestation of host plants with broodlac is the first step in lac crop management [34]. It is an important operation in lac production [21], [35-40]. It is performed by tying a bundle of broodlac twigs with a twine on the succulent branches of host tree [7-8]. Live gravid female lac insects that are ready to give birth to young larvae are found in the brood lac [9], [41]. The newborn larvae crawl out of their mother cells and land on the fresh, succulent twigs of their host plants. Insects that settle there develop encrustations after sucking the plant sap [42].

Broodlac inoculation is a timely activity performed at the beginning of the lac crop [17], [43]. It is done in July for rainy (*katki*) crop [13], [15], [37] and October-November for winter (*baisakhi*) crop of *rangeeni* strain [40],[43],[44]. In *aghani* crop of *kusmi* strain, broodlac inoculation is done in July [17-18]

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while for *jethwi* crop it is from January to February [45]. Performance of broodlac is crucial for lac production [21]. This is dependent on quality of broodlac. The success of lac insect settlement on host plants is highly dependent on the thickness of the broodlac encrustation. Broodlac is a term used for the encrusted branches or twigs that contain live lac insect eggs or young larvae. This encrustation serves as both a protective layer and a vital resource for new generations of insects as they settle on fresh host trees. When the broodlac encrustation is appropriately thick, it offers optimal conditions for the lac larvae to establish themselves, as they can more easily access the host plant's sap for nourishment and maintain stable attachment. The primary determinant of lac insect settlement is the thickness of the broodlac encrustation [46]. A delay in harvesting brood lac, crop inoculation and improper transportation methods can lead to significant losses in lac production [47-48].

Quality of broodlac

The most crucial component for lac production is the timely availability of high-quality, predator-free brood lac [7], [49]. High fecundity of insects and reduced inoculum requirements are guaranteed by high-quality brood lac. The quality of broodlac is directly correlated with the emergence profile of lac insect crawlers. The quality of the broodlac determines its number [17]. A smaller amount of superior broodlac is always required. The productivity of the following crop is directly impacted by broodlac that has a very low number of crawlers because of either little encrustation or heavy pest infestation [50]. One of the most important factors in producing the lac harvest is the quality of the brood employed. Lac producers can become self-sufficient by producing high-quality broodlac [25]. Numerous factors, including the number of predators in the brood, the level of parasitisation [51], the thickness of the encrustation, the extent of settlement, the size of the twig on which the lac insect grows, and others, might affect the quality of the brood [52]. Furthermore, the prevalence of predators, including lepidopteran predators like *Eublemma amabilis* Moore and *Psuedohypatopa* (Holcocera) *pulverea* Meyr., as well as other parasitoids, affect the productivity and quality of broodlac. According to estimates, 50 percent of lac output is lost due to linked hazardous fauna [53]. Parasitization of lac insects reduces fecundity by 10 to 100 percent. In such cases more brood lac are required for inoculation as compared to healthy brood. Early-stage parasitization leads to the destruction of the lac insect [54] making it unsuitable for brood lac use. Parasite-infested brood lac can spread infections to the lac culture [55]. Using quality broodlac enhances lac yield and significantly increases farmers' income [56].

Quantity of broodlac

The quantity of broodlac required for a host depends on its condition [17], [57-59], size [8], [37-38], [60], availability of number and length of succulent branches [12],[16],[25] and girth [13] of the tree. A healthy, well-covered brood lac stick typically allows for sufficient larvae settling on the twigs of the tree to be infected over a distance of 15 to 20 times its length [16]. For raising combined crop of summer and rainy season, around 400-500 g brood is required for an average size *B. monosperma* tree [61]. A medium sized *kusum* tree requires approximately 5-10 kg of broodlac [45]. For *Z. mauritiana* and *B. monosperma*, the amount of broodlac used ranged from 500g to 700g per plant [33], [37]. Depending on the size of the plant, 15–30g of broodlac was inoculated per *Cajanus cajan* plant [44]. The "crowding effect," which is more noticeable in the *rangeeni* strain, is seen under conditions of surplus brood [54]. Many lac growers use too much brood lac per tree, which hinders lac productivity [62], and large-scale inoculation lowers lac crop performance [63].

Table 1 Broodlac requirement -crop and host wise for inoculation

Host plant	Strain	Crop	Broodlac required (g)	Reference
Butea monosperma	*Rangeeni*	*Katki*	600g to 1200g	[12],[16]
			200g to 400g	[13],14]
			500g to 1000g	[37]
			233.33g to 308.33g	[15]
		Baisakhi	500g	[43]
Zizyphus mauritiana	*Kusmi*	*Aghani*	300g to 600g	[60]
			400g to 600 g	[17]
		Jethwi	500g to 600g	[33]
	Rangeeni	*Baisakhi*	600g	[21], [36]
			700g to 1000 g	[33]
		Katki	500g to 600g	[33]
Cajanus cajan	*Rangeeni*	*Baisakhi*	15g to 30g	[44]
			15g	[40], [64]
Schleicheria oleosa	*Kusmi*	*Jethwi*	6000g to 7000g	[65]
		Aghani	7833.33g to 8000g	[66]

There are various methods of tying the brood lac i.e. longitudinal style, lateral style and interlaced style. In longitudinal style, the brood lac is tied along the branch, while in lateral style; the brood lac is tied across the gap between two branches. However, in the interlaced style, brood lac is tied among the branches of several new shoots [67]. There are two types of broodlac inoculation i.e. Artificial and self-inoculation [68].

Natural or self-inoculation

This type of inoculation is a simple process and occurs naturally. In this method the crawling larvae from the mother lac cell attached themselves to the branches of the same plant again. Natural inoculation does not ensure a uniform settlement; therefore, it is discouraged [69]. It is also referred as selfing. It produces a lower yield of lac and does not ensure a continuous supply of broodlac for inoculation [70]. Additionally, continuous production of lac from the same host without resting weakens the host plant as well as the lac insects due to poor nutrition supply [63].

Artificial inoculation

When broodlac (the lac-infected branches containing live insect larvae) is transferred from one host plant to a different, fresh host plant, this process is known as *artificial inoculation* [71]. Broodlac stick is cut with a pair of Secateurs into pieces of 6-inch length and 4-5 sticks are tied into a bundle. This is then tied at several places on the host tree, such that the lac insects uniformly settle on most of the succulent shoots [16], [28], [43], [72].

Preparation of broodlac bundles for inoculation

Broodlac inoculation

Shifting

Phunki

Fig 1 Illustration of different steps of broodlac inoculation

Broodlac management

Broodlac health

Predators and parasites frequently settle on lac encrustation as insects [73]. This results in a decrease of lac insects, which lowers lac crop productivity. The quality of broodlac is impacted by parasitisation during the sexual maturity stage, which can result in crop failure during the crop maturity period [74]. Rats and squirrels can also seriously harm brood sticks, lowering their numbers by as much as 50 percent [75-76]. Two lepidopterans, *Eublemma amabilis* [43], [77-78], and *P. pulverea* [79], are major lac insect predators. *Tachardiaephagus tachardiae*, *Aprostocetus purpureus*, and *Eupelmus tachardia* are the three main parasitoids of lac insects [80].

Table 2 Pest and disease incidence in broodlac

Pest / disease	Symptoms	Reference	Lac yield loss (%)	Reference
Lac insect predators	Holes in broodlac	[81]	35-40 percent 20 to 40 percent	[76], [82] [83-87].
Fungal infections	Blocked larval emergence	[55]	40.9 to 59.85 percent	[88,89]
Parasites	No emergence or very low emergence of young ones from the parasitized cells	[55]	The quality of the resin produced declined by 17.92 percent and 17.44 percent	[88,89]

Precautions

Management of host plants

Host plants should be healthy and timely pruned [25], [90-92]. It promotes the growth of new, short shoots that are suitable for the settlement of lac insects [42].

Selection of broodlac

Healthy broodlac should be selected [7], [13], [21], [93] before inoculation. Broodlac sticks without encrustation or with high incidence of insect predators should be rejected for inoculation [76].

Climatic conditions

The lac insect thrives in mild climates. A mild climate (24–27 °C) and 1000–1500 mm of annual rainfall could be ideal for lac production. Extreme temperatures or fluctuations can adversely impact growth and survival of lac insects. During broodlac inoculation, it is essential to prevent both over exposure and underexposure to sunlight [94]. Inoculation of broodlac should be avoided if rain is anticipated [95].

Timing of inoculation

Within a week to ten days of their first appearance, lac larvae crawl from the brood [43]. The inoculation schedule needs to coincide with both the host plant's development period and the lac insects' natural life cycle [42]. Larval emergence is a determining factor [1]. For optimal results, inoculation should be carried out two to three days after the larval emergence from the broodlac. The danger of brood loss and dispersal rises with inoculation delay. One of the main obstacles to ongoing lac production is the availability of new brood [96], hence efforts should be made to promptly introduce the brood to host plants [97].

Quantity and timing of broodlac use

Prior to lac inoculation it is important to estimate required amount of brood lac per plant [16]. The quantity of broodlac should be neither excessive nor insufficient.

Harvesting of broodlac

Mature broodlac should be harvested at the right time. The best time to harvest from the tree when the gravid lac female cells turn yellow [43] specifically just before larvae begin to emerge. Harvesting at this stage ensures minimal wastage and maximum potency of the broodlac [35]. Brood lac should not be stored for more than a week. This limitation is likely due to the tendency of crawlers to escape from the brood pouch in search of food if not introduced to a host plant in a timely manner [98].

Tying of broodlac

Depending on the availability of succulent branches on host tree, 4 to 6 brood lac bundles were tied at the junctions. These junctions were where the most succulent branches emerged after pruning [57-59], [91], [99]. Broodlac should be tied to the upper surface of branches [42], [95]. This approach prevents twigs from falling and ensures full contact, facilitating the quick and easy crawling of nymphs. It is important to monitor for any broodlac that may drop down [69].

Induced swarming

In winter swarming of nymphs from broodlac is slow or gets delay. In order to induce swarming, broodlac sticks are stored in a moderately warm room at 20 °C, after which inoculation should be carried [90].

Shifting of broodlac bundles

Shifting of broodlac was attempted for the effective usage of broodlac [43]. After 7–8 days after inoculation, the broodlac bundles should be carefully moved to other branches on the same tree [38]. In branches where there was little to no larval settlement, this is done to guarantee that the brood is distributed uniformly [12-13], [17], [22], [37], [91], [100]. It also increases the efficiency of broodlac [25]. Observations of lac insect settlements at various broodlac inoculation points should be made one week after tying the broodlac sticks. If lac insects have fully occupied the available succulent shoots, the broodlac should be removed and relocated to other areas where there is still space for lac insects [18].

Phunki removal

After three weeks of inoculation, the lac insect larvae from broodlac settle on the host tree. The act of removing remaining brood lac, or *phunki* [93], [101] twigs from the host plant following the full emergence of lac nymphs from the mother lac insect cells [64] is known as *phunki* removal. *Phunki* is infact "Sticklac" [7]. It should be eliminated following 21 days of broodlac inoculation [7], [92], [102-103] and typically consists of predators [37]. The removal of *phunki* is a crucial procedure [58], [104] and it also involves the removal of predators [40]. Lac resin, which is found in *phunki*, has the potential to yield profits equal to one-fourth of the cost of raising brood [7], [18].

Biological cultural and chemical management

Cultural methods

It is advised to enclose brood sticks in a 60-mesh nylon net bag while they are being inoculated [105-106]. This technique let's just lac crawlers settle on fresh shoots while trapping parasitoids and predators. Utilizing predator and parasite-free broodlac for each crop, while avoiding self-inoculation, is suggested to prevent pest introduction [12-13], [92]. They also recommended prompt removal of broodlac once the lac insects adequately cover the trees. This method is used to avoid the continuation of *E. amabilis* life cycle, which could infest the crop during the swarming period [77]. However, growth of fungus inside the mesh bag clogs it and arresting the movement of crawling lac insects. Thus, broodlac inoculation fails [28].

Biological control

Biological control is the application of living natural enemies to control pest [107]. It includes the control of animals, weeds and diseases [108]. *Componotus compressus* [109] and *Solenopsis geminata* (the small red ant) prey on *Eublemma* larvae as they emerge from their eggs and attempt to enter protective cells. The ants capture the larvae by biting them with their mandibles; effectively preventing them from entering and damaging the lac cells [77]. The efficacy of *Bacillus thuringiensis* var. *kurstaki* (Bt) formulations on the lac insect *K. lacca* was studied. Two concentrations of Bt (0.34% and 0.51% a.i.) were tested by dipping broodlac for 5, 10, and 15 minutes. The results indicated that Bt treatments significantly reduced populations of the lepidopteran predators *E. amabilis* and *P. pulverea*, while causing no significant harm to the lac insect itself. Specifically, the 0.34 percent concentration effectively controlled these pests, making Bt a viable option for integrated pest management in lac production [110].

Chemical management

The toxicity of endosulfan (Thiodan) was evaluated against the noctuid predator *E. amabilis* and the blastobasid predator *P. pulverea*, both of which prey on the lac insect *K.lacca*. Broodlac pieces (15-20 cm) from *B. monosperma* and *S. oleosa* were dipped in endosulfan solutions at concentrations of 0.1 to 0.4 percent for 1, 1.5, or 2 minutes. Results showed no significant mortality difference between the endosulfan treatments and tap water controls for either predator. However, exposure to 0.4 percent endosulfan for 1 minute significantly reduced *E. amabilis* populations by 75 percent, which was greater than any other treatment. No significant differences were observed in the mortality of *P. pulverea* across the treatments [111].

The effects of several insecticides, including ethofenprox, endosulfan, and profenfos, on the lac insect predator *E. amabilis* Moore and two significant parasitoids, *T. tachardiae* and *A. purpureus* (Cam.), were assessed by dipping broodlac in solutions of these insecticides. Endosulfan inhibited *E. amabilis* populations, whereas profenfos was harmful to lac insects. The parasitoids *A. purpureus* and *T. tachardiae* populations were not substantially impacted by any of the pesticides [112]. It is no longer advised to utilise endosulfan in the lac production system due to the Supreme Court of India's ban on its use, which went into force on May 13, 2011.

Eight insecticides—indoxacarb, fipronil, spinosad, ethofenprox, endosulfan, bifenthrin, lambdacyhalothrin, and carbosulfan against two prevalent parasitoids (*T. tachardiae* and *E. tachardiae*) and two key predators (*E. amabilis* and *P. pulverea*) of the lac insect *K. lacca* was evaluated in the laboratory by dipping broodlac in insecticidal solutions for 10 and 15 minutes. Significant reductions in the populations of parasitoids and predators were observed with indoxacarb, fipronil, spinosad, ethofenprox, and endosulfan, ranging from 20.90 to 100 percent for predators and 50.80 to 100 percent for parasitoids, depending on the insecticide and exposure time. No adverse effects on the emergence and survival of the lac insect were noted [113].

Broodlac, obtained from summer *kusmi* lac crops on *S. oleosa*, was treated with insecticides including indoxacarb (0.007%, 0.014%, 0.021%), spinosad (0.005%, 0.007%, 0.01%), fipronil (0.007%, 0.014%, 0.02%), and ethofenprox (0.02%, 0.03%, 0.04%) for 15 minutes. The treated broodlac was then inoculated onto lac host plants, *Flemingia semialata*, in the field. The results indicated no adverse effects on the emergence and survival of lac insects. Significant reductions in populations of lepidopteran predators and hymenopteran parasitoids were achieved. Notably, spinosad provided the highest reduction in *E. amabilis* emergence (100%), followed by indoxacarb (97.92% to 100%), ethofenprox (75% to 93.75%), and fipronil (72.92% to 91.67%). All insecticides effectively reduced the emergence of *P. pulverea*. For parasitoids, reductions ranged from 47.06 to 89.71 percent for *T. tachardiae*, 61.54 to 100 percent for *A. purpureus*, 38.46 to 100 percent for *E. tachardiae* (male), and 45.45 to 100 percent for *E. tachardiae* (female) [114].

In an investigation eight flubendiamide concentrations by dipping broodlac for 5, 10, and 15 minutes were tested. The concentrations ranged from 0.0039 (0.1 ml L^{-1}) to 0.0315 percent (0.8 ml L^{-1}). The insecticide's safety for lac insects was demonstrated by the results, which revealed no discernible effect on the survival of lac insect larvae in their first instar. On the other hand, there were notable declines in the numbers of two important predators, *P. pulverea* and *E. amabilis* [115].

By dipping broodlac (a functional seed of lac culture) for 5, 10, and 15 minutes, seven concentrations of emamectin benzoate (5% SG), ranging from 0.00025 a.i. (0.05 g/L) to 0.0030 percent a.i. (0.6 g/L), were assessed. The findings proved the insecticide's safety for lac insects by showing no appreciable negative impacts on the survival of adult female lac insects and second instar larvae. Nonetheless, notable declines were noted in the numbers of two important lepidopteran predators, *E. amabilis* and *P. pulverea*. In particular, both predator species were successfully handled by treating *rangeeni* broodlac with 0.00025 percent a.i. emamectin benzoate for 10 to 15 minutes and kusmi broodlac with 0.0005 percent a.i. for 5 to 10 minutes [116].

An experiment was conducted to evaluate the safety and efficacy of the 'Augusta™', containing 0.6 percent natural lactone and 0.3 percent natural alkaloid. Effective predator control was achieved with a 0.0014 percent of commercial insecticide formulation 'Augusta™' for 5 minutes, resulting in a 94.12 percent reduction of *E. amabilis* and 64.7 percent reduction of *P. pulverea* in *rangeeni* broodlac. Similar reductions were observed in *kusmi* broodlac from *S. oleosa*, with 90.48 percent, 92.59 percent, and 56.82 percent suppression of *E. amabilis*, *P. pulverea*, and *A. purpureus*, respectively. *Kusmi* broodlac from *Z. mauritiana* showed 90.91 percent and 81.82 percent suppression of *E. amabilis* with 0.0045 percent and 0.0018 percent concentrations, respectively, for 5 minutes. Higher concentrations and longer dipping times did not yield significantly better results [117].

Broodlac, was treated with seven concentrations of chlorantraniliprole 18.5 percent SC, ranging from 0.001 (0.05 ml $L^{-1)}$ to 0.0111 percent (0.6 ml L^{-1}), with dipping durations of 5, 10, and 15 minutes. The results demonstrated that chlorantraniliprole did not adversely affect the survival and settlement of 2^{nd} instar larvae or adult female lac insects, confirming its biosafety. However, significant reductions in populations of the lepidopteran predators like *E. amabilis* and *P. pulverea* were achieved. Effective concentrations included 0.0037 percent for 5 minutes or 0.0020 percent for 10-15 minutes for *rangeeni* broodlac, and 0.0056 percent for 5 minutes or 0.0037 percent for 10-15 minutes for *kusmi* broodlac [118].

The bio-efficacy of Emamectin benzoate, Indoxacarb, and Rynaxypyr at various concentrations and exposure times was assessed by dipping brood lac to control the predator *E. amabilis*. Emamectin benzoate at 0.003 percent for 15 minutes proved highly effective, reducing the predator population by 92.07 percent to just 0.66 insects per 30 cm lac stick. All insecticides significantly decreased predator numbers [119].

Effective lac cultivation requires careful management of broodlac quantity, timing, and handling. Estimating the proper amount of broodlac per plant, harvesting at the right maturity stage, and avoiding prolonged storage (over a week) are critical for maximizing lac yield and minimizing losses. Broodlac bundles should be securely tied to host branches, and, if needed, relocated to optimize insect settlement. Cultural practices, biological, and chemical controls (like Bacillus thuringiensis and specific insecticides) help protect against pests while preserving lac insects. This integrated approach enhances both productivity and pest management in lac production.

CONCLUSION

Lac production relies heavily on broodlac. So, broodlac production and management are essential both before and after the inoculation of host trees. For the broodlac to prevent crop failure, predators and parasitoids must be controlled via cultural, biological, and chemical methods. For lac production to be successful, the brood must be inoculated, moved, and removed from the host tree on time. Effective lac cultivation relies on careful management of broodlac, including its quantity, timing, and application techniques. Proper estimation of broodlac per plant is critical to avoid insufficient or excessive inoculation, which can hinder lac growth. Harvesting at the right maturity stage, when female lac cells turn yellow, preserves brood quality and minimizes losses. Broodlac should be quickly used after harvesting to prevent larval escape, with bundles tied on succulent branch junctions to ensure effective crawling.With the details given in the present review article the farmers as well as researchers involved in the cultivation or investigation particularly on lac will be benefitted definitely.

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