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ADVANCES IN LAC INSECT CULTURE RESEARCH AND SCOPE FOR INNOVATIVE ENTREPRENEURSHIP USING NATURAL RESINS AND GUMS

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ABSTRACT

Lac insects are specialized group of phytosuccivorous insects (Coccoidea: Tachardiidae) that secrete resin of industrial importance having diverse applications. Around 101 species of lac-insects and over 400 species of lac host-plants have been reported but insects belonging to sub-family Tachardiinae are considered important for *laksha-culture* (lac insect farming). Not only the lac insect, but also the host-plants and various biotic associations play a significant role in determining the quantity and quality of the produce. India is endowed with rich wealth of lac insect resources. 27.7% lac insect biodiversity reported from the world is found in our country under two genera *i.e*., *Kerria* and *Paratachardina*. *Kerria* the true lac secreting genus includes 28 species worldwide, 23 of which are recorded from India. Cultivation of lac / tapping of natural resins and gums not only provides livelihood to millions of lac growers but also helps in conserving the vast stretches of forests, lac insects and associated biota. Lac also provides sustained high economic returns, generates employment opportunities and has the potential to lay a strong foundation for lac based rural cottage industries. Lac farming can easily be integrated with agriculture thus helping in land use diversification for increased income. Indian Institute of Natural Resins and Gums (ICAR- IINRG) has recently developed new technologies of lac insect farming including newer host plants and developed value added products from lac and other natural resins and gums. Lac integrated farming system models and many of these products have the potential to pave the way for rural industrialization and entrepreneurship development. This review article discusses all these aspects in detail

Key words: Lac insect, *Kerria lacca*, Tachardiidae, lac farming, natural resins and gums, entrepreneurship development

Lac is the only natural resin of animal origin secreted by a specialized group of insects called lac insects. Nine genera and 101 species of lac insects have been reported from the world. 28 species under two genera have been observed in our country (Rajgopal et al., 2021; Varshney and Sharma, 2020). Indian lac insect, *Kerria lacca* (Kerr) is the most important lac insect utilized for cultivation of lac. More than 400 plants have been reported as lac-hosts all over the world. *Kusum* (*Schleichera oleosa* (Lour.) Oken.), *Palas* (*Butea monosperma* (La.) Taub), *Ber* (*Zizyphus mauritiana* Lam.) and *Ficus* spp. account for about 90% of total lac production in the country. Besides these hosts, lac cultivation can be commercially carried on about 30 other host-plants. Recently, *Calliandra calothyrsus* Meisn. and *Flemingia semialata* Roxb. ex W.T.Aiton have been shown to be very promising plants for intensive lac cultivation.

India is the world leader in production and export of lac. India produces more than 20,000 tons of lac per annum. Lac production is confined presently to Eastern India *i.e.* Jharkhand (54.6%), Chhattisgarh (18.4%), Madhya Pradesh (13.8%) and West Bengal (5.6%) (Yogi et al., 2021). *Kusmi* and *rangeeni* are two strains of *Kerria lacca* (Kerr) which can be distinguished based on: nutritional requirement, quality of the lac produced, time taken to reach crop maturity and productivity. Other important lac insect species commercially exploited for cultivation of lac are *K. chinensis* (Mahdihassan,) and *K. sharda* sp. nov. Lac cultivation can be done on standalone tree hosts, bushy plants like *semialata* or it can be integrated with general agriculture also (Sharma and Ramani, 2011; Sharma et al., 2016; Sharma, 2017; Sharma, 2021).

ADVANCES IN LAC CULTURE

Lac can be suitably grown on marginal and degraded lands and requires negligible inputs like pesticides, fertilizers and water etc. It has no competition with other agricultural / horticultural

crops and is important source of cash flow to farmers having low investment and labour capabilities. Lac culture acts like an insurance crop particularly during drought years and is a good source of livelihood especially tribal farmers inhabiting forests and sub-hilly tracts (Yogi et al., 2016). Following strategies are to be employed for sustainable production of lac in the region: (i) intensive lac cultivation on bushy host plants, (ii) integration of lac culture with agriculture, (iii) extension of lac cultivation to potential non lac growing areas and (iv) providing training to traditional lac growers in scientific methods of lac cultivation.

Traditional lac cultivation on major standalone host-plants

i. *Kusum* (*S. oleaca):* It is major host plant for *kusmi* lac cultivation. Mainly two crops of *kusmi* strain (summer season-*jethwi* and winter season-*aghani*) are harvested annually. *Jethwi* crop is cultivated during January-February to June-July and *aghani* crop is cultivated during June-July to Jan-Feb.

ii. *Palas* (*B. monosperma):* It is major host plant for *rangeeni* lac cultivation. Mainly two crops of *rangeeni* strain (summer season-*baisakhi* and rainy season- *katki*) are harvested annually. *Baisakhi* crop is cultivated during October -November to June -July and *katki* crop is cultivated during June -July to October -November.

iii. *Ber* (*Z. mauritiana):* It is major host plant for *kusmi* and *rangeeni* lac cultivation and is employed for winter season *kusmi* crop or summer season *rangeeni* crop.

Newer technologies of lac cultivation

New lac insect-host plant Combinations (Fig. 1)

i. *Early maturing kusmi lac on F. semialata: F. semialata* is commonly known as Winged Stalked *Flemingia* but among the lac growers it is popular as *semialata.* It is a small bushy shrub and a valuable host plant for lac insect , mainly grown for *kusmi* lac cultivation. Globally it is planted for conservation of soil and as a fodder crop. *Semialata* is economically important because it is a bushy host of perennial nature suitable for *kusmi* lac cultivation and can be integrated with fruit and vegetable crops. Meena et al. (2022) reported more than 30 insect pests, attacking this bushy host plant.

F. semialata has shown great promise for lac production due to its fast growth, tender shoots and suitability for intensive lac cultivation and is a boon to particularly those farmers who do not have lac-host trees but are interested in lac cultivation (Sharma and Ramani, 2011). However, problem encountered during normal *kusmi* lac production on *semialata* was detachment of the lac encrustation from the twig towards the crop maturity period leading to not only deterioration in quality of broodlac and decrease in the yield of lac but also un-sustainability of broodlac production on this host.

Major recommendations of the technology developed are: (i) Early maturing variety of *kusmi* strain (maturing in June and January - about one month before the normal time *i.e.* July and February) should invariably be used for lac cultivation on *semialata,* (ii) Lac insects should not be allowed to settle on more than 35% inoculable space of the available shoots, (iii) paired row system of planting should be followed and (iv) Irrigation at fortnightly interval after cessation of the monsoon (December - January) should be provided to lac cultures on *semialata*

An increase in yield (44%) of per meter broodlac and 30.89% increase in sticklac have been recorded and no detachment of broodlac from the stem has been observed by following the recommendations. Early harvest also promises better growth and plants are ready on time for inoculation of the next crop. More than 40% higher income to the farmers in comparison to conventional practice. Under paired system of planting lac cultivation can be integrated with vegetable cultivation leading to increased income, better quality broodlac and land use diversification.

ii. *Late maturing kusmi lac on ber, Z. mauritiana:* Ber is the most preferred host for lac cultivation among the growers because it can be utilized for both the strains of the lac insect and comparatively, it is also one of the fastest growing lac-host among the tree species with a very good pruning response. Under this technology for *kusmi* lac cultivation, ber is pruned in the month of March / April and late maturing variety of

Early maturing *kusmi* lac on *Flemingia semialata*

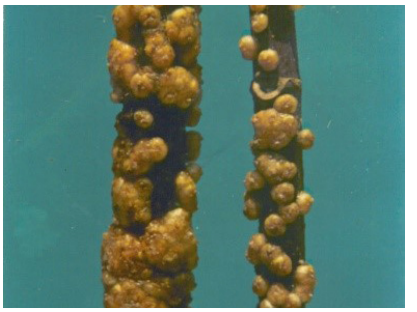
Late maturing *kusmi* lac on *ber*

Kerria chinensis culture on *Calliandra clothyrsus*

Lac cultivation on *Arhar*

Yellow kusmi lac insect on ber

Yellow trivoltine lac insect



New colour variant of the lac insect 'cream'

High density plantation of *ber* for lac cultivation

Lac Integrated Farming System Model

Insect-Filter for lac pest management

Fig. 1. Different host plants of lac insects being used for cultivation

kusmi strain of lac insect is inoculated in the month of July-August @ 20 g per pruned point. Recommended package of practice for *kusmi* lac cultivation on ber is followed and the crop is harvested in the coming March / April which serves as pruning also. Yield of lac on more than one year old shoots as recommended earlier has not been consistent and has resulted in unpredictable output. Continuous cultivation on be*r* of *kusmi* lac especially of early maturing variety harvested in January / February adversely affects the plant growth parameters leading to decreased output.

Two main interventions viz., use of late maturing breed and four-six month old shoots for inoculation has resulted in sustainability of *kusmi* lac production on *ber*. Inoculation with late maturing variety of *kusmi* strain (maturing in July / August - about one month after the normal time *i.e.* June / July) delays the lac crop harvesting time to March / April which not only tends to coincide with the pruning time of the tree but also results in more lac yield (3-26%) in comparison to early maturing varieties (Sharma and Ghosal, 2011).

Normally, new flush of leaves appear in April from the trees pruned in February. However, continuous rearing of *kusmi* lac on *ber* during winter season has been observed to adversely affect the pruning response of the tree leading to not only deterioration in quality of broodlac but also decrease in the yield of lac. Some of the parameters affected are: (i) delayed appearance of flush on the pruned tree, (ii) reduced number of new shoots from a pruned point, (iii) reduced length and diameter of the shoots emerging from the pruned point. Cultivation of *kusmi* late variety which matures in March / April has shown better performance and sustainable yield without affecting plant growth.

iii. *Lac cultivation on fruit* ber *varieties for winter Kusmi lac cultivation:* Jujube or Indian plum or ber (*Z. mauritiana* L) is a well-known nutraceutical fruit crop grown over throughout Indian subcontinent. Ber plant is a fast-growing and hardy tree that thrives with extreme of environment viz., change in temperatures and rainfall in present/future scenario of climate change. The tender shoot of the ber plant is also used for the lac insect culture in many places in India but it is limited to wild species of the ber.

Of the 23 ber fruit varieties screened for lac production four varieties known for fruit purpose, viz., Kaithali, Jogia, Seb × Gola (F1) and Banarasi Karaka have been identified as potential lac hosts. These ber cultivars / varieties may be promoted at farmers' field to enhance their income through lac production (Ghosh et al., 2016). These ber varieties have significantly higher broodlac than CAZRI Gola, the most susceptible variety for lac culture.

With an input cost of Rs 1, 78,926/hectare, output from broodlac and phunki is Rs 4,85,740 /hectare giving a net profit of 171%. The developed technology opens new window for the farmers with ber varieties suitable for lac production and in case of breakdown of lac culture, the nutritious fruit; thus, expanding the scope of lac production and livelihood.

iv. *Lac cultivation on* Arhar (*Cajanus cajan* (L.) Millsp.): Arhar an important pulse crop has also been recorded as a lac host. Out of three varieties of arhar tested for intensive lac cultivation on plantation basis, late maturing variety (Bahar) has been found to be the most suitable. Under paired row system with a spacing of 50 cm between plants and paired rows, and one meter between rows, about 26,400 plants can be accommodated in one ha. Seeds sown in June become ready for inoculation in October / November for *rangeeni* summer crop.

By inoculating 50g broodlac per plant, approx. five times broodlac can be obtained along with the pulse grains. Although 32% reduction in grain yield occurs due to lac cultivation on arhar but profit obtained from lac is much higher than the crop loss. In terms of raw lac, about 1750 kg scraped lac and 900 kg pulse can be obtained from one ha land.

Additional expenditure on about 1500 kg broodlac is required. About 25% more income in comparison to recommended sole crop system of arhar can be generated, even if lac produced is sold as raw lac. An additional income of Rs 50-60 thousand per ha

is generated despite reduction in pulse yield. Lesser number of plants per ha in comparison to sole crop would lead to decreased cost of labour in maintenance. The farmer gets lac as produce in addition to the pulse. Land use diversification reduces the risk of crop failure.

On the basis of broodlac and scrapedlac yield, five genotypes of pigeon pea viz., IPA 8-2, Bahar, Assam local, Acc.no. 591139 and RCMP 5 have been identified as promising for lac production (Ghosh et al., 2014). Rearing of lac insect on pigeon pea reduces 100 seed weight (13.03%) and grain yield per plant (12.08%) significantly but there is no significant reduction in crude protein content in seeds (1.02%).

v. Lac culture on *Calliandra clothyrsus* Meissner*: C. calothyrsus* has been identified as a good and potential host for *K.chinensis* as well as *K. lacca.* Very good crop is obtained during rainy season. Summer season crop is also satisfactory under irrigated conditions. This multi-purpose and quick growing plant can be utilized for lac cultivation after two years of planting (Mohanasundaram et al., 2022).

Early maturing *kusmi* lac on *Flemingia semialata*	Late maturing *kusmi* lac on ber
Kerria chinensis culture on *Calliandra clothyrsus*	Lac cultivation on Arhar

Novel technologies / concepts

i. *High density plantation of* ber *for lac cultivation: Ber* plants are raised under triple hedge system in the plot. The plant to plant distance is maintained 1.0m (within) and row to row 0.75m (between); the inter-strip spaces between two triple hedges are 2.5m. Thus, 7445 plants can be accommodated in one hectare. Whereas, in the recommended planting system (4X4m) of ber accommodates about 625 plants per hectare.

Winter season crop of *kusmi* strain is raised on two-year-old ber plants. Using 12 kg of brood lac, 35kg lac (19 kg brood lac and 16 kg rejected lac) can be harvested. After three years *aghani* crop can be raised using a total 29.4 kg broodlac, in two strips containing 268 plants with an harvest of 110 kg lac (including 30kg broodlac) was harvested. No additional cost is required. After establishment of plantation (after three years) total income of Rs. 4,20,586/- can be obtained by spending Rs. 1,71,285/- per ha/ year with a net profit of Rs. 2,49,301/- (Anonymous, 2010; 2011).

Using this technology lac cultivation can be started in three years whereas in normal planting it takes 5-6 years for establishment. This technology would enable the lac cultivation in shorter and quicker time like horticultural crops.

ii. *Lac Integrated Farming System (LIFS) Model*: LIFS Model developed is multitier hortilac system in comprising of lac host plants (*Flemingia semialata* and ber, *Z. mauritiana*) and fruit trees aonla (*Emblica officinalis* Gaertn syn. *Phyllanthus emblica*), guava (*Psidium guajava* Linn.) and lime (*Citrus aurantifolia* Swing). Paired rows of *semialata* alternate with fruit trees. The components integrated in LIFS have synergistic relationship with each other and complementary in growth characteristics and nutritional requirement. Aonla and ber have been selected as the top canopy trees as their crown is open, avoiding any inhibition of light to the lower plants and less competitive for moisture being the native of dry sub-tropical climate. Guava and lime are next in vertical hierarchy followed by *semialata*. Guava and lime are short statured trees and have narrow canopy, hence do not interfere with growth of *semialata*. Vegetables are used as live mulch underneath *semialata* for retaining soil moisture for longer time and lowering the soil temperature in summer season for lac crop sustainability (Singhal et al., 2014).

A net income of more than Rs. 78,000 is generated in the second year of planting which reaches to a peak value of Rs. 6.75 lakh/ha in the ninth year. LIFS is highly remunerative since returns through lac is higher than agricultural crops. Moreover, lac production coincides with the seasons when virtually no major agricultural crop produce is available. Thus, LIFS can contribute towards income security while field crops and fruit trees will provide nutritional security. Besides, it has high potential for generating employment for

both men and women particularly in off-agricultural season. Lac is an important source of cash flow to the marginal and small farmers also besides a profitable venture for large farmers

Integrated farming systems play an effective role in the utilization of the natural resources in the most effective manner for sustainable crop diversification of farm enterprises which have less demand on space and time with very limited resources in the rainfed area. Lac integrated farming system is very remunerative as it is low cash and labour input crop with high returns; compatible with existing rural livelihood activities in terms of its labour requirement and encourages conservation of host trees and leads to re-greening of the land. This system will help in domestication of lac production, thus unburdening the forest trees which are prone to heavy pruning and other unscientific lac operations by rural community living at the fringes of forest area

iii. *An efficient and indigenous Insect-Filter for lac pest management:* Exploiting the size gradient and phototactic nature of the lac associated insect fauna viz., predators, beneficial and harmful parasitoids, a simple efficient and indigenous device for sorting out different categories of insects has been developed which separates these three categories automatically into three compartments.

Used up broodlac is kept in a container and a meshed side unit separates the beneficial parasitoids, *Bracon greeni* Ashmead, *Apanteles tachardiae* Cameron *, Pristomerus sulci* Mahd. and Kolu and *Brachymeria tachardiae* Cameron to the extent of 69, 60, 100 and 100% respectively. These insects can be released to augment the natural population and check predators (Jaiswal et al., 1998). The device has been further modified and upgraded to improve its efficiency (Jaiswal et al., 1999).

High density plantation of ber for lac cultivation	Lac Integrated Farming System Model	Insect-Filter for lac pest management

New lac insect breeds

i. *Yellow kusmi lac insect*: Yellow *kusmi* lac insect has been developed through selection and multiplication. The insect has good productivity on kusum, ber and *semialata* and yields yellow lac dye.

Yellow kusm*i* lac insect on ber	Yellow trivoltine lac insect	New colour variant of the lac insect ‘cream’

ii. *Yellow trivoltine lac insect*: A new recombinant lac insect has been evolved through crossbreeding of yellow bivoltine *kusmi* and crimson trivoltine lac insect which yields yellow dye and has trivoltine characteristics.

iii. *A new colour variant of the lac insect ‘cream’:* A new colour variant of lac insect has been evolved from the inbred lines and designated as ‘cream’. The resin produced by the lac insect is very light and its body is light yellow in colour.

INNOVATIVE ENTREPRENEURSHIP OPPORTUNITIES

India is a rich centre of plant diversity having more than 45,000 species. Gum and resin-producing plants from Indian forests along with NTFPs (Non-timber forest products) have for many years been seen as providing fertile ground for community development initiatives, especially those focused on rural, remote, indigenous, and / or economically marginalized communities and also helping in the conservation of forests. Production and marketing of such natural products are greatly influenced by vagaries of weather, uncertain prices, limited and diminishing resources, *etc.*

India has a long history of local community involvement in managing forests. Forest dwellers are engaged in various activities like collection, bundling, grading, and packaging of NWFPs (Non-wood forest products) at the village level. It is the major source of income as well as nutritional security of the forest dwellers during the lean period. During the summer season, the gum-producing trees exudate the drops of gum which are very nutritive as well as have medicinal use.

The NRG (Natural Resin Gums) producing states in India are Rajasthan, Gujarat, Madhya Pradesh, Chhattisgarh, Andhra Pradesh, Uttarakhand, Himachal

Pradesh, Jharkhand, Maharashtra, Odisha and NEH Region. Since production of exudate and seed gums as well as lac involve tree species, especially in forest regions, they are treated as NTFPs.

About 70% of the NWFPs collection in India takes place in the tribal belt of the country. Around 55% of employment in forestry sector is attributed to this sector alone. NRGs of commercial importance like lac (*Kerria lacca* Kerr), pine resin (*Pinus roxburghii* Sarg.), *guar* gum (*Cyamopsis tetragonoloba* L.), gum *karaya* (*Sterculia urens* Roxb.)*, dhawada* gum (*Anogeissus latifolia* Roxb.), tamarind gum (*Tamarindus indica* L.), *char / piyar* gum (*Buchanania lanzan* Spreng.) and *babul* gum (*Acacia nilotica* L.) are produced in India (Thombare et al., 2018).

Some of the recent developments in the value addition sector of NRGs at ICAR-IINRG, Ranchi are as follows:

Lac

Being natural, non-toxic, eco-friendly, tasteless, odourless and having many exciting properties for industrial use, lac has a tremendous potential to be used in several industries. The properties of this resin, such as film-forming ability, solubility in spirit-based or alkaline solvent but resistance to water, chemical transformation at higher temperature to become an entirely different and stable material, etc., make it a unique natural material to be further explored in new domains. Besides its existing applications, it has a bright future in developing many more new products and greener technologies, creating a better world to live in (Sharma, 2016; Thombare et al., 2022).

Lac and other resin based Coating formulations for fruits, spices, and vegetables

Lac-based coating formulations are used in the coating of fruits and vegetables for extending their shelf-life; tablets, pills for protection from moisture and slow-release applications, and also chocolates, lozenges, coffee beans, *etc.* to act as a moisture barrier. The U.S. Food & Drug Administration (FDA) has certified lac as a protective glaze for candy and pharmaceuticals because of its non-toxic / hypoallergenic quality. Different lac-based coating formulations have been developed for fruit, spices, and vegetables at ICAR-IINRG, Ranchi for extending the shelf life of these products.

i. *Fruit coating formulations for Kinnow and Pomegranate:* Its application produces better results in respect of gloss, spread area, and firmness of the fruits. It dries rapidly after application and prevents weight loss and shrivelling enhancing storage life. Its application improves the cosmetic appearance, increases the mechanical strength of products, and prevents pathogenic attacks. They contain no synthetic biocides as lac present in the formulation has got the inherent property of being antifungal. Unlike commercial formulations, lac-based formulations are operator's friendly as it does not produce any obnoxious smell during the operation of the plant. Being aqueous-based formulations, these can be used in plants combining washing and treatment in one operation.

ii. *Coating formulation for spices:* The lac-resin-based formulation has been developed for post-harvest treatment of seed spices like coriander, cumin, and ginger for extending shelf life. The essential oil present in coriander due to its volatile nature tends to decrease during storage, resulting in loss of flavour. The essential oil in cumin also decreases storage.

In addition to flavor loss, whole cumin is particularly prone to a fungal infestation when stored in ambient conditions, typically during monsoons. Both coriander and cumin are also targeted by insect pests. Post-harvest issues of these seed spices and ginger can be addressed by coating with lac-based formulation. Its application improves the cosmetic appearance, increases the mechanical strength of products, and prevents pathogenic attacks. It is completely odourless and flavourless after application and enhances storage life through retention of natural flavors.

iii. *Coating formulation for vegetables:* Lac-based coating formulations have been developed to address the problem of extensive post-harvest losses in the horticulture sector. It is cost-effective and convenient

and has exhibited remarkable performance in extending the shelf life of vegetables like brinjal, capsicum, tomato, and pointed gourd. Their applications produce better results in respect of gloss, spread area, and firmness. It is completely odourless, flavourless and dries rapidly after application on suitable substrates. It has no gelling property during storage. The coating can be easily removed by washing thoroughly with water. It is easy to be applied by simple dipping, spraying, brushing, and mechanized waxing plants.

Lac-based varnishes for wooden, earthen, and bamboo items etc.

The French polish applied to wooden items involves polishing/coating several layers of a thin film of lac prepared in a solvent for increasing the life and appearance of wooden items. Lac-based varnishes like lac wood shine, non-spirit lac-based wood varnish, Multipurpose glazing varnish, and aqueous lac varnish, *etc*. have very good potential for its production even at the rural level. Their preparation is simple and requires little investment in terms of equipment / infrastructure.

i. *Lac Wood Shine and Non-spirit lac-based wood varnish:* The two types of varnishes, lac wood shine, and non-spirit lac-based wood varnish developed at ICAR-IINRG, Ranchi are suitable for polishing wooden items. Lac wood shine is spirit based whereas the second one is spiritless varnish. These are eco-friendly, non-toxic, impart a fine finish, and possess qualities like hardness, gloss, heat, and water resistance besides being an excellent embellishing agent. The polished surface neither whitens, when it comes in contact with water nor shows any sign of staining or sticking after coming in contact with any hot object. The varnishes are amenable to conventional application methods: by pad and brush. The films dry quickly in comparison to commercial samples.

ii. *Lac Glaze:* Lac Glaze, the shellac-based Multipurpose glazing varnish can be used for polishing items like metal objects / artifacts of brass, copper, and aluminum materials which requires periodic cleaning of the oxidative coating by rubbing / polishing formulation. It can be used on other materials like plastic, resin, leather, painted artworks, murals, rubber, *etc.*, which become dull and unattractive with time. It can also be used for the restoration of an old painted object made of plaster Paris. Application of this provides sheen on the above surfaces, which remains unaffected for 2-3 years.

iii. *Aqueous Lac Varnishes for earthenware and bamboo-based articles:* The aqueous lac varnishes for polishing/coating earthenware and bamboo-based articles are made by making the lac water soluble on treating with a chemical agent. The varnish can be used for decoration and protection of earthenware and bamboo-based articles, which in turn, fetch a better price in the market. The polished surface does not lose shine and does not whiten when it comes in contact with water.

iv. *Air-drying and baking-type insulating varnishes:* Both air-drying and baking-type lac-based insulating varnishes have been developed for coating winding material for motors, fans, *etc.* The varnish is suitable for application on HT motors also. Baking-type insulating varnishes have high thermal resistance, high dielectric strength (~90 kV/mm), increased thermal resistance of films (~230°C), increased thermal rating (177-179°C), and resistance to moisture, transformer oil, and tracking.

Lac-based cosmetics

NRGs, being biocompatible, non-toxic, and safe, are experiencing high demand in the cosmetics industry. Some of the NRG based products are - lac-based nail polish, lac dye-based *alta*, *palas* tannin-based crack cream, and *moringa* tannin-based crack cream. Lac nail polish is developed using lac formulations with a variety of permitted edible colours. Natural *alta* is prepared by using lac dye and certain skin caring agents, in red and orange colour options. These formulations are safer as compared to synthetic cosmetics, which mostly use industrial colours and some toxic chemicals. Crack creams based on *palas* and *moringa* tannins are effective in healing cracks.

Lac wax policosanol-based plant growth regulator (PGR)

The lac wax policosanol is a mixture of octacosanol (C28), triacontanol (C30), do triacontanol (C32) and other lower fatty alcohols. The PGR activity of policosanol when evaluated *in-vitro* using wheat seedling germination and field evaluation on fenugreek under potted condition at different concentrations of policosanol has shown its potential as PGR with significantly higher activity as compared to commercially available, triacontanol formulations.

Lac-based coating formulations for paper packaging

Coating formulations have been developed for application on paper packaging materials to replace the plastic lamination from the food packets. The formulations are smooth, uniform, flexible, and glossy. The strength of the paper increases and other properties like barrier to oxygen and water vapor transmission also improve significantly after coating.

Lac-glue-based sticky insect trap

Lac-based glue formulations have been developed and modified to improve their tack and thread forming ability which is crucial in trapping and holding flying insects. Glue formulation is prepared by adding suitable vegetable oil-based fillers and suitable diluents to hydrolyzed lac. Field trials conducted at ICAR-IINRG, Ranchi, for the lac-based glue and commercial glue for sticky traps in the semialata, arhar, and Mustard crops have shown fairly good attraction efficiency against sucking pests. The efficiency of the lac formulations has been observed up to 80% as compared to Commercial formulation (Chipku®), however, the advantage of lac-based glue formulation is that it is natural and non-pollutant.

Natural resins and gums

Gums and resins are low volume, high value products. These can be processed to add value in quality for higher returns. In some products value addition through primary processing alone results in three times higher returns. Developing products of commercial use further augments returns, employment, and export earnings. In India, lac and guar gum are processed on a commercial scale, but for most other resins and gums, there is a huge scope for processing and value addition (Sharma et al., 2021).

Dietary fibers

i. *Dietary fibers from guar gum*: Dietary fiber is the carbohydrate part of our diet which is resistant to digestion. Its intake provides many health benefits like reduced risk for developing heart disease, stroke, hypertension, diabetes, obesity, and certain gastrointestinal diseases. Guar gum is considered to be a potential source of dietary fiber but due to its higher viscosity, its use as dietary fiber is restricted. To address the problem, guar gum is modified to Partially Hydrolyzed Guar Gum (PHGG) through enzymatic hydrolysis. The enzymatic process is safer as the PHGG is non-toxic and edible. Besides, the intake of PHGG in diet may also enhance the population of beneficial bacteria in the animal digestive system.

ii. *Arabic gum-based dietary fibers:* Gum Arabic is a widely used food hydrocolloid with a major application as a natural emulsifier, stabilizer, and texturizing agent. Besides it also finds use as a source of soluble dietary fibre in low-calorie food and beverages. The problem of non-uniformity and impurities in the gum can be addressed by isolating soluble fibre portion from the gum arabic which is popularly known as dietary fibre. Dietary fibre is isolated from gum Arabic by using enzymatic means for obtaining a safer, non-toxic, and edible product with low calorific value. Its intake in the diet provides many health benefits like reduced risk for developing heart disease, hypertension, diabetes, obesity, *etc*. The dietary fibre (PHGG and Gum Arabic) enhances population of *Lactobacillus* spp. which is probiotic bacteria and usually present in the digestive systems of animals. Prebiotics are a carbohydrate part of the diet that stimulates the growth of beneficial bacteria in the animal digestive system and ultimately improves the host's health.

Guar gum-based super-absorbent hydrogels

Novel super absorbent hydrogels synthesized from guar gum is able to absorb 500 ml distilled water per gram of dry weight. The hydrogel is almost completely

biodegradable within six months under the soil. These hydrogels are effective in the controlled release of Phosphorus (P) and Boron (B) in soil for up to 60 days as studied in pot culture experiments. The water-absorbing hydrogel after addition to the soil as fine powder improves its moisture retention up to 1.5 times and also its porosity up to 9% of its original. Besides these agricultural applications, these hydrogels may also be used in the preparation of baby diapers, sanitary napkins, *etc.*

Gum hydrogel and nanoparticles

Hydrogels are cross-linked polymers with the ability to swell in an aqueous medium. Natural gum like guar gum-based hydrogels infused with nanoparticles have resulted in a wide range expansion of biomedical applications such as wound dressing for antibacterial applications. Nano-composite hydrogel is synthesized by dispersing the gum in alkaline pH in the inert atmosphere reacting with a suitable monomer, initiator, and cross-linker. The silver nanoparticle from *Palas* tannin prepared using the green synthesis methodology is permeated into the *guar* gum hydrogel to formulate tannin silver nano-composite hydrogel. The product so formed can be utilized as a wound healing formulation in an animal model.

i. *Gum ghatti-hydrogel-based nanoparticles for wound healing:* In continuation with the synthesis of natural gum-based nano-composite hydrogel, Gum *ghatti* wascan also be taken as starting material to synthesize hydrogel involving monomer, initiator, and cross-linker under optimized conditions. The silver nanoparticle from *Palas* tannin is infused by *in-situ* and *ex-situ* methods into the gum *ghatti* hydrogel to formulate tannin silver nano-composite hydrogel. The controlled release of the silver nanoparticle from the matrix of the hydrogel indicates the usefulness of the product for wound healing purposes in the animal model. Nano-composite-hydrogel is non-toxic and safe to blood cells which can be applied the for wound healing.

ii. *Gum-based silver nanoparticles:* The silver nanoparticles (AgNPs) are presently gaining importance in numerous applications such as water-purification, nano-impregnated textile fabrics, anti-microbial, anti-fungal, and therapeutics. Synthesis of *Acacia nilotica* (L.) Willd.ex Delile and Jhingan gum-induced AgNPs by adopting a green synthetic methodology is easier, more efficient, eco-friendly, and incurs low cost in comparison to the chemical mediated synthesis. The AgNPs formulations may find its applications as anti-microbial and anti-fungal agents against several plant pathogens.

The synthesized *A. nilotica* and Jhingan gum induced AgNPs have promising anti-microbial efficacy against both Gram-negative and Gram-positive pathogenic bacteria and are non-toxic to animal cells proving their safety for their applications in plants and animals. AgNPs formulations find applications in controlling phyto-pathogens in crops like tomato, pea, *etc*. to be used as novel plant protectants in the future.

Herbal gulal (natural colour) from Palas flower

Most of the *Holi* colours available in the market are toxic and can result in skin allergies to eye irritation, blindness, and much more. In light of the potential hazards of synthetic colours, *Palas* flower based gulal is safe, non-toxic, eye and skin-friendly natural colour (Srivastava et al., 2019).

CONCLUSION

Cultivation of lac / tapping of natural resins and gums not only provides livelihood to millions of lac growers but also helps in conserving the vast stretches of forests, lac insects and associated biota. Lac growers give more importance to regular income from cultivation of lac over the years to one time income from timber or fuel. Thus, lac-culture plays a vital role in protection of our bio-resources. Lac also provides sustained high economic returns, generates employment opportunities and has potential to pave a strong foundation for lac based rural cottage industries. With increasing demand for natural products, the time is ripe to introduce lac

in farming system and on idle lac host trees in the forests. It is evident from the fore-going account that promoting and encouraging lac culture will not only check environmental degradation but also rebuild the ecological balance. Therefore, lac cultivation can be introduced in the region on plantation basis especially on bushy lac host plants.

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