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Broodlac in wirenet basket tied for inoculation

TWENTY-FIVE YEARS OF RESEARCH IN LAC

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THE resin is the hardened secretion of the tiny lac insect thriving on certain trees which are consequently called host trees. Though the resin was known from time immemorial, only at the end of the last century the importance of the resin was realised and attention was given for its systematic cultivation and proper utilisation. Over 80 per cent of the world produce of lac is from India. It provides part time occupation and much needed subsidiary income to about 40 lakh cultivators mostly *adivasis* and as such contributes sufficiently to their welfare.

There are two distinct strains of lac insects in India, namely *Kusmi* and *Rangeeni*. The former is mainly available from *kusum* (*Schleichera oleosa*) tree or other hosts with *kusum* brood while the latter from hosts other than *kusum*. Each strain passes

Trained Galwang bush

through two generations in a year and consequently there are four crops per year. The two *Kusmi* crops are each of six months duration and are called *Jethwi* (January-February to June-July) and *Aghani* (June-July to January-February) while in *Rangeeni* crops one is of eight months and the other of four months duration which are called *Baisakhi* (October-November to June-July) and *Katki* (June-July to October-November). Of the total Indian output, nearly 80—90% are obtained from *Rangeeni* crops, the *Baisakhi* being the major commercial crop. The *Kusmi* crops, though produced in smaller quantities, are superior in quality, have greater demands and fetch better price.

Untapped Potentialities

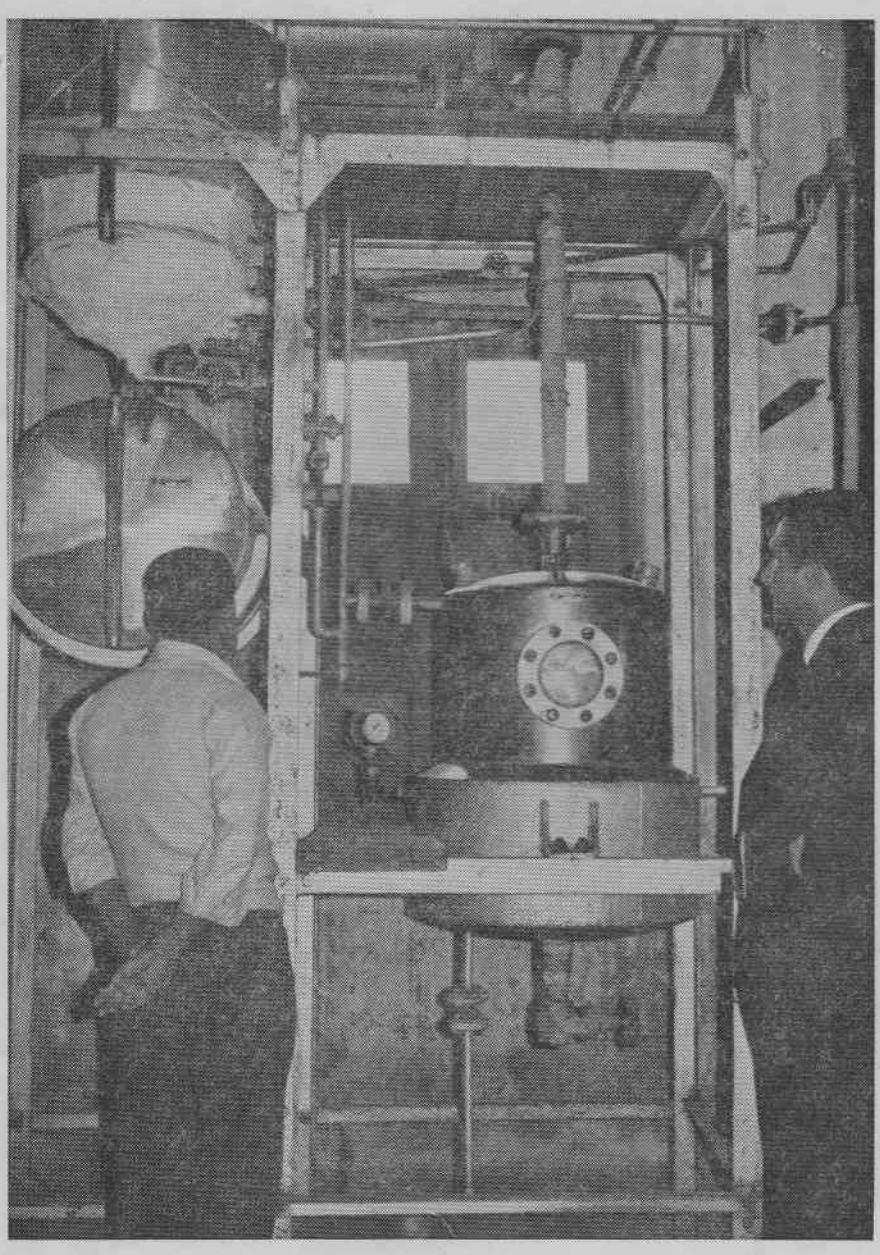
India possesses untapped potentialities for lac production. Limitations in production are, however, posed by the volume of exports. Before the second World War, India had a virtual monopoly in the export of refined lac to the world but after the War, Thailand has emerged as a serious competitor. The cost of production of lac in Thailand is lower than India as the yield per tree there is higher. However, the quality of Thai lac is poor. On the other hand, though lac is the only natural resin par excellence, it started facing stiff competition from synthetics since the last World War. Before the War the biggest outlet for lac was in the gramophone industry which has gradually been replaced by synthetics. Lac has also been ousted from some of its surface coating. Though the greatest advantage of lac over its synthetic rivals is its versatility as it has some of the qualities which are unique in character and which no single synthetic resin so far possesses, there are certain drawbacks from which lac suffers for certain specific applications.

In order to meet the above challenges, the major task ahead in the post-Independence days was to tackle urgently the following main problems in the various Divisions of the Institute: (1) Development of improved cultivation techniques and other measures to reduce the cost of cultivation of lac of improved quality; (2) Working out newer modifications and newer uses of lac for increasing the consumption of lac in this country as well as abroad, and (3) Development of improved techniques for processing of lac, for economic utilisation of by-products of lac and for grading and analysis of lac.

Major Achievements

The major achievements so far obtained during the last 25 years of our Independence on the above lines are briefly enumerated below:

Improved method of lac cultivation. The main host trees under lac cultivation in India are (i) *kusum* (*Schleichera oleosa*), (ii) *palas* (*Butea monosperma*) and *ber* (*Zizyphus mauritiana*). In order to ensure maximum sustained production of lac from season to season in the host trees, a coupe system of cultivation for *Rangeeni* hosts was evolved. The number of coupes in which the hosts will be divided will depend on the species of hosts and their growing habits. *Palas* should be divided into three coupes with equal number of trees in each; two coupes to be utilised for raising the *Baisakhi*-cum-*Katki* crops in alternate years from Oct.-Nov. to Oct.-Nov. of the succeeding year while the third



Wax extraction pilot plant

coupe for the commercial *ari* (immature) crop every year from Oct.-Nov. to April of the succeeding year. *Ber* may be utilised for growing a commercial *ari* crop like the third coupe under *palas*. In the case of the slow growing *kusum* trees, these are divided into four coupes and each is utilised for raising crop once in every two years. The trees thereby get sufficient rest for one and a half years.

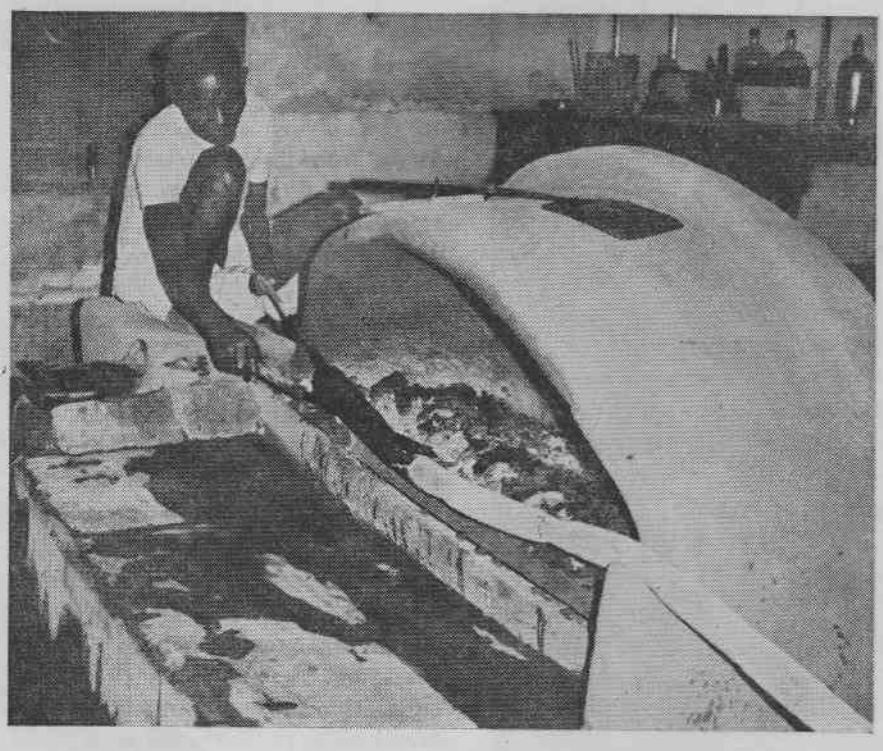
Maximum yield of lac can only be obtained if sufficient number of young shoots are made available to the lac larvae for settling after emergence. This objective can only be met by the most important and essential operation of timely pruning of the host trees. The proper time of pruning of *palas* and *ber* trees is about the middle of April while in the case of *kusum* trees the cropping or harvesting operation itself serves as pruning.

Lac crops should be harvested only one week earlier prior to larval emergence to ensure satisfactory emergence of healthy larvae for next generation. This period has been found quite satisfactory for transportation of broodlac from place to place without any detriment to inoculation. To obtain maximum yields from a crop by infecting at proper time without wasting lac larvae it is absolutely necessary to know the dates of emergence. To forecast dates of emergence of lac larvae a scientific system has been developed based on the development of embryos in the ovary of the females by examining under a microscope. It has, however, been found that the temperature and humidity play a very important role in egg laying and coming out of larvae from inside the lac test of the mother. Egg laying practically stops if the temperature falls below 17°C in summer and below 15°C in winter. Hence under the above conditions the emergence normally is delayed for some time.

As a result of systematic investigations, it has been established that *ber* should be exploited for *Katki* (winter) crop and *palas* for the *Baisakhi* (summer) crop where both the species are available.

The important host trees, *palas*, *ber* and *kusum* are slow growing species and require at least 10 to 15 years to become ready for lac cultivation and consequently it is not practicable to have cultivation on plantation basis on these hosts. Hence for intensive cultivation of lac on plantation basis, specially the superior *Kusmi* lac, alternate hosts were searched and *bhalia* (*Moghania macrophylla*) a natural bush, 2.5—3.0 m high, has received considerable attention. It has been found to be suitable alternate host not only for *Kusmi* lac but also for *Rangeeni* lac and already recommended for intensive cultivation of lac specially *Kusmi* lac on plantation basis. However, this host has been found to be unsuitable for *Jethwi* crop as it is unable to sustain large population of the insects during the summer months. On the other

hand, another host, *galwang* (*Albizzia lucida*) which has been trained into bushes, has been shown to sustain lac insects during the summer months. Therefore for sustained lac production, a mixed plantation of *bhalia* for *aghani* crop and *galwang* for *Jethwi* crop has been recommended. It is possible to raise plantation of these mixed bushes under agricultural conditions on acre basis. *Bhalia* becomes ready for inoculation within one and a half years and *galwang* within three years from the time of raising. The raising of *bhalia* and *galwang* bushes from cuttings with the use of growth hormones has also been achieved. As all the operational schedules can be performed easily from the ground itself, the cost of cultivation in comparison to the conventional hosts will be greatly reduced. In these bushes the cropping operation itself serves the purpose of pruning and the bushes become ready for re-inoculation within a year and therefore, three coupes will be necessary in rotation.



Soft coke hearth for lac melting

Besides the above two hosts, *Khair* (*Acacea catechu*) and *porho* (*Ficus cunia*) also proved to be promising alternate hosts for *Kusmi* lac. To bring down the cost of cultivation, attempts were also made to train the conventional hosts into bushes to which *ber* and *palas* responded well. This has raised a hope of bringing these trained bushes into lac cultivation on plantation basis.

A successful crop can only be raised if healthy, mature and pest-free broodlac is selected for inoculation. The brood rate for inoculation also has some direct bearing on the yield of crop. It has been clearly established that the rate of broodlac should be such as to give settlement of lac larvae over 10 to 15 times the length of the brood sticks which are normally 15 to 30 cm in length.

Enemy insects of lac and their control. There are two kinds of enemy insects, parasites and predators. The parasites are small winged insects, called *Chalcids* which lay their eggs inside the lac tests and are responsible for damage to the extent of 5—10 per cent. The most important predators of insect are two moths, *Eublemma amabilis* and *Holcocera pulverea* whose larvae feed on the lac insects. The former moth has six generations in a year and the latter five. The damage caused by these pests is nearly 30—40 per cent and sometimes the total crop is damaged.

Various effective measures such as biological, cultural, chemical and mechanical have been attempted in order to control the above pests. These are based on the knowledge of the behaviour of the enemy insects and on the knowledge made available through detailed studies on the most important source of predators and parasites to lac crops which are broodlac and sticklac not used for brood purposes. Hence cultural and mechanical measures are most appropriate to attack the pests at the very source and biological and chemical control measures during the progress of the crops in the fields. The methods evolved for prevention of losses to a large extent are briefly described below:

(i) Healthy brood lac, free from enemy insect infestation, should be used for inoculation.

(ii) Self-inoculation of lac crops should be avoided as far as possible except where necessary because old lacs favour the spread of enemy insects.

(iii) The brood bundles used for inoculation should not be allowed to remain on the hosts beyond 2 to 3 weeks.

(iv) All lac sticks other than brood and all *phunki* brood (after use as brood lac) should be scraped at once and removed from the vicinity of inoculated hosts. Sufficient care should also be taken to destroy the larvae and pupae of the pests from the scraped lac.

(v) Wherever possible brood should be encased in 60—80 mesh brass wirenet baskets (30 cm × 7 cm) for inoculation particularly for areas where lac cultivation is being

introduced for the first time. The baskets permit free passage to the lac larvae but not to the enemies.

(vi) The growing of *Rangeeni* lac in predominantly *Kusmi* areas and *vice versa* should not be encouraged as the pests from the more fully grown crops of one variety may infect the less mature crop of the other variety grown in the same area.

Chemical Control

Apart from above methods, the possibility of chemical control has been considered though great risk is involved in as much as the lac insects may get killed while controlling the key pests. The insecticides should be such that these will be non-toxic to the lac insects but sufficiently toxic to the pests so as to kill them. Though DDT and BHC as 5 per cent dust and 0.1—0.3 per cent sprays were found safe for the lac insects at all stages of development, these were not fully effective against the pests. Recent behavioral and feeding studies revealed that the newly hatched *E. amabilis* caterpillars show vigorous movements for a period varying from 2 to 12 hours before attacking any lac cell on the host plants. This observation provided an important clue for chemical control of this particular key pest. Screening of various modern insecticides revealed that a number of insecticides especially of hydrocarbon groups are harmless to the lac insect while harmful to caterpillars of *E. amabilis*. A very selective contact poison, namely Endosulfan (Thiodan) has been recently found to be very effective in controlling *E. amabilis* in a concentration of 0.03%; the emulsion being sprayed once after inoculation. Field trials are yet to be seen.

Since the continuous use of pesticides leads to resistant variety of insects, the only next best course left was to switch over to biological methods of control. To achieve this, attempts were made to utilise both the beneficial insects as well as the insect pathogens.

Both the predators have a good number of insect enemies but unfortunately, in nature, all these enemy insects occur in small proportions. In order to upset this balance, some of these most effective beneficial insects, *Bracon greeni*, *Apanteles tachardiae*, *Elasmus claripennis* and *Pristomerous sulci* were successfully bred in large numbers in the laboratory, and released in the fields. Though the results have shown promise they were not very satisfactory.

Microbial control has of late gained considerable importance in controlling insect pests control. One such microbial insecticide, *Bacillus thuringiensis*, a pathogenic bacteria, has proved to be very effective in controlling the two key pests even in field experiments. Further preliminary survey on the naturally occurring pathogens has revealed that the two predators are susceptible to a number of disease producing pathogens in their immature stages.

It will be evident from the above accounts that for effective control of parasites and predators an integrated approach needs to be evolved, and work in this direction has already been planned and is in progress.

Taxonomical studies have resulted in recording fourteen species till 1958 and a few more have since been added to this list. The lac insect was known as *Laccifer lacca* (Kerr) but recently has been rechristened as *Kerria lacca* (Kerr). Morphology, anatomy, bionomics and some aspects of physiology have also been studied. The biological complex of the lac insects has also been studied in details. The controversial mode of reproduction has been clarified through breeding and cytological analyses to enable definite genetical investigations possible in these insects. Thus it has been proved beyond all doubts that both *Rangeeni* and *Kusmi* strains reproduce sexually and no partheno-genetic reproduction occurs in either of the strains under any condition as was previously believed. Further studies on the reproductive activity have shown an unusual mating behaviour (lac females are usually mated to a number of males) which could allow these insects to retain genetic variation in their natural aggregates. More recently cytogenetic analysis have unravelled a unique genetic system in that the male lac insect transmits only the maternal genome through the sperm due to heterochromatisation and elimination of the paternal chromosome set during spermatogenesis. This knowledge now forms the basis of current and future genetic improvements in lac insects.

Study of the strain crosses in lac insects has shown that the *Kusmi* strain is genetically endowed to survive normally on *kusum* but not the *Rangeeni* and that the ability of *Kusmi* strain to survive is dominant to the inability of *Rangeeni* to do so.

Detailed life history of a number of pests, predators and beneficial parasite of the predators of lac insects as well as of pests of host plants have been studied in connection with their control.

In the Chemistry and Technology Divisions work on improved processing techniques, grading and analysis, modification of shellac for utilisation in new fields, fundamental work so as to gain an insight into the nature of the molecule and ad-hoc work as was referred from time to time were undertaken.

Improved methods of refining and manufacture

The conventional methods of seedlac and shellac manufacture were studied thoroughly and improvements made to produce economically seedlac of improved colour, lower bleach index, less impurities content and increased yield. Another development to eliminate the drudgery of workers is the fabrication and introduction of a machine for separating sand from seedlac. Regarding shellac manufacture, a major improvement is in evolving of the autoclave method which can be adopted by both small scale as

well as large scale manufacturers. Conditions have been determined for substituting conventional wood charcoal with soft coke for the manufacture of shellac which substantively economises the shellac production. Conditions have also been determined and pilot plant fabricated for the successful manufacture, in our country, of stable bleached lac of both the regular (with full compliment of wax) and refined (without wax) varieties.

One of the most important achievements is the development of a process for the manufacture of shellac direct from sticklac. During the processing of sticklac to seedlac and then to shellac, there is a loss of 20 per cent of lac resin. This improved process has resulted in the recovery of almost all of the resin thereby eliminating the by-products and the shellac obtained has better properties than those manufactured by the conventional methods. Another advantage of the process is that waxy, dewaxed, and decolourised (with wax or without wax) shellacs can be prepared. This is a major breakthrough in the field of processing.

Economic Utilisation

Lac factory effluents contain sufficient amount of lac resin, wax and the total amount of water soluble lac dye. These are valuable products and their economic reclamation will necesarily add to the overall economy of the lac industry. Normally the effluents are allowed to drain out into the adjoining fields and due to the presence of insect bodies producing unhygienic atmosphere in the surroundings. A very simple process has been developed for hygienic disposal of these effluents stopping putrefaction. During this process the lac, wax and most of the dye are obtained as a slurry. Methods have been standardised for reclamation of these products from the slurry and the remaining dye from the mother liquor. To recover the wax from the slurry a wax extraction pilot plant has been assembled. The residue contains sufficient nitrogen and is a good source of manure.

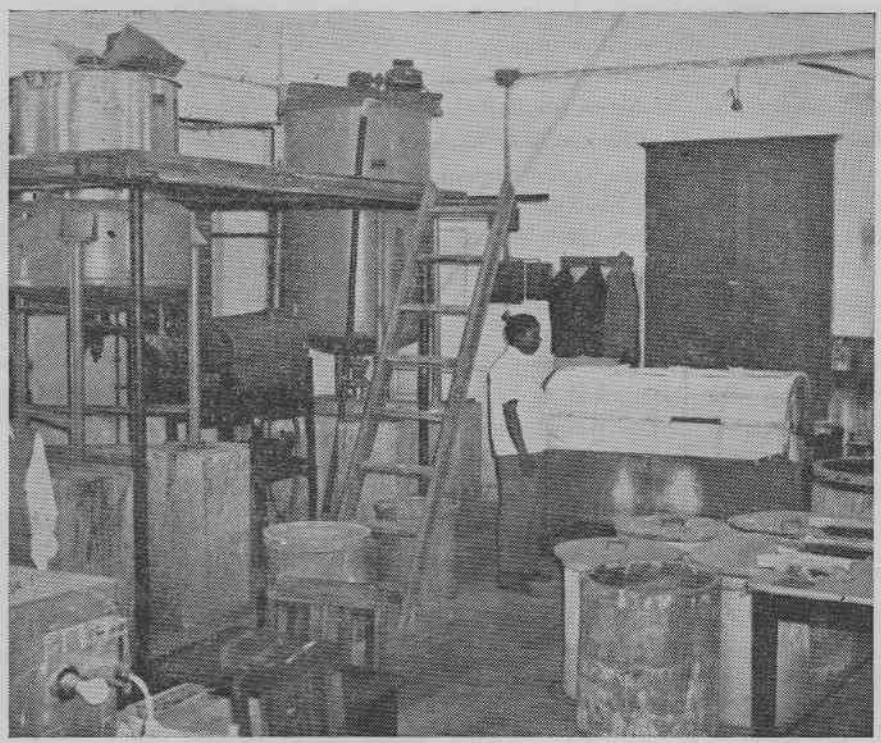
The wax as obtained above or from refuse lacs is normally very dark coloured and as such has restricted uses though it happens to be a valuable product of commerce. A method has recently been developed for the manufacture of light coloured wax, from the crude wax, having higher melting point, better solvent retention power and low penetration value indicating harder wax. This achievement will lead to better utilisation of the dark coloured wax.

The by-products of lac industry such as *molamma*, *kunhi*, *kiri*, etc. contain sufficient amount of lac. In the absence of its reclamation and utilisation, these are accumulated and ultimately sold to Germany at a very cheap price. Successful methods have been developed for the manufacture of shellac, bleached lac and *total* hydrolysed lac from these by-products. These developments have opened up avenues for their utilisation in our country thereby adding economy to the lac industry.

Analysis and Grading

During the period under review a few new methods for determining some of the essential analytical requirements for lac were evolved. These are (i) a rapid method for the determination of moisture content, (ii) a modified and quick method for the determination of insoluble content, (iii) a method for the assay of lac resin in sticklac, (iv) a method for the differentiation between *Kusmi* and *Rangeeni* lacs, (v) a method for the determination of age of lac, and (vi) a simple and 'universal' method for the determination of the bleach index/bleachability. The last method has been accepted in the Indian Standard Specifications as the only method for the purpose and is under study for use in the international specifications.

Apart from the above analytical



Bleached lac pilot plant

methods, the Institute has also provided all technical help for the formulation of Indian and International Specifications for seedlac, shellac, bleached lac and sealing wax.

Fundamental Work

Physical

The thermal and electrical properties of lac, its constituents modifications and modified products were studied which have resulted in valuable information on the performance of shellac in the electrical industries and especially for the development of insulating varnishes based on lac. The determination of specific heat of various lacs has also led to the evolution of a method for assessing the age of lac.

Physico-Chemical

In this field, lac has been studied in the solid state as well as in solution form. Viscosity and osmotic pressure experiments indicated that in dilute solution lac is molecularly dispersed and the seemingly colloidal behaviour in concentrated solution is due to clusters of solvated complexes. Further, studies on the double refraction of lac solutions of varying velocity gradients and concentrations revealed a linear increase with velocity gradient indicating that lac molecules are neither flexible nor kinked. Studies on the kinetics of polymerisation of lac and its constituent acids have led to the understanding on the nature of polymerisation.

Organic

The baffling problem and one of the most important was the study of the nature of the lac molecule and its constituent fractions. During the period sufficient advances have been made towards this end. Patient and systematic studies with the help of conventional and modern chromatographic techniques on the constitution of lac resin and two of its components, namely the ether insoluble hard or pure resin and the ether soluble soft resin, have resulted in the isolation and identification of a number of new acids, both aliphatic hydroxy fatty and hydroxy sesquiterpenic acids. The structures of these constituent acids have also been established. The lac resin has been found to be made up of not less than nineteen constituent acids of which the major ones are aleuritic and jalaric acids. It is still not precisely known how these acids are combined together in the versatile lac resin.

From the present day knowledge it may be inferred that lac resin is composed of at least six components, the average molecule has free hydroxyl and carboxyl groups, a part of the vicinal hydroxyls of aleuritic acid and the aldehyde group of jalaric acid is combined and that ether, acetal, acylal and ester linkages are present.

The constitution of the water soluble lac dye (laccaic acid), another difficult problem, was also solved. It has been found to be composed of five components whose structures have been established conclusively. The structure of the water insoluble dye, erythrolaccin, which is responsible for the golden yellow colour of the resin has also been conclusively established.

Modification and Utilisation

Due to its versatility lac has enjoyed a superiority over all other resins, natural or synthetic. But since the Second World War it is facing great competition from special purpose synthetic resins which have almost thrown it out of the gramophone industry, partially replaced it in the surface coating industry and are constantly threatening its use from other fields too. This is because of its well known limitations, namely low softening and melting points, poor water and solvent resistances, colour, brittleness and lack of specialised performance required by modern technology. To keep pace with the modern technological and exacting demands and also to stabilise its position vis-a-vis the competition from the expanding synthetic rivals, various attempts have been made and are being made in this Institute to modify lac for producing special purpose products of improved performances. A good measure of success has been achieved in individual directions which it is strongly believed, is helping in stabilising its position especially in surface coatings and electrical industries. These modified products have also opened up newer fields for its utilisation. Some of these are described below.

A water soluble variety of lac has been produced for coating of earthenware articles, which imparts glossy and water, heat, oil and soap resistant films after air drying or baking. The coated earthenwares are cheap substitute for the comparatively more expensive porcelain, china or glassware and are being adopted in increasing number of villages and village industries' associations. This modified lac also finds use in the manufacture of inks.

Etch primer or wash primer is quick-drying paint like composition which on application on metal surface produces passivation and gives on drying adherent base, for subsequent painting. A very successful composition has been developed using lac in place of polyvinyl butyral resin. It possesses outstanding adhesion to and acts as an effective anticorrosive primer for light metals and alloys and dries to a smooth, hard, matt and adherent film which may take any finishing paint.

Lac has been modified with butylated melamine formaldehyde resin and the spirit varnishes prepared from it, termed Melfolac, dries very quickly on any surface giving smooth, highly glossy and flexible films resistant to heat, water and spirituous liquors. Its performance compares well with the synthetic wood lacquers and thus ushering a new era in the utilisation of lac in the field of heat and water resistant coatings. In addition to its satisfactory performance in the

surface coating field, it also serves as a very good insulating varnish by virtue of its high breakdown voltage of 2.25 KV/mil which is nearly three times to that of parent lac. Heavy Machine Building Plant of the Heavy Engineering Corporation, Ranchi has found this varnish to be suitable for motor repairs.

Lac modified with urea or epoxy resin has been found to give films which are very suitable for internal coating of tin containers to be used for packaging of various consumer goods including lac varnishes and paints.

The modern trend is the development of aqueous varnishes. Apart from economy, it eliminates fire and health hazards in industrial establishments as well as for the consumers. On this line a few noteworthy developments in the lac based aqueous finishes have been achieved. Ammoniacal solution of lac has been found to be fully compatible with aqueous solutions of maleinised linseed oil and self-dispersing alkyds. Films from these blends have shown remarkable adhesion, elasticity, toughness, hardness, gloss and resistance to heat, water, chemical and most organic solvents. These varnishes also showed promise as vehicles for the formulation of anticorrosive water thinned red oxide primers for steel. These have the added advantage of being highly suitable for deposition by the modern electrocoating technique, application conditions for which have also been standardised in the Institute. Recently interesting aqueous dispersions based on graft and copolymerisation products of lac with vinyl monomers have been developed which have given films of better hardness, flexibility and impact resistance than either of the products alone. For internal decoration of buildings normally costly and imported acrylic emulsions are used. In order to substitute this acrylic emulsion, two aqueous formulations based on lac have been developed which on limed or porous surface give smooth, hard and adherent films.

In connection with the economic utilisation of by-products of lac industry, an alcoholic method has been developed for the production of total hydrolysed lac from refuse lacs. This hydrolysed lac has been rebuilt to a new lac, termed *Rebulac*, simply by heating at 150°C. Baked films from ammoniacal solution showed outstanding flexibility, gloss, hardness and adhesion which was in direct contrast to aqueous lac varnishes which under similar conditions will flake off. Pigmented primers also behaved similarly. Another composition which can dry at room temperature to hard film as above has also been developed by heating a mixture of hydrolysed lac and linseed oil fatty acids in the ratio of 3:1. Since these primers give very glossy and hard finishes with good adhesion and flexibility, these show an important future promise in the field of surface coating for various ferrous and nonferrous metals as a single coat finish.

Lac as such is incompatible with drying oils but on modification with rosin and glycerine becomes compatible. Such compositions are soluble in white spirit and have been found suitable for use as interior varnishes as well as clear baking oil insulating varnishes of the baking type and empire cloth. Compositions based on lac/castor oil or linseed oil and glycerine on treatment with toluene diisocyanate have been found to give air-dried films possessing good hardness, gloss, elasticity and resistance to water, solvents, acids and alkalies.

In our green revolution fertilizer has played and is playing an important role. The less the dissolution rate of these in soil the more of these will be available for healthy growth of crops. But the fertilizers are highly water, soluble and leach through the soil with rain or irrigation water, ultimately becoming unavailable to the plant in time of need. In order to decrease the dissolution rate so that most of the fertilizer is made available to the plant, a technique has been developed for coating urea granules with a composition based on lac and rosin. The rate of dissolution in water and the nitrogen content of this coated urea were found comparable with the T.V.A.'s sulphur coated urea. Preliminary agronomical trials so far have shown encouraging results.

Lac-rubber Combination

Lac and modified lacs have been found to be very useful compounding ingredient for synthetic as well as natural rubber. It acts as a processing aid with curing agents assisting in milling and mixing of the various rubber compounding ingredients. This compounding has given products of improved hardness, tensile and tear strength, impact resilience, modulus, ageing and swelling towards aliphatic and aromatic hydrocarbons.

It has further been observed that the incorporation of lac into natural rubber lowers the dielectric loss while the dielectric constant remains almost constant. These properties are of great use in the manufacture of cables as there will be very low power loss during electrical transmission.

As the use of rubber articles is increasing enormously in our daily life, it is felt that the incorporation of even a small proportion of lac in the manufacture of better quality rubber products will increase sufficiently the utilisation potential of lac to a greater extent.

Ad-hoc research. This Institute is the only one in the world devoted exclusively to lac research and a number of *ad-hoc* problems are referred for solution by interested parties from time to time. The problems solved were far too numerous to be listed here and only a few may be mentioned here, namely a dry mounting tissue paper for mounting photoprints, a lac cement for the fixing of brass caps to low wattage electric bulbs, a lac based cementing composition for tube light chokes, a method for utilisation of polymerised bleached lac for French polishing, iso-propyl alcohol as an alternate solvent to methylated spirit for French polish which is in short supply in our country, gasket shellac cements, etc.