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DEVELOPING A SAFER (BIOLOGICAL) PRESERVATIVE AGAINST BAMBOO BORER BASED ON TRADITIONAL KNOWLEDGE

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Month, Year

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DEVELOPING A SAFER (BIOLOGICAL) PRESERVATIVE AGAINST BAMBOO BORER BASED ON TRADITIONAL KNOWLEDGE

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Project Number	:	KFRI 513/2006
Title	:	Developing a safer (biological) preservative against bamboo borer, based on traditional knowledge.
Principal Investigator	:	Dr. RV Varma
Duration	:	18 months (April 2006 – December 2007)
Objectives	:	1. To standardise the product formulation and application technology of the biological preservative 2. To study the shelf life of the product 3. To evaluate the efficacy of the preservative through an interactive process
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ABSTRACT

During the course of an early study on post- harvest technology to economize bamboo resource utilization, a few biological preservatives based on traditional knowledge were tested. Amongst these, a biological preservative based on traditional knowledge from carpenters involved with temple construction was the most promising. Here an attempt was made to refine the procedure and protocols connected with the preparation of this bio-preservative. The main objective was to scientifically develop a protocol and evaluate the product consisting of 9 biological products against borers and termites attacking bamboo. The laboratory tests proved the efficacy of the preservative against borers attacking bamboo and also under field conditions prevented termite attack. Commercial production procedure of this bio-preservative and evaluation through an interactive process to gain acceptance among the user agencies have to be explored.

1. INTRODUCTION

Bamboos are widely distributed throughout the world except Europe (Tewari, 1992) and have become an integral part of the rural life in Asia. Bamboo belongs to the family *Poaceae* and sub family *Bambusoidae*, and one of the most important and precious non wood forestry raw material. India holds the second position in bamboo resources next only to China. Out of 111 genera and 1575 species of bamboos found in the World, 18 genera and 128 species occur in India and 6 genera under 22 species in Kerala. More than 50 per cent of the harvested bamboo is reported to be used for paper making. It is also used for several other end uses including house construction, making household articles and also for making articles in cottage industries.

Bamboo is a versatile forest-based resource which plays an important role in the economy of the country. India utilizes about 3 million tonnes of bamboo for pulp manufacture as compared to 1 million tonnes used by China (Dhamodharan *et al*., 2002). But there is always difficulty to cope up with the demand of bamboo. National Commission on Agriculture (NCA) estimated the non industrial bamboo requirement in India in 2000 as 3.459 million tonnes and for pulp and paper as 3.546 million tonnes. Present production of bamboo from all sources is reported to be nearly 4.5 million tonnes.

Low durability against bio-deterioration and low penetrability of preservatives are a few drawbacks of bamboo, in its commercial use. The harvested and stored bamboos, if not protected adequately, are often seriously infested by insect borers, causing colossal waste of the raw material. Natural durability of bamboo ranges between 1-36 months depending upon the species and climatic conditions (Liese, 1980). Enormous quantity of bamboo gets degraded during transportation, storage in the depots as well as in mill yards due to stain fungi and insects. Insects belonging to different orders are capable of destroying bamboos both in live and stored conditions, causing threat to the bamboo-based industries.

Bamboos after felling are severely attacked by borers mainly from the family Bostrychidae (Coleoptera). Three species are widespread and cause considerable damage to stored bamboo and finished products. They are *Dinoderus minutus* Fab., *D. ocellaris* Steph. and *D. brevis* Horn. The habit and life histories of the three species are similar. These beetles are capable of causing heavy damage to stored bamboos and are able to reduce a stack of bamboos into a powdery mass of frass. The finished products made out of bamboos are also prone to attack by insect borers (Mathew and Nair, 1988).

From ancient times, the rural communities in different bamboo growing countries have been practicing various traditional preservative techniques to protect bamboo and other articles from insect pests. Sulthoni (1988) had suggested that since bamboo is cheap and easily available among the rural community, the preservative treatment should also be simple and inexpensive. Compared to chemical treatments, traditional methods are always eco-friendly, cost-effective and do not require extra skill and special equipments. The most commonly used traditional preservative methods of bamboo are water soaking and smoking (Bhat and Varma, 2006). Many other treatments are also being practiced by tribal and other people who deal with bamboo. The effective method to protect bamboo from pests is to treat them with appropriate preservatives. A longer service life of the treated products could be attained by the preservative treatment. Thus it becomes imperative that bamboo should be treated prior to its use in order to enhance its service life.

Investigations carried out in different parts of the world have conclusively established that bamboos, when adequately treated with suitable wood preservative become resistant to the attack of insects and fungi and give satisfactory service life. As part of the project on post-harvest technology to economize bamboo resource utilization (Bhat and Varma 2006), data were also generated on traditional methods of bamboo preservation. Under this, a few traditional practices of preservation were subjected to scientific evaluation and a biological preservative used by traditional carpenters in Kerala was found promising.

It is a concoction of nine ingredients mostly of plant origin. In some of the Devi temples of Kerala, every year there is a ritual of drenching the deity (Commonly made out of Jack wood) with a liquid obtained from distilling the bark and roots of teak (*Tectona grandis*). This is known as *Chaanthaattam* and is believed to increase the durability of the idol. Similarly the durability of bamboo can also be increased many times by impregnating it with preservatives of plant origin.

The present study envisages further refinement and evaluation of this bio-preservative against bamboo borers. As mentioned above, the traditional knowledge gained was only on a biological preservative made out of a combination of different plant products against wood borers. The preservative is a combination of 9 biological ingredients which belong to the plant families of Arecaceae, Zingiberaceae, Combretaceae, Plumbaginaceae, Burseraceae, Dipterocarpaceae and Pedaliaceae. Interaction with various carpenters and experts in the Ayurvedic manufacturing units was necessary to know more about the preparation of biological formulations and optimum quantity of each ingredient to be mixed, while preparing the formulation. Since the formulation was to be made available in a semi liquid form, the methods practiced by some local paint industries were also consulted. Several laboratory and experiments under outdoor conditions were also required to test the effectiveness of the preservative against wood borers. The main thrust of the study was to standardize the product formulation and test its efficacy under local conditions to manage post-harvest pests of the bamboos.

Thus the present project was undertaken to standardize the protocol for preparing the biological preservative and to evaluate the potential against borers attacking stored bamboos both under laboratory and field conditions. Three preservatives with the eight ingredients with sesame oil as the medium (Preservative-I), Sesame oil and Cashew shell oil as medium (Preservative-II), and cashew oil alone as medium (Preservative-III) were prepared and tested against borers. Attempt was also made to test the shelf life of these products under laboratory conditions.

2. REVIEW OF LITERATURE

2.1. Biodeterioration of bamboos

Although bamboo is one of the strongest structural materials available, it often succumbs to deterioration caused by a number of insect pests during storage or in service leading to considerable economic loss. Major pests attacking bamboos are from the insect orders- Orthoptera, Hemiptera, Lepidoptera, Hymenoptera and Coleoptera (Singh and Bhandari, 1988; Haojie *et al*., 1998; Koshy *et al*., 2001). Out of 20 insect species reported (Browne, 1968; Chakrabarti and Maity, 1980; Mathew and Varma, 1988) only a few are considered to be economically important.

Among the bamboo pests, post-harvest pests are of concern because of the economic loss caused to stored bamboos and finished products (Beeson, 1941; Plank, 1950; Sen-Sarma, 1977; Nair *et al*., 1983; Singh and Bhandari, 1988; Hidalgo, 2003). About 50 insect pests have been reported to attack felled bamboo culms and finished products. Many of them are coleopteran borers belonging to the families of Bostrychidae, Lyctidae and Cerambycidae (Haojie *et al*., 1998). The most destructive Bostrychids are *Dinoderus minutus* Fab., *D. ocellaris* Steph. and *D. brevis* Horn. They are responsible for over 90 per cent of insect damage to harvested culms and finished bamboo products (Haojie *et al*., 1998).

2.1.1. Nature of borer attack on stored bamboos

Borers enter the bamboo through the basal cut ends or other exposed portions such as trimmed branch bases at the nodes or other exposed regions due to mechanical damage. Adult beetles begin attack from the inner portion of the basal cut region (Nair *et al.*, 1983). Generally bamboos are attacked within 24 hours, after it has been harvested (Plank, 1950; Abd. Razak *et al.,* 1995). Adult beetles make tunnels longitudinally inside the culms and the female beetles lay eggs in the inner part of the culm wall just below the pith cavity membrane. Newly hatched larvae start tunneling at the place of emergence. They are voracious feeders and can cause much more damage than the adults (Plank, 1948).

2.2. Borer menace in bamboo-based industries

In Kerala, the Hindustan Newsprint Limited (HNL) and Bamboo Corporation are the two major bamboo-based industries. Bamboos are stacked open in the storage yards of HNL and bamboo mats are stored in the godown of Bamboo Corporation for longer periods before being used. Powder-post beetle attack is common in such storage yards, causing considerable economic loss. Mathew and Nair (1988) recorded intense build up of *Dinoderus* population in bamboo storage yard at Hindustan Newsprint Ltd., during the months of May, June and July in 1982. Among the storage pests recorded, *Dinoderus* spp., was the most common as well as the most harmful to stored reeds and bamboos at HNL. (Gnanaharan *et al*., 1996)

2.2.1. Economic loss due to borer infestation

Poor storage conditions in bamboo depots promote borer attack. The problem is acute in humid tropical countries (Kumar *et al.*, 1985). It has been estimated that bio-deterioration due to termites, borers and fungi collectively cause 12 to 18 per cent loss per annum (Singh, 1974; Guha and Chandra, 1979), of which borers alone cause about 2 to 4 per cent loss by reducing fiber content which in turn reduces the recovery of the pulp (Rajor *et al.*, 2000). Nearly 30 to 40 per cent loss has been reported from stored bamboo depots (Kumar, 1977). Laboratory study conducted by Guha and Chandra (1979) revealed that a loss of over 22 per cent in wood substance occurred in one year resulting in a corresponding loss of around 10 per cent in unbleached craft yield during storage in the open. About 40 per cent of the bamboo stack was reported to be lost within a period of 8 to 10 days because of ghoon borer attack (Thapa *et al*., 1992). However, quantitative estimates on the loss of bamboo due to bio-deteriorating agents alone are not available.

2.3. Management of borer infestation

Different methods have been practiced to protect felled bamboos against powder-post beetles. Harvesting bamboo culms during particular seasons of the year, in accordance with lunar periodicity, practicing traditional methods of preservation, application of chemical or biological pesticides etc., are some of the methods practiced to protect felled bamboo against borers. Felled culms treated physically or chemically can result in resistance against borers and fungi. Microwave and infrared techniques have also been developed for killing the borers within the bamboo culms (Kang *et al*., 1986). Laboratory and field trials have shown that loss due to fungi and insects could be significantly reduced, if proper preservative treatments are carried out at the time of stacking, even under open storage.

2.3.1. Traditional practices

Traditional bamboo weavers and local people are practicing various methods, simple equipments and local products from nature to protect stored bamboo. Green bamboos are usually treated before making huts or other articles. These methods are always simple, eco-friendly and can be practiced by local people (Stebbing, 1905; Gardner, 1945; Rehman and Ishaq, 1947; Plank, 1950; Sulthoni, 1988; Kumar and Dobriyal, 1990; Hidalgo, 2003; Bhat and Varma, 2006). Important traditional methods practiced to increase the durability of bamboos are heating (smoking) the culms over open fire (Rehamn and Ishaq, 1947) and submerging felled culms under running or stagnant water for a certain period of time (Sulthoni, 1990). Since bamboo is considered as locally used non-wood material, much importance has not been given to study the pest problems in the bamboos by forest managers and forest entomologists (Sharma, 1988). However, tribal and other rural communities carry out traditional preservative techniques to protect felled bamboos. Generally the traditional knowledge associated with bamboo preservation is valued mainly because the methods are cost-effective and will suit under rural conditions.

In Andra Pradesh, a hall type structure using treated bamboo was built a few years ago to test it as a cyclone resistant structure and turned out to be a highly useful and protective structure. Using modern knowledge of structural engineering coupled with inherent qualities of bamboo as a building material will be as strong and durable as reinforced concrete structures. When modern techniques of engineering have been employed, preservative treatment is not a major issue, but would require skilled laborer.

2.4. Integrated Pest Management (IPM) approach

Conventional methods of bamboo preservation do not ensure total protection against *Dinoderus* attack. In recent times use of chemicals belonging to the category of easily biodegradable group of fourth generation insecticides has been proposed (Thakur and Bhandari, 1997). But the growing concern about the ill effects of chemical pesticides has necessitated a change in our strategy to manage insect pests in general and bamboo pests in particular under an Integrated Pest Management (IPM) perspective. Recent technical advances in the production and use of entomopathogenic fungi have also stimulated interest in developing them as environmentally compatible biocides. Among the entomopathogenic fungus, *Beauveria bassiana* belonging to the sub class Hyphomycetes of Deutromycets is a well-known entomopathogen of Coleopteran, Hemipteran, and Lepidopteran insects (Juliya, 2007) and has been recorded as useful biocontrol agent against forest insect pests, including *D. minutes.* Technical advances in the mass production and use of entomopathogenic fungi have made them promising and environmentally compatible biocides. Since there is lot of international market for bamboo products, use of biological preservative has added significance.

3. MATERIALS AND METHODS

3.1. The Biological Preservative

A biological preservative made out of a combination of different plant products which was used by ancient carpenters engaged in temple construction in Kerala, was standardized and tested against *Dinoderus* borers in the laboratory and field. This preparation is unique because the information is based on a traditional knowledge, passed on orally and not documented elsewhere. A brief description of the uses / properties of the nine different ingredients used in the preparation of the preservative is provided below from the literature. All these ingredients were procured from the local market.

3.2. Ingredients

(i) ***Acorus calamus*** belongs to the family *Araceae.* The plants have long creeping roots that spread out just below the surface of the soil. In India, the dry root of *A. calamus* was used in Ayurveda to cure fever, asthma and bronchitis, and as an all round sedative.

(ii) ***Curcuma longa***, (Turmeric) a perennial herb, is a member of the Zingiberaceae (ginger) family. Turmeric has a long tradition of use in the Chinese system of medicine, particularly as an anti-inflammatory agent, and for the treatment of flatulence, jaundice, menstrual difficulties, hematuria, hemorrhage and colic. The rhizome is the portion of the plant used; boiled, cleaned and dried, yielding a yellow powder.

(iii) ***Terminalia chebula*** belongs to the family Combretaceae. It is called the "king of medicines" and is always listed first in the Ayurvedic meteria medica because of its extraordinary powers of healing. Fruit contains a constituent which possesses antibacterial and antifungal properties. The seed of the plant was used for the preparation of the preservative.

(iv) ***Plumbago indica*** belongs to the family Plumbaginaceae. This plant is commonly cultivated in the gardens throughout India. Root is the most commonly used part which contains an acrid crystalline principle called 'Plumbagin'. It is a powerful irritant and has well established antiseptic properties. The root portion of the plant was used.

(v) ***Boswellia serrata*** is a moderate to large branching tree found in the dry, hilly areas of India and belongs to the family Burseraceae. When the tree trunk is tapped, a gummy oleoresin is exuded. A purified extract of this resin is used in modern herbal preparations. It is an Indian herb with a rich tradition in the ancient health system of Ayurveda. Many studies have confirmed that *B. serrata* has potent anti-inflammatory and anti-arthritic activity. Extract of the resin was used.

(vi) ***Vateria indica*** is a small genus confined to tropical Asia and belongs to the family Dipterocarpaceae. The genus is valued for timber, oils and resins. White Dammar or Dhupa is a commercially important product. The resin finds extensive use in Indian medicine. Mixed with ghee and long pepper, used for the treatment of syphilis and ulcers. The resin readily dissolves in turpentine and is in good demand in the manufacture of varnishes.

(vii) **Lac** (*Laccifer lacca*) is produced by scale insects which drain the sap from the bark of their host tree, allowing them to secrete lac resin which is scraped off and manufactured into shellac. It is a natural polymer and is chemically similar to synthetic polymers, thus it is considered as a natural plastic. Shellac is edible and is used as a glazing agent on pills and candies. To produce just 1kg of resin, around 30,000 insects lose their lives.

(viii) **Bee wax** is a product from bee hives. It is secreted by honeybees of a certain age in the form of thin scales. The colour varies from yellowish-white to brownish, depending on purity and the type of flowers visited by the bees. It is used as a coating for cheese, to protect the food as it ages. In the Roman period, bee wax was used as waterproofing agent for painted walls and as medium for the Fayum mummy portraits.

(ix) **Sesame oil** is extracted from the seeds of *Sesamum orientale*, belonging to the family Pedaliaceae, an annual plant with branching stems, 4 or 5 feet high. The best quality oil is largely used in the manufacture of margarine. Sesame oil is considered as a substitute for olive oil in making the official liniments, ointments and plasters. This oil was used as the medium for preparing preservative.

In addition to Sesame oil, cashew nut shell oil was also tested as a medium along with the eight ingredients as mentioned above.

3.2.1. Procurement of the materials

Ingredients required for the preparation of the preservative - *Acorus calamus* (Arecaeae), *Curcuma longa* (Zingiberaceae), *Terminalia chebula* (Combretaceae), *Plumbago indica* (Plumbaginacea), *Vateria indica* (Dipterocarpaceae), *Boswellia serrata* (Burseraceae), Bee wax, Shellac and Sesame oil (Fig.1) etc., were procured from shops dealing with plant based Ayurvedic products. All the materials required for the preparation of preservative were brought to the laboratory and made into small pieces, sun dried and powdered.

Fig.1. Ingredients of biological preservative

3.2.2. Standardization of the product formulation

The recipe for the biological preservative as mentioned earlier was obtained from some of the carpenters specialized in wood works of temples. Other than the names of ingredients, not much clue was obtained on their use, application or method of preparation. To standardize the preparation of the preservative, expertise available in different Ayurvedic or related manufacturing units like Vaidyarathnam, Seetharam, Oushadhi, Sanjeevani etc., in Thrissur District of Kerala State were consulted. Based on the information gathered from experts in these commercial manufacturing units, the formulation was prepared in the laboratory. The general assumption, based on experience with other preparations of similar products was that a total of 60 g of all the ingredients to be taken and boiled in 300 ml of sesame oil / water, or 240 g of all the ingredients in 1200 ml of oil /water. Earlier it was not known as to in what proportion the various ingredients to be taken for making the preservative. Since 8 ingredients were used, the quantity required from a single material was fixed as 30 g.

Thus, thirty grams each of the ingredients were taken and boiled in 1200 ml of pure Sesame oil. Ingredients like *Vateria indica*, *Boswellia serrata* and Shellac were added only when the oil was boiled. The preparation thus obtained was filtered using cotton cloth. Small slices of bee wax were placed inside the vessel to mix well with the formulation. The final product obtained after boiling was a pale yellowish liquid suitable for brush application. The preservative was allowed to cool and later stored in a glass bottle.

3.3. Preparation of the Preservative

i. An aluminum pot was placed over the oven and fire provided using fire wood and 1200 ml pure sesame oil was poured. It was shaken well and 30 g of each of the ingredients were added one by one (Fig.2). Instead of directly adding, shellac was made into a small bundle within a fine linen cloth and

Fig.2

Fig.2. Preparation of preservative

immersed in the oil. *Vateria indica* was added just before the formulation was taken out from the oven. When froth appeared at the upper layer of the oil, heating was stopped and the pot was taken out from the oven. Bee wax was not directly added to the boiling preservative. It was made into small slices and placed inside another steel vessel where the prepared formulation was filtered using a fine linen cloth. It was then placed as such for a few hours to cool after which it was stored in glass bottles (Fig.3**)** before being used.

ii. In the case of Preservative II, sesame oil and pure cashewnut shell oil were used as the medium. Here, 900 ml sesame oil was mixed with 300 ml cashewnut shell oil to form 1200 ml solution. To this, all other ingredients were added as given above and the methods of preparation were the same (Fig.3).

iii. Preservative III was prepared fully in cashewnut shell oil (1200 ml). Cashewnut shell oil was procured from a Cashew Factory in Kollam District of Kerala. All the powdered ingredients were boiled in the cashewnut shell oil and the formulation prepared was cooled and stored in glass bottles (Fig.3).

Fig.3. Preservatives I, II and III

3.4. Shelf life of the preservatives

Shelf life of the preservatives was checked by conducting experiments on *B. bambos* using laboratory-cultured *D. minutus* beetles. Experiments were carried out on a monthly basis so as to study its efficacy after being kept in air tight glass bottles. The experiment was carried out for a period of 5 months in the laboratory.

3.4.1. Feeding Experiments

The efficacy of the preservative was tested in the laboratory on felled bamboo samples using *D. minutus* beetles. A small quantity of the formulation was taken in a Petri-dish and with the help of a brush, the preservative was applied on 10 cm thick round bamboo pieces and placed in glass tanks for feeding experiments. Choice and no-choice tests were carried out and control samples were also maintained. Total population of beetles emerged at 90 days was recorded by peeling out the test samples.

In the laboratory, feeding experiments were conducted in specially designed glass tanks 60 cm x 25 cm x 25 cm (Fig. 4). Each tank was divided into three compartments using glass partitioning. Thus, each feeding chamber had a dimension of 20 cm x 25 cm x 25 cm. Three sets of experiments were carried out in the three chambered glass tanks. In each replicate, the source of food was two round bamboo pieces. In each of the chambers, 20 adult *Dinoderus* beetles were released. Once the insects were released, the glass tank was covered with a nylon net reinforced with iron frame so as to avoid the escape of beetles.

Fig.4. Experimental glass tank with bamboo culms

Fresh bamboo culms were collected from Attappady forest area in Palakkad District. Preservatives were applied over 10 cm long round bamboo samples and tested against borers using the preservatives (Fig.5). Two samples were used for each replicate and triplicate samples along with a control set were maintained each month.

Fig.5. Brush application of the preservative

After placing the samples inside the glass tanks, 20 laboratory cultured *D. minutus* beetles were released. Then it was covered over by linen sheet and further reinforced with a metal frame over it to prevent escape of borers (Fig.6). At 90 days, the population emerged was retrieved by peeling both control and treated samples. The beetles were counted and the ratio between the number of beetles introduced and the number of beetles counted on the 90th day was calculated which is referred to as the Population Multiplication Index (PMI) (Nair *et al*., 1983) and the data were statistically analyzed.

Fig.6. Feeding experiments in the laboratory

4. RESULT AND DISCUSSION

4.1. Laboratory experiments

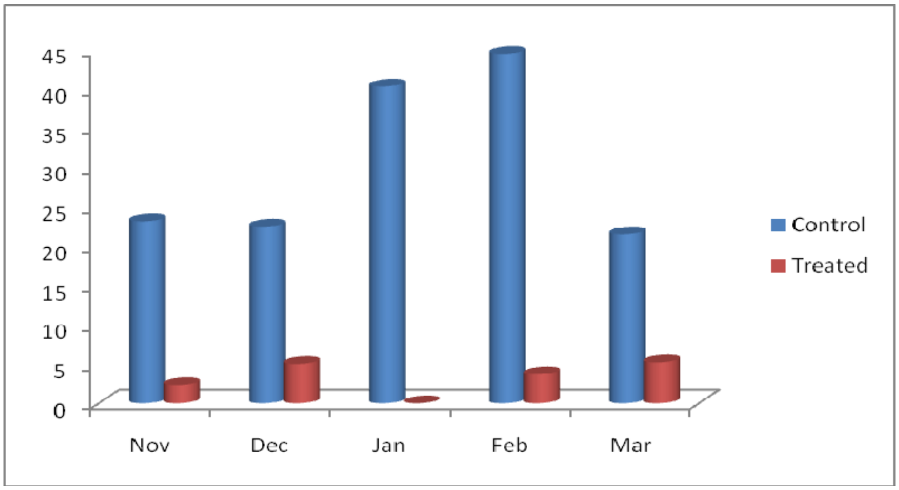
Variation in borer attack was checked on monthly basis in *B. bambos* for a period of 5 months to observe the efficacy of the preservatives kept in glass bottles. Borer population emerged at 90 days was recorded by peeling out the samples. Results obtained after five month exposure showed effectiveness of the treatment. In all the months, borer attack on treated samples was very low as compared to control samples. Statistical analysis showed remarkable difference between treatment and control. Mean borer population obtained from the control samples was 30.4 whereas in the treated samples, the mean population was 3.24 (Table1). Preservative II and III provided complete protection against *Dinoderus* borers in which the treated samples totally escaped borer infestation.

Table 1. Mean borer population in control and treated samples

Month	Mean borer population	
	Control	Preservative 1
November	23.17	2.3
December	22.50	5.0
January	40.33	0.0
February	44.50	3.7
March	21.50	5.2
Mean	**30.4**	**3.24**

Borers showed preference for the untreated control samples and fed on them. In the control samples, minimum attack was noticed in the month of March which was 21.50 and maximum in the month of February during which period the mean per cent of borer population was 44.50. In the case of treated samples (preservative - I) no attack was noticed in the month of January in which all the samples escaped borer infestation and maximum attack was noticed in the month of March during which the percentage of attack was 5.2. The mean population observed during the five month treatment using preservative I is graphically represented in Fig. 7.

Fig.7. **Mean borer population emerged from control and treated samples of *B. bambos***



4.2. Effectiveness of the three preservatives

Mean borer population obtained from the samples treated with preservatives I, II, III and control samples were statistically analyzed. This data would also give an idea about the efficacy of the preservatives in checking the borer attack. Paired t-test was carried out to compare the borer population under different treatments. Number of *Dinoderus* borers emerged was high in control samples and t-value was highly significant in all the three treatments (Table 2).

Table2. t-value obtained from the control and treated *Bambusa bambos* samples

Preservative	Treated	Control	t-value
I	3.23	22.83	6.651**
II	0	40	8.959**
III	0	22.5	5.043**

Significant at 1% level

Out of the three preservatives, preservative II and III, which possessed cashew nut shell oil as the medium showed more potential than sesame oil alone as the medium. Cashewnut shell oil alone as the medium was also effective. Cashewnut shell oil is a cost effective material and is being used as one of the component in the manufacture of paints and also considered as a versatile industrial raw material. There are more than 200 patents of cashew shell oil for its industrial application. The crude oil is also used to ward off insects and fungal stains of wooden structures in buildings. The data also show that cashewnut shell oil would be a better option than sesame oil as a medium for the preparation of the preservative.

4.3. Field experiments on efficacy of the preservatives against termites

Efficacy of biological preservatives was also tested against termites using rubber wood as test samples. The standard graveyard method was adopted for this experiment. This experiment was meant to test the efficacy of the preservative against termite infestation. The experiment was under field conditions for 6 months.

4.4. Methodology

Rubber wood samples were collected and cut into small blocks of 2.5 cm x 2.5 cm x 20 cm. The biological preservatives I, II and III were applied on the samples and tested outside in a termite infested area within the KFRI campus. Latin square type of layout was adopted for this experiment. Minimum of 4 rows and 4 columns were required for this experiment and the wood stakes were partly buried into the soil without any repetition either in the row or column (Table 3). Since graveyard experiment required minimum 4 treatments, the control samples were also considered as an experimental set. In total, 16 samples were used. Initial volume and weight of all the samples were recorded. Each preservative was applied on to the samples using a fine brush. Treated and control samples were taken to the field and out of 20 cm of total length,15 cm of each sample was buried under the soil and 5 cm exposed. The test samples were buried in 4 rows and 4 columns. The samples were placed in such a way that each row and column received equal number of treated and control samples without any replication.

Table 3. Table showing the order of treated wood stakes buried in the soil

TI	TII	TII	CLa
CLb	TI	TII	TIII
TIII	CLc	TI	TII
TII	TIII	CLd	TI

TI= Preservative-I

TII= Preservative-II

TIII= Preservative-III

CL=Control a, b, c, d

A known termite infested area within the campus was selected for conducting the graveyard test. The area was watered at frequent intervals for a period of one month so as to maintain the required moisture level. Treated and control samples were buried in 1 square meter area at a distance of 25 cm each (Figs.8, 9). Watering the plot was done once in a while to accelerate termite activity.

The intensity of attack by termites was observed by taking out the samples at specific intervals. The test samples were recovered after 6 months and the percentage of weight loss of wood on ov dry basis was compared and the significance of difference in wood loss was tested by Analysis of Variance.

Fig.8 Rubber wood stakes buried under soil

Fig. 9 Wood stake attacked by termites

4.5. Results and Discussion

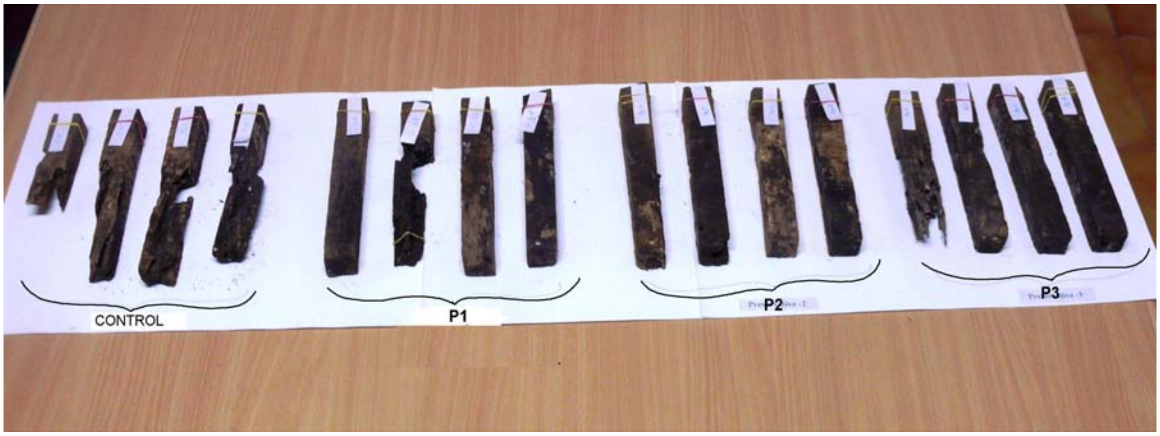
The test wood blocks were taken out at the end of six months and weight and volume of each sample was recorded in the laboratory (Table 4). The percentage of weight loss of wood was compared and the significance of difference in wood loss was tested by Analysis of Variance.

Table 4. Wood loss due to termite feeding before and after the experiment

Control	Before Experiment			After Experiment			Remarks (Termite Attack)
	Length (cm)	Weight (g)	Volume	Length (cm)	Weight (g)	Volume	
C1a	20	136.6	160.8	11	57.6	61	Severe
C1b	20	138.9	167.7	20	107.1	136	Severe
C1c	20	145.0	168.1	20	119.0	125.9	Severe
C1d	20	134.2	163.2	17	82.0	83.7	Severe
Preservative -I							
PIa	20	136.4	170.6	20	133.2	168.3	No attack
PIb	20	129	176.2	16	52.7	72.3	Severe
PIc	20	152.6	167.3	20	138.5	161.3	No attack
PId	20	179.3	167.5	20	134.2	165.3	No attack
Preservative -II							
PIIa	20	165.5	172.8	20	149.1	166.8	No attack
PIIb	20	152.1	173.1	20	141.8	162.7	No attack
PIIc	20	157.3	161.1	20	137.9	154.2	No attack
PIId	20	148.5	172.6	20	125.9	165.2	No attack
Preservative -III							
PIIIa	20	133.3	164.8	18	66.3	84	Severe
PIIIb	20	149.7	156.5	20	134.1	150.2	No attack
PIIIc	20	144.9	162.4	20	133.7	158.5	No attack
PIIId	20	148.3	173.5	20	140.1	169.8	No attack

All the control samples were attacked and considerable portion of wood was eaten by termites whereas samples treated with biological preservatives I, II and III showed good resistance against termite attack. Among the treated samples, only two samples were found attacked which were treated with preservative I and III. All other samples were free of termite attack (Fig 10).

Fig.10. Wood samples showing intensity of feeding by termites on test samples after 6 months



Severe termite attack reduced weight and volume of the samples which were recorded before and after the experiments. Statistical analysis was done using the weight loss data which showed significant difference between treatment and control samples. ANOVA was done for comparing weight loss for both treatment and control. Analysis was also done separately for weight and volume loss. F-value obtained for weight loss was 4.351 which is significant at 5 % level (Table 5). F-value obtained for the comparison of volume was 4.143. This also shows significant difference at 5 % level (Tables 6 and 7)

Table. 5. Results of ANOVA for comparing weight between treatments

	Sum of Squares	df.	Mean Square	F-value
Between Groups	9114.932	3	3038.311	4.351*
Within Groups	8379.233	12	698.269	
Total	17494.164	15		

*Significant at 5 % level

Table.6. Results of ANOVA for comparing volume between treatments

	Sum of Squares	df	Mean Square	F-value
Between Groups	8532.307	3	2844.102	4.143*
Within Groups	8237.453	12	686.454	
Total	16769.759	15		

*Significant at 5 % level

Table 7. Results of comparison of mean weight and volume

Treatment	Weight		Volume	
	Mean	Std. Deviation	Mean	Std. Deviation
Control	91.425[b]	27.319	101.65[b]	35.32
Preservative I	139.825[a]	37.045	149.98[a]	30.12
Preservative II	155.850[a]	7.378	162.23[a]	5.61
Preservative III	135.225[a]	24.898	148.38[a]	23.66

This bio-preservative is a unique product and is purely based on a traditional knowledge which was further refined and experimented over a period of 3 years initially. All the ingredients used in the preparation of this biological preservative possess several medicinal properties and some of them have both pesticidal/antifungal properties as well. The bio-preservative tested was found to offer adequate protection to bamboo culms with no adverse effect. From age-old times, the rural communities of bamboo growing countries in Asia have been practicing various traditional preservative techniques to protect bamboo and articles made out of bamboo from insect pests. Compared to chemical preservatives, traditional methods are eco-friendly, cost-effective and requiring low level of technology and hence easy to practice. However, studies carried out in Kerala and Tamil Nadu have shown that the lifestyle of rural folk, especially the adivasi people has so modernized and there is loss of knowledge base (Sahai *et al*., 2005). It may also be noted that there has been little acceptance of the knowledge passed on from older to younger generation. Use of chemical preservatives under household conditions will have far reaching consequences, including health hazards to humans.

In the present study, the cost for preparation of one liter of the bio-preservative, worked out to be about Rs.90/-, whereas a standard chemical preservative *viz.* Dursban costs Rs.250/liter.

5. EFFECTIVENESS OF THE PRESERVATIVE AGAINST SAPSTAIN FUNGUS

Efficacy of the biological preservative (I) was tested against the sapstain fungus, *Botryodiplodia theobromae* in the laboratory using rubber wood samples. Deep discoloration caused by this fungus on sap wood is a serious problem known in rubber wood. Different chemical preservatives are being used to protect rubber wood against sap stain fungus. This biological preservative was tested mainly to find out its efficacy in preventing the attack of the sap stain fungus, *B. theobromae*. Rubber wood was used as a test material.

5.1. Methodology

Fresh rubber wood samples were obtained from a saw mill at Ollur, Thrissur District. The samples were cut into small square pieces of 7 cm length, 5.5 cm width and 1cm thickness. A total of 15 samples were used for the experiment. Five samples were kept as control and 10 samples were treated.

All the rubber wood samples were rubbed with a cotton cloth to remove dust particles. Using a fine brush, the preservative was applied over 10 test samples. Fungus cultured in Agar medium in the laboratory was used for the experiment. After solidifying the agar, *B. theobromae* was inoculated at the centre of rubber wood samples over 5 mm area. The samples were then placed inside Petri dishes over ‘V’ shaped glass rods. It was then covered with another Petri plate and well sealed with a kiln film. Wet tissue paper was placed inside the Petri-dish so as to provide moisture for easy growth of the fungus. Untreated control samples were also maintained as described above.

5.2. Results

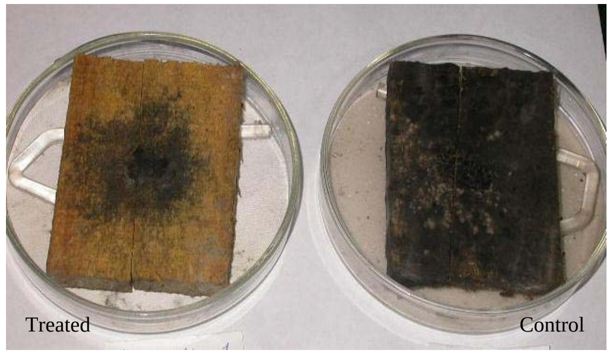


Fig.11. Treated and control samples

One month after the treatment, samples were examined for fungal infestation. All the control samples were attacked and black colour appeared in all the samples (Fig.11). A cross section of the test wood showed that the infection had spread to the interior of the wood (Fig.12). Intensity of fungal infection was very low in treated samples (Fig.13). The infection did not spread to the interior as observed in the control samples.

Fig.12. Section of control samples

Since the whole wood samples of the control were attacked, mean percentage of attack in the control sample was considered as 100 and in the case of treated samples it was 10.97 with a standard deviation of 4.49. Fungal infection on treated samples was compared with 100 per cent attack (control) using one-sample t-test. The t-value calculated was 62.64 which was significant. The infestation of this fungus on rubber wood samples treated with the bio-preservative was very low and found to be effective in minimizing fungal infestation. Thus this bio-preservative also possesses antifungal properties. Though the test wood material used here was rubber wood, it is indicated that treating with this biological preservative can also reduce possible fungal attack on bamboo in addition to borer attack.

Fig.13. Section of treated samples

6. EVALUATION OF THE EFFICACY OF THE BIOLOGICAL PRESERVATIVE ON FINISHED PRODUCTS

One of the objectives at the time of taking up this project was to evaluate the efficacy of the product (Biological preservative) by providing it to bamboo artisans and industries for testing and to get the feedback from them. However, due to time constraints, only one attempt could be made, the details of which are given below.

At a place called Thenkurrissi in Palakkad District, the local people are engaged in manufacture of bamboo and reed articles as a cottage industry. Here the artisans were persuaded to make use of the biological preservative and tested against borer attack. A number of baskets were made using biological preservative treated bamboo clums. Several baskets, both treated and untreated were kept together in their storage yard. Observations were recorded on borer infestation at monthly intervals. This was continued for three months. Up to the 3rd month, no borer attack was observed either in the treated or in the untreated baskets. Further observations could not be continued, because the artisans could not keep their products for long periods without marketing. Thus the observations could not be continued and the results are inconclusive.

7. GENERAL DISCUSSION AND CONCLUSIONS

The pest control/preservative scenario in future is sure to be faced with a drastic reduction in the use of chemical pesticides. Slowly and gradually synthetic pesticides will have to be replaced by bio-pesticides. In India, Government of India through the DBT, has introduced many schemes to promote use of bio-pesticides for more than two decades. Though efforts have been made, in practical terms the prospects of using bio pesticides have not become a reality as envisioned. Some of the drawbacks for the wide spread use of bio-pesticides/ bio-preservatives are the lack of interest on the part of the manufactures, probably due to limited profit, lack of awareness among the consumers on benefits and probably the lack of consistent and convincing results to prove the efficacy of bio-pesticides/ bio-preservatives against target insect pests.

The scope of using bio-preservatives based on traditional knowledge has seldom been evaluated scientifically. In the present study, a bio-preservative based on traditional knowledge, was found quite promising. All the ingredients are locally available and the preparation is cost effective. Under indoor conditions, the effectiveness of the preservative is assured. Studies to further enhance the shelf life of the product may be taken up. Though field trials / outdoor experiments were conducted only in a limited way under storage conditions, this preservative can be safely used. Large scale production methods of the preservative have to be standardized. Awareness programmes on the scope of using bio-preservative has to be strengthened, because of the negative impacts of chemical preservatives on human health and environment. There is also a need to associate bamboo artisans and bamboo industries in evaluating such products in order to prove repeatability of results and acceptability.

REFERENCES

Abd. Razak O., Abd. Latif. M., Liese, W. and Haron, N. 1995. *Planting and utilization of Bamboo in Peninsular Malaysia*. Res. Pamphlet. No.118. Forest Research Institute, Malaysia. 1-117.

Beeson, C.F.C. 1941. *The Ecology and control of the forest insects of India and the neighboring countries*. Reprint 1961. Govt. of India publications, 767p.

Bhat, K.V and Varma, R.V. 2006. Optimization of harvesting and post-harvest technology to economize bamboo resource utilization. *KFRI Research Report. No.285*. Kerala Forest Research Institute, Peechi, 67p.

Browne, F.G. 1968. *Pests and diseases of forest plantation trees*. Clarendon press, Oxford, U K. 1330p.

Chakrabarti, S. and Maity, S.P. 1980. New genus, species and new records of Cerataphidine aphids (Homoptera: Aphididae) from North-West Himalaya. *In: Proc. Zool. Soc., Calcutta*, 33: 55-63.

Dhamodaran, T.K., Gnanaharan, R. and Sankarapillai, K. 2002. Bamboo for Pulp and Paper: A state of the art review. *Final Report of project KFRI-Cons. 59*. KFRI, 154p.

Gardner, J.C.M. 1945. A note on the insect borers of bamboos and their control. *Indian For. Bull*. (New Ser.) *Ent*., 125: 17p.

Gnanaharan, R., Varma, R.V and Balasundaram, M. 1996. Scientific approach to minimize bio-deterioration of stored raw materials at Hindustan News Print Ltd. Kottayam. *KFRI Extension Report*, 8p.

Guha, S.R.D. and Chandra, A. 1979. Studies on the decay of bamboo (*Dendrocalamus strictus*) during outside storage. *Indian For.* 105(4): 293-300.

Haojie, W., Varma, R.V. and Xu Tiansen. 1998. *Insect Pests of Bamboos of Asia: An Illustrated Manual. INBAR*, New Delhi, 200p.

Hidalgo-Lopez, O. 2003. *Bamboo: The Gift of God*. Oscar Hidalgo, Colombia, 553p.

Juliya, R.F. 2007. Fungal pathogens associated with forest insects in the Kerala part of the Western Ghats. Thesis submitted to FRI University, Dehra Dun, p. 125.

Kang, Y., Hu, W.Z., Pan, X.D. 1986. Study on control of bamboo Bostrychid borers through heating by infrared techniques. *Entomological knowledge.* 23(2): 64-66.

Koshy, K.C., Harikumar, D. and Narendran, T. C. 2001. Insect visits to some bamboos of the Western Ghats, India. *Current Sci*., 81(7): 833-838.

Kumar, S. 1977. Protection of pulpwood during storage. A probe into the current practices and future scope. *IPPTA Zonal Seminar on Afforestaion, Exploitation and Preservation of Forest Raw Materials.* FRI, Dehra Dun: 116-120.

Kumar, S. and Dobriyal, P.B. 1990. Preservative treatment of bamboo for structural uses. *In* : Rao., I.V.R., Gnanaharan, R. and Sastry, C.B. (Eds.). *Bamboos Current Research. Proc. International Bamboo Workshop held in Cochin, India, 14-18 November, 1988.* Kerala Forest Research Institute, India and International Development Research Centre, Singapore. 199-206.

Kumar, S., Kalra, K.K and Dobriyal, P.B. 1985. Protection of pulp bamboo in outside storage. *J. Timb. Dev. Assoc. of India*. 31(4): 5-12.

Liese, W. 1980. Preservation of bamboos. *In*: G. Lessard and A. Chouinard (Eds.). Bamboo Research in Asia. IDRC. 165-172.

Mathew, G. and Nair, K.S.S. 1988. Storage Pests of Bamboos in Kerala. *In*: Rao, I.V.R., Gnanaharan, R. and Sastry, C.B. (Eds.), *Bamboo Current Research. Proc. Int. Bamboo Workshop.* Nov.14-18; 212-214.

Mathew, G. and Varma, R.V. 1988. Occurrence and pest status of some insects attacking bamboos in newly established plantations in Kerala. *Bamboos: Current Research. Proc. Int. Workshop,* Cochin, India. 195-198.

Nair, K.S.S., Mathew, G., Varma, R.V. and Gnanaharan, R. 1983. Preliminary investigations on the biology and control of beetles damaging stored reed. *KFRI Research Report. No.19*: 35p.

Plank, H.K. 1950. Studies on factors influencing attack and control of the bamboo powder- post beetle. *USDA. For. Exp. Sta. Bull*. No. 48: 39p.

Rajor, A., Sharma, R.K., Maheswari, V.L and Kothari, R.M. 2000. Bamboo metabolism by borers provides a clue to eco-friendly approach for their control. *Indian For.* 126 (8): 838-841.

Rehman, M.A. and Ishaq, S.M. 1947. Seasoning and shrinkage of bamboo. *Indian For*. *Rec*. (*n.s*), 4 (2): 1-22.

Sen Sahai, S, Ujjuval Kumar and Waquar Ahmed (2005). Indigenous knowledge: Issues for developing countries. Kumar Enterprises, New Delhi 66 pp. Sarma, P. K. 1977. Insect pests and their control in rural housing. *Indian J. Entom*. 39: 284-288

Sharma, S.N. 1988. Seasoning behavior and related properties of some Indian species of bamboo. *Indian For.* 114 (10): 613-621.

Singh, P. and Bhandari, R.S. 1988. Insect pests of bamboos and their control. *Indian For*. 114 (10): 670-683.

Singh, S. 1974. The incidence of the borer (ghoon) attack on felled bamboos- some investigations and observations. *Indian Pulp and Paper* 29: 7-14.

Stebbing, E.P. 1905. A further note on the preservation of bamboos from the attack of the bamboo beetles or shoot borers. *Indian For.* 31(5): 249-253.

Sulthoni, A. 1988. A simple and cheap method of bamboo preservation. *In* Rao, I.V.R., Gnanaharan, R. and Sastry, C.B. (Eds.) *Bamboo current Research*: *Proc. Int. bamboo workshop*, 14-18 November, 1988. KFRI/IDRC, 209-211.

Sulthoni, A. 1990. Bamboo: Physical properties, testing methods and means of preservation. *Proc. of a workshop on design and manufacture of bamboos and rattan furniture*, 6-17 March 1989, Jakarta. FAO of the United Nations, Kuala Lumpur: 4. 1-4. 16.

Tewari, D.N. 1992. *A Monograph on Bamboo*. International book Distributors, Dehra Dun, India. 498p.

Thakur, M.L. and Bhandari, R.S. 1997. Recent trends in protection of harvested bamboos from ghoon borers. *Indian For.* 123 (7): 646-651.

Thapa, R.S., Singh, P and Bhandari, R.S. 1992. Prophylactic efficacy of various insecticides for the protection of bamboos in storage against ghoon borers, *Dinoderus* sp. *J. Acad. Wood Sci*., 23(1).