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# Copperized Karanj Seed (*Pongamia pinnata*) Oil as an Alternative to Chemical Preservative in Plywood Manufacturing

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

Most chemicals used in wood preservation are toxic to the environment. Use of synthetic preservatives are highly prevalent in plywood manufacture. Wood, which is the basic raw material for plywood manufacture, being ligno-cellulosic material is liable to degradation due to microbiological organisms and other biological wood destroying organisms causing significant loss. Therefore, it is necessary to develop an alternate naturally available preservative which will be effective for plywood manufacture. Karanj or *Pongamia pinnata* is known for its anti-fungal and pesticide properties that make it an ideal material as wood preservative. Therefore, an attempt was made to develop an eco-friendly green preservative using naturally available plant resources with high toxicity to wood destroying organisms and low toxicity to humans. Copper was incorporated

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into Karanj seed extractive and 12mm thick plywood samples were prepared at different concentrations 0.5% to 5% of preservative which were subjected to tests for efficacy study and mechanical properties as per Indian Standards. From the results obtained in this study, it can be concluded that 3% concentration of the preservative can be utilized in plywood manufacture which can resist against wood borers and termites. Concentration above 3% of the preservative interfere with the bonding properties of the resin and significantly reduces glue shear strength.

*Keywords: Natural wood preservative, karanj (Pongamia pinnata) seed; plywood; glue shear strength; anti-termite.*

## 1. INTRODUCTION

Wood is a lingo-cellulosic material and liable to degradation due to wood destroying organisms. Wood is mainly decomposed due to borer, termite and fungi. Borers create holes in wood by when exiting larvae, termites eat wood to drive on cellulose and nutrients they need to live and fungus kind micro-organisms attack wood that has moisture on causing it to rot. Therefore, to improve the utility of wood, it is to be protected against these insects and micro-organism attacks. The process of treating wood with chemicals and other biochemical substances is called wood preservation. There are mainly three types of wood preservatives: I oil-borne II water borne III fumigants. The preservatives applied to wood using dipping, soaking, brushing or spraying methods. Many different types of preservatives are being used as surface treatments and Glue Line Treatments by the plywood industries. Some preservatives being used presently are ACC, CCB, Bifenthrin, Fipronil etc. by the plywood industries in India.

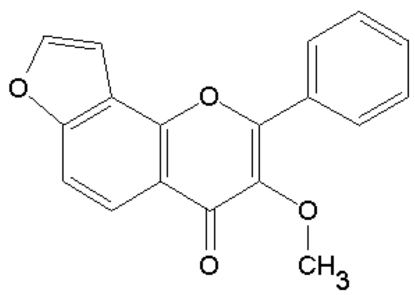
Recent research cites potential cancer risk to the workers who are using chromated arsenic as preservative and CCA is banned in many countries also. In order to mitigate the health risks, many research organisations are working on development of natural preservatives. To develop eco-friendly wood preservatives, many studies have been conducted. Work has been reported on extractives from heartwood [1,2,3], work has also been reported on extractives from leaves of *Ipomea carnea* [4], bulb and leaves of *Sternbergia candidum* [5], leaves of Neem (Swathi et al., 2004). “These extracts possess several toxic constituents exhibiting high toxicity against wood destroying microbes. Efforts have been made by many workers to use these plant products with toxic metals and tested for durability against termites and fungi” [6] (Jain *et al*., 1989; Jain and Virendra Narayan, 1991;) [7].

Karanj belongs to family of Leguminoceae. The leaves are good source of green manure and being leguminous, they enrich the soil with nitrogen. It is a medium sized globous tree generally attains height of about 18 m and a trunk diameter >50 cm. It can grow under a wide range of agro-climatic condition and is a common sight around coastal area, riverbanks, tidal forests and roadsides.

## 2. LITERATURE REVIEW

Karanjin: the furano flavonoid.

Structure of Karanjin: -



“The principal furano flavonoid constituent of Karanjin was the first crystalline compound reported” [8]. “It was isolated from Karanj seed oil and roots and its structure constitution and synthesis were thoroughly investigated by several workers. It was followed by discovery of Pongamol” [8]. “Various furano and chromene derivatives of Karanj possess angular orientation of the furan or the chromene ring. Further, most of these are derivatives of resorcinol in so far as ring A is concerned. The methoxylated derivatives as observed in the chromeno chalkones viz. glabrachromene I and II and pongachalkon, have also been discovered” [8]. “Karanjin, chemically has three methoxy-furano-2’,3’,7,8-flavon, mole formula $C_{18}H_{12}O_4$, a known fatty component of oil, slowly separates out from the oil on standing [9], at a faster rate, at low temperature (< 4ºC). Yields up to 1.25 % of Karanjin and 0.85 % of Pongamol have been reported” [8]. “So, older samples of oil have lesser Karanjin %. Karanjin content in seeds is highly variable, depending on place of origin and season of collection of seeds. Even from de-oiled oil cakes, Karanjin can be extracted and its amount was found to be 0.37% and 0.40 % on fresh and dried de-oiled oil cake weight basis” (Majumdar, 2006). “Crude Karanjin obtained on standing can later on be purified and crystallized into niddle like crystals” [10]. “In another study residual Karanjin in raw and variously processed cake was quantified using HPLC where the raw expeller Karanj cake was found to contain about 0.19 % of Karanjin” [11]. “Though a non-polar solvent, soxhlet extraction of expeller pressed cake with petroleum ether drastically reduce Karanjin content from 0.9% to 0.01%. Socking of cake for 24 hours in 1 % NaOH w/w solution reduces Karanjin content with little further benefit by increasing alkali. Isolation of Karanjin was also done using different solvents such as isopropanol, tolune and dimethyle carbonate and DMC (di methyle carbonate) was found to be best with 0.36% of yield of 97% pure Karanjin” [12]. Studies conducted at National Botanical Research Institute (NBRI,Lucknow) have shown that methanolic extract of Karanj oil had maxim anti-feed and growth reduction activity on polyphagous crop pest, *spodoptera litura* due to presence of high concentration of Karanjin and Pongamol while methanolic extract of bark showed good anti-feedant and grown regulatory activity against the same pest and effective oil based formulation having azadirachtin enriched fraction of neem oil and Karanjin enriched fraction of Karanj oil is developed by the same institute for control of *S.litura*. In another study, Karanj oil was found to be most toxic followed by neem and mahua while combination of neem and Karanja (1:1) was less toxic than individual oils alone on spidermites (tetranychus) urticae. Karanjin in dilutions up to $10^{-5}$was found to suppress the growth of *Mycobacterium tuberculosis* [13-16].

## 3. MATERIALS AND METHODS

### 3.1 Extraction of Karanjin From Karanj Seeds And Copperization

500 gms of dried fine powder of Karanj seeds were taken in 3-necked round bottom flask containing 1 liter n-hexane and reflux for 5-6 hours. Filtration was done to separate the residue and oil. The residue was again dissolved in aqueous methanol (1:1) and extracted with n-hexane to remove the remaining oil from extractive. The aqueous methanol layer was taken and extracted two times with petroleum ether. The aqueous layer was discarded and the organic layer was evaporated and 5.2 gms of semi-solid extractive was taken for copperization with Copper (I) oxide. The extractive was copperized with 5 % of Copper (II) oxide for 28 hours under reflux to incorporate copper by using hexane and refluxed over a heating mantle using water condenser to prevent evaporation of solvent.

### 3.2 Synthesis of PF Resin (Resol Type)

100 gms of Phenol was charged into 3-necked round bottom flask followed by 180 gms of formalin and stirred. 8 gms of NaOH was dissolved in 16 ml water and cooled up to room temperature and added into the flask. NaOH solution was added slowly and rise in temperature was observed. Heating started up to 55°C and then stopped and left the temperature rise up to 90°C±2 due to exothermic reaction, continued the reaction till the flow time of the resin in hot condition in $B_4$ Cup is 14-15 sec. and water tolerance up to 1:6. The reaction mixture was cooled and the batch discharged.

### 3.3 Adhesive Mix

The adhesive mix (glue) was formulated by taking the above PF resol resin with additive conventionally used in plywood industries and Copperized Karanj extraction with different concentration from 0.5% to 5% on liquid basis.

### 3.4 Plywood Manufacturing

12 mm thick plywood was manufactured by taking Gurjan *(Dipterocarpus sp.)* as face and

back veneer with thickness equal to 0.4 mm and Semul *(Bombax ceiba)* core veneer with thickness equal to 1.8 mm. Above mentioned glue incorporated with Copperized Karanj extractive varying from 0.5% to 5% in concentration was used for adhesion. 4 plywood samples of 600 x 600 mm for each concentration were manufactured, total 24 samples were prepared in a hot press at 14 kg/cm$^2$, temperature 140-145$^0$C for time 14 minutes.

### 3.5 Preparation Of Samples

a) The samples for efficacy test were prepared according to IS: 4833:1993 for termite resistance. Test samples or plywood with 12 mm thickness were prepared from defect free air-dried veneers of semul wood *(Bombax ceiba)*. Samples were of size 100 x 25 x 12 mm and were prepared for field test.

b) The samples for efficacy test for borer were prepared according to IS: 4873 (Part-II);2008 for borer resistance. Test samples or plywood were of size 100 x 40 x 12.5 mm were prepared from defect free air-dried veneers of semul wood *(Bombax ceiba).*

c) The sample for evaluation of water resistance, resistance to microorganism test (mycological test), bond quality (glue shear strength), and adhesion of plies were prepared according to IS: 1734:1983.

## 4. TESTING

### 4.1 Mechanical Testing

The plywood samples made with glue incorporated with different concentration of Copperized Karanj extractive were tested as per IS 1734: 1983 part 4 (determination of glue shear strength), part 5 (Adhesion of plies), part 6 (determination of water resistance), part 7 (mycological test).

### 4.2 Efficacy Evaluation

**a) Field test of preservatives against termites:**

Testing was performed according to IS: 4833:1993. Six replicates for each concentration along with control was taken. The treated/untreated samples were tied together to form a chain and buried in the high termite prone area at six different places. Observations were made every month in the first year, every two months in second year and half yearly in third year. Specimens were re-installed at the same position after every inspection. Recording of results were as per the ratings given in the standard.

**b) Evaluation against powder post beetles (borers):**

Testing was performed according to IS: 4873 (Part II): 2008. For initiation of culture beetles are obtained from naturally infested wood stored outside which was maintained in the laboratory. Untreated timber of semul/mango/rubber or dry tapiocca chips were kept along with infested samples for continuous multiplication of beetles. Test samples (plywood) with each concentration were exposed individually. The condition during test was 25-30$^o$C and 70-75% RH. Number of exit holes were recorded and reported.

## 5. RESULTS AND DISCUSSION

Plywood with different concentrations were prepared using the developed preservative and subjected to bond quality assessment by glue shear strength in dry state, wet state and mycological state. Results of glue shear strength for dry, wet and mycological test are provided in Table 1 and its graphical interpretation is provided in Fig. 1. From the data it is observed that lower concentration of the preservative i.e. 0.5% to 3% shows satisfactory results for all states. It is seen that the bonding property decreases with the increase in the preservative concentration. Concentrations above 3% show low compatibility with glue and interfere with the bonding properties of the plywood.

The knife test conducted on preservative concentrations 0.5%,1%,2%,3% shows pass standard whereas concentrations above 3% shows poor glue bonding in resistance to water test. Plywood sample shows pass standard results when tested for resistance to micro-organism for all concentrations of preservative except in 5% concentration. The results are provided in Table 2.

The efficacy test of preservative against termites was done on exposure period of 36 months with inspection made every month in the first year, every two months in second year and half yearly in third year. It was observed that after 36 months of exposure the control samples got light attack with termite attack area between 5% and 20% of surface area. Light attack was also found on 0.5% and 1% of the preservative concentration with termite attack on 5% and 20% of surface area, however all concentrations above 1.0 % shows trace attack with termite attacked area less than 5% of surface area. The results have been given in Table 3.

The efficacy test of preservative against borer was also done for 36 months. Examination of the exposed samples showed that exit holes were present in control, 0.5% and 1% concentrations, and no exit holes were found in concentrations ranging from 2% to 5% which indicates that no borer attack was observed in concentrations ranging from 2% to 5% of preservative concentration. The results have been given in Table 4.

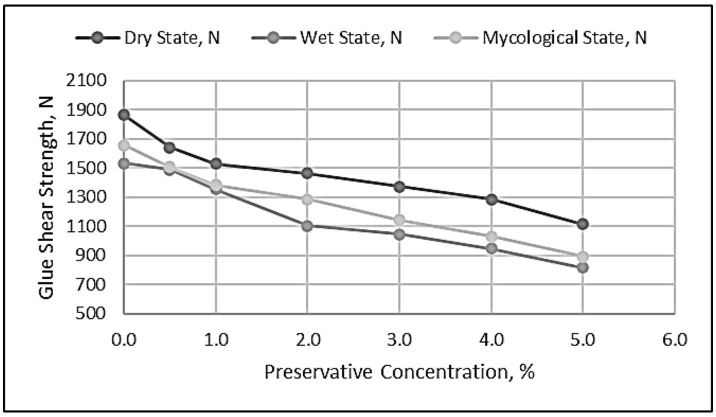



**Fig. 1. Glue shear strength at different preservative concentration**

**Table 1. Results of glue adhesion test for dry, wet and mycological state**

| Preservative Concentration, % | Glue Shear Strength, N | | |
|---|---|---|---|
| | **Dry** | **Wet (BWP grade)** | **Mycological** |
| 0.0 | Avg: 1863<br>Min: 1573 | Avg: 1532<br>Min: 1375 | Avg: 1654<br>Min: 1438 |
| 0.5 | Avg: 1642<br>Min: 1452 | Avg: 1487<br>Min: 1285 | Avg: 1508<br>Min: 1375 |
| 1.0 | Avg: 1529<br>Min: 1377 | Avg: 1353<br>Min: 1164 | Avg: 1382<br>Min: 1244 |
| 2.0 | Avg: 1464<br>Min: 1253 | Avg: 1104<br>Min: 926 | Avg: 1285<br>Min: 1106 |
| 3.0 | Avg: 1372<br>Min: 1128 | Avg: 1047<br>Min: 814 | Avg: 1142<br>Min: 957 |
| 4.0 | Avg: 1285<br>Min: 983 | Avg: 946<br>Min: 763 | Avg: 1032<br>Min: 861 |
| 5.0 | Avg: 1114<br>Min: 939 | Avg: 818<br>Min: 669 | Avg: 894<br>Min: 639 |

**Table 2. Results of adhesion of plies dry state, resistance to water and resistance of micro-organism test**

| Preservative Concentration, % | Adhesion of plies, dry state | Resistance to water after 72 hrs | Resistance to micro-organism |
|---|---|---|---|
| 0.0 | Excellent | Pass Standard | Pass Standard |
| 0.5 | Pass Standard | Pass Standard | Pass Standard |
| 1.0 | Pass Standard | Pass Standard | Pass Standard |
| 2.0 | Pass Standard | Pass Standard | Pass Standard |
| 3.0 | Pass Standard | Pass Standard | Pass Standard |
| 4.0 | Pass Standard | Poor | Pass Standard |
| 5.0 | Pass Standard | Poor | Poor |

**Table 3. Efficacy test against termites after 36 months of exposure as per IS 4833 (1993)**

| Preservative Concentration, % | Numerical ratings | Condition of samples |
|---|---|---|
| 0.0 | 1.0 | Light attack, termite attack area between 5% and 20% of surface area |
| 0.5 | 1.0 | Light attack, termite attack area between 5% and 20% of surface area |
| 1.0 | 1.0 | Light attack, termite attack area between 5% and 20% of surface area |
| 2.0 | 0.5 | Trace attack, termite attacked area less than 5% of surface area |
| 3.0 | 0.5 | Trace attack, termite attacked area less than 5% of surface area |
| 4.0 | 0.5 | Trace attack, termite attacked area less than 5% of surface area |
| 5.0 | 0.5 | Trace attack, termite attacked area less than 5% of surface area |

**Table 4. Efficacy test against borer after 36 months of exposure as per IS 4873 (Part 2) 2008**

| Preservative Concentration, % | Damage |
|---|---|
| 0.0 | Exit holes present |
| 0.5 | Exit holes present |
| 1.0 | Exit holes present |
| 2.0 | Exit holes absent |
| 3.0 | Exit holes absent |
| 4.0 | Exit holes absent |
| 5.0 | Exit holes absent |

## 6. CONCLUSION

This study was about developing a new eco-friendly wood preservative based on plant extract. Plants serve as rich resource of natural preservatives. This study was an effort to utilize one of these resources on development of a green preservative. From the results obtained in this study, it can be concluded that concentrations above 3% of Copperized Karanj preservative give a weaker glue line and interfere with the bonding properties of the resin which is inappropriate for plywood manufacture. Concentrations of 2% of preservative and above are effective against borer attack Therefore 3% concentration of Copperized Karanj preservative can be used in plywood for borer resistant interior applications. However, the preservative ranging from 0.5% to 5% concentration incorporated in plywood is not suitable for termite resistance.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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