

## 2.5 Wood Products

### Overview

Current research in the field of wood, its constituents and wood products is to utilize every bit of woody and ligno-cellulosic raw material available. Current research is focused towards using plantation timber; use of FT-NIR and ultrasonics for wood quality assessment; modification of wood surfaces for enhancing its stability, durability and surface qualities; development of new methods of timber drying; testing of exotics and imported species for their durability and treatability; developing surface coating systems, development of ecofriendly preservatives.

Jute-Polypropylene, Wheat straw–Polypropylene and Bamboo–Polypropylene composites prepared using m-Isopropenyldimethylbenzyl-isocyanate (m-TMI)-Poly Propylene (PP) coupling agent and evaluated mechanical properties. Nanoclay was compounded with polypropylene to study the effect of concentration of nanoclay, effect of coupling agent, and type of nanoclay. Experiments on extraction of cellulose nano-whiskers by acid hydrolysis were completed. Effect of temperature, sonication time, acid concentration on yield and morphology was also studied, and the process of extraction of nanocellulose was standardized.

The effect of coating the surfaces of two timber species with multiple layers of two film forming finishes was investigated. It was found that Poly Urethane is much better in blocking moisture and giving a shiny look to the surface of Shisham and mango wood surface as compared to shellac polish. In fact, the first three coats of shellac polish are practically not capable of controlling the entry of moisture into both the species studied. The application of both these finishes resulted in slightly thicker coat in the case of Poly Urethane on both the surfaces. Multiple

coats of PU will provide better moisture protection to both the species studied than even with six coats of spirit shellac.

Environment friendly preservative ZiBOC was developed and patented. Twenty imported wood species are being studied for their natural durability under Indian climatic condition. Studies on the performance of imported wood species untreated and treated with newly developed and conventional preservatives are also carried out. Treatability evaluation is also being done of few imported wood species. Different treatment regimes were developed for the treatment of difficult to treat species to give appropriate retention of preservatives.

Anatomical approach was applied to evaluate treatability class of plantation grown *A. auriculaeformis*, *A. mangium*, *E.urograndis*, *E.tereticornis*, *G.arborea*, *G.robusta*, *H. brasiliensis*, *M. dubia* and *P.deltoids*. For water borne preservatives, *G. robusta* and *H. brasiliensis* were classified under 'a' treatability class, *E. eurograndis* and *M. dubia* were classified under 'b' treatability class and *A. auriculaeformis*, *A. mangium*, *E. tereticornis*, *G.arborea* and *P. deltoids* were classified under 'c' treatability class. Whereas, for oil type preservatives, *Grevillea robusta* classified under 'a' class, *Acacia mangium*, *Hevea brasiliensis*, *Melia dubia* and *Populus deltoids* 'b' class. *Eucalyptus eurograndis* and *Eucalyptus tereticornis* classified under 'c' class, *Acacia auriculaeformis* and *Gmelina arborea* 'd' class.

The timber of plantation grown *Acacia mangium* was observed for its durability in the graveyard test and it was found that the controlled samples (untreated) were not attacked more than 2% after 3 years of exposure, whereas, treated samples were all intact without any damage. Few products were prepared and observed the performance. The timber was found to be



dimensionally steady and has very good working qualities especially for handicrafts.

Gas permeability of five imported hardwood species - Gurjan- *Dipterocarpus* spp., Pyinkado - *Xylia dolabriformis*, Merbau-*Instia bijuga*, Red meranti- *Shorea* spp., and Balau-*Shorea* spp., was studied. Gurjan was found to be the higher flow rates than the rest of the species of timber tested. Balau- *Shorea* spp. was found to be the most impermeable species of timber and is highly refractory.

The data on old doors, used windows, used frames and shutters were evaluated both by conventional test method and ultrasonic method (Non-destructive technique) in order to see the degradation of strength with time. Both the methods were in agreement which shows that the ultrasonic method which is a non-destructive method can be useful to find the service life of used structures and will give the guidance for reusing the same.

The sensitivity of teak wood to the changes in climate was studied; cross dating and standardization of discs were carried out. Chronologies based on growth rings/expressions of growth periodicity and vessel morphology were developed from available information on temperature fluctuations, rainfall and soil type, atmospheric disturbances to ring analysis and wood quality.

Studies on evaluation of wood quality parameters with respect to the growth rate i.e. girth carried out on *Melia dubia* of same age but varying girth showed that there is not much significant variation in the formation of heartwood while comparing the three girth classes (big, middle and small). The overall higher values in the shrinkage indicate that the timber should be properly seasoned by following proper kiln schedule. In air-seasoning, care must be taken by painting both the ends of timber so that defects like twist,

cupping, crook and splits etc. can be avoided. The strength properties (compression parallel and perpendicular to grain and hardness) were found to have higher values for tree of middle girth class which confirms the hypothesis that higher the specific gravity higher the strength properties.

An indigenously designed laboratory based convection heating type vacuum kiln has been installed last year in the Wood Seasoning Discipline, FRI, Dehradun.

A field workshop was organized by IWST, Bangalore in association with Karnataka State Handicrafts Development Corporation Limited, for the benefit of the handicraft artisans of Multicraft, Metugally, Mysore on 25<sup>th</sup> March 2011. It was a lab to land extension programme conducted for extending the newer findings on the methods of production and protection of wooden handicrafts.

Projects	Completed Projects	Ongoing Projects	New Projects Initiated During the Year
Plan	13	10	12
Externally Aided	3	3	0
<b>Total</b>	<b>16</b>	<b>13</b>	<b>12</b>

### 2.5.2 Wood and other Lignocellulosic Composites

Particle boards prepared with lops and tops of poplar at two pressure levels of 17.5 kg/cm<sup>2</sup> and 21 kg/cm<sup>2</sup> with 6%, 8% and 10% resin content with out and with 0.5%, 1.0% and 1.5% wax as sizing showed that particle board can be prepared with 21 kg/cm<sup>2</sup> specific pressure and 10% amount of resin without wax as sizing material. However, with addition of 1% wax as sizing material, particle board can be prepared with 17.5 kg/cm<sup>2</sup> lower specific pressure and 10% amount of resin and with addition of 0.5% and 1% wax as sizing



material particle board can be prepared with 21 kg/cm<sup>2</sup> specific pressure and 8% lower amount of resin. Particle boards prepared with lops and tops of eucalyptus at three pressure levels of 17.5 kg/cm<sup>2</sup>, 21 kg/cm<sup>2</sup> and 24.5 kg/cm<sup>2</sup> with 6%, 8% and 10% resin content showed that particle board can be prepared with 24.5 kg/cm<sup>2</sup> specific pressure and 10% and 12% amount of resin. Particle boards with lops and tops of five poplar to eucalyptus particle ratio (100:0, 75:25, 50:50, 25:75 and 0:100) were prepared at two pressure levels 17.5 kg/cm<sup>2</sup> and 21 kg/cm<sup>2</sup> with 6%, 8% and 10% resin content, with and without addition of thermally conductive filler. The addition of thermally conductive filler showed improvement in internal bond strength, water absorption, and thickness swelling due to surface absorption, length expansion and width expansion of the boards. Therefore, thermally conductive filler can be used in particle board manufacture as a sizing material as well as for improvement of internal bond strength.

Mechanically blended UF and PF adhesives cannot be effective for Boiling Water Resistance (BWR) grade plywood. Therefore, phenol, urea and formaldehyde have to be reacted at the resin preparation level itself in the resin kettle. The Phenol Urea Formaldehyde (PUF) adhesives of Boiling Water Resistance (BWR) grade can be prepared at 150°C pressing temperature using Phenol Urea Formaldehyde (PUF) adhesives with 70:30, 60:40 and 50:50 phenol to urea molar ratio having 30 minutes condensation reaction time during resin preparation.

Jute-PP composites using m-TMI-g-PP coupling agent showed the significantly high improvement in mechanical properties as compared to virgin PP followed by Bamboo and wheat straw composites. These composites can be moulded to any shaped articles. The applications are in the field of moulded products (furniture components, automobile interior, electrical/electronic appliances). In recent years, wood

fibres have gained significant interest as reinforcing material for commercial thermoplastics. They are now fast evolving as a potential alternative to inorganic fillers for various applications. Wood fibre offers several advantages like low density, high specific properties, low cost, etc. However the primary drawback of using wood fibres for reinforcement is the poor interfacial adhesion between polar-hydrophilic wood fibres and nonpolar-hydrophobic plastics. This results in poor mechanical properties of the final product. The interfacial adhesion can be improved by using compatibilizers or coupling agents. In this study, two coupling agents (MAPP and m-TMI-g-PP) investigated with six natural fibres (jute, bamboo, rubber wood, wheat straw, dry leaf litter and Lantana) using polypropylene thermoplastics. Rheological properties were also evaluated using torque rheometer. Results indicated that Jute-PP composites with m-TMI-g-PP coupling agents improved the maximum mechanical properties. The tensile strength increased by 78% as compared to PP and Flexural strength increased by 65% as compared to PP at 50% filler content. Wheat straw-PP composites and Bamboo-PP composites showed almost the same properties. Results clearly indicated that dry leaf litter can not be used in making natural fibre-thermoplastic composites as its processing becomes difficult and also there was no improvement in the properties at all.

Under the studies on co-polymerization kinetics using filler supported catalyst system, glass ethylene was polymerized using cellulosic filler supported catalyst system and studies on effect of temperature, monomer concentration (pressure) and catalyst concentration were completed. Using this novel technique, very high catalyst efficiencies (upto 50,000 kg of PE/mol of TM/h/[M]) could be achieved with almost no reactor fouling even at very high solid content in the slurry. A kinetic model for ethylene polymerization using ?ller supported catalyst



system was also developed to predict the instantaneous reaction rates.

In another study of synthesis and characterization of hybrid Polypropylene-Montmorillonite-Wood Fibre Nano-composites, nanoclay was compounded with polypropylene. Specimens as per ASTM standards were prepared and mechanical properties (tensile, flexural, compression and impact strength) were determined. Micro-mechanical and macro-mechanical modelling of the composites was also completed. Further, hybrid composites of nanoclay-wood flour-polypropylene were prepared using twin screw extruder. Specimens as per ASTM standards were prepared and mechanical properties (Tensile and flexural strength) were evaluated. Micro-mechanical and macro-mechanical modelling of the composites is under progress.

Under the study on cellulose nano-whiskers from bamboo, experiments on extraction of cellulose nano-whiskers by acid hydrolysis were completed. Effect of temperature, sonication time, acid concentration on yield and morphology was also studied, and the process of extraction of nano-cellulose was standardized. The product was characterized using scanning electron microscopy. Further work on preparation of nano-composites is in progress.

### 2.5.3 Wood Processing

Drying behaviour of timbers of deodar and teak was studied in a convection type vacuum kiln. The drying time of these two timbers reduced remarkably in the vacuum kiln as compared to the conventional steam-heated kiln. The vacuum kiln is clean energy based emission free timber drying technology.

Treatment techniques for difficult to treat species were developed. In stake size of specimens, complete impregnation of

preservative was achieved in industry important douglas fir species.

Timber engineering museum was completely renovated for architect, builder, students and general public.

Different types of joints with round Bamboo fabricated and tested for mechanical strength. New computerized universal testing machine was also installed which is also capable in cyclic testing.

### 2.5.4 Value Addition and Utilization

To determine the natural durability of imported timbers in Indian condition, observation on the natural resistance of twenty species of imported woods were taken upto thirty six months after implantation in Trivandrum, Nallal, Visakhapatnam, Hyderabad, Jodhpur and Jabalpur and upto 24 months in Dehradun. In marine condition, the resistance was observed at the exposure of 36 months. These timbers are classified for their resistance against wood decay fungi. 11 species, viz. teak from different countries, different species of Shorea, Pterocarpus, Dryobalanops and Xylia species showed good resistance against both the brown and white rot fungi (less than 10% of weight loss) and these timber species were grouped under "high resistance class". *Fagus sylvatica*, *Fagus sp*, *Fraxinus angustifolia*, *Fraxinus excelsior*, *Acer pseudoplatanu*, *Acer sp*. and *Havea brasiliensis* decayed very fast with more weight loss, and they are grouped under "non-resistant class" (weight loss was around 35-40%). Indian *Michelia champaka* also did not show good resistance and it is grouped under class-3.

Studies on durability of *Acacia auriculiformis*, *A. mangium*, *Grevillea robusta*, *Eucalyptus terreticornis*, *Maesopsis eminii*, *Melia dubia*, *Ailanthus malabaricum* and *Ailanthus excelsa* plantation timbers from different age



group against decay fungi and termites were carried out. *A. auriculiformis* and *A. mangium* of 10, 15 & 20 yrs timber can be classified under Class I, whereas, 5 yrs comes under Class II. *E. tereticornis* showed good resistance against decay fungi (Class I). *G. robusta* belongs to class III and *M. dubia* falls under “non-resistance class (IV).”

Treatment of red, yellow and white meranti with ZiBOC and CCA preservative showed white meranti easily treatable whereas red & yellow meranti were difficult to treat. Different imported species namely *Pterocarpus* spp. from Gabon-West Africa and Indonesia, Maple wood (*Acer* spp.) from Germany, *Intisia* spp. from Malaysia and Australia, *Tectona grandis* from Myanmar, South Africa, Ivory Coast and Malaysia, *Xylia dolabriformis* from Myanmar, *Shorea* spp. from Malaysia, *Hevea* spp. from Malaysia, *Pinus* spp. from New Zealand and Australia, *Grevillea robusta* from New Zealand and Australia etc. received from IWST Bangalore were tested for natural durability. It was observed that all the species are exhibiting moderate to bad termite and fungus attack within 28 months of grave yard test. Treatment schedule was developed for *Melia azedarach* and *Eucalyptus tereticornis*. It was observed that retention of preservation was increased by initial dipping in hot water, before pressure treatment followed by diffusion treatment with conventional and newly developed preservative. Performance of ZiBOC treated imported wood species was studied in different agro-climatic regions. It was found that ZiBOC treated wood performing at par with CCA treated wood even after 58 months of field installation.

Penetration of two different fluid types, silver nitrate in water and Red oil dye (molten wax) was studied in *Acacia auriculiformis*, *Acacia mangium*, *Eucalyptus eurograndis*, *Eucalyptus tereticornis*, *Gmelina arborea*,

*Grevillea robusta*, *Hevea brasiliensis*, *Melia dubia* and *Populus deltoids*. A penetration index of more than 0.66 indicates more or less uniform distribution of the chemicals in all the structural elements and easy to treat which are classified as class “a”, *Grevillea robusta* and *Hevea brasiliensis* were classified under “a” treatability class. Penetration index falling between 0.33 and 0.66 classified as “b”, which showed some deficiency in fibre penetration or partial blocking of the flow paths. *Eucalyptus eurograndis* and *Melia dubia* were classified under “b” treatability class. *Acacia auriculiformis*, *Acacia mangium*, *Eucalyptus tereticornis*, *Gmelina arborea* and *Populus deltoids* were classified under “c” treatability class with silver nitrate solution (water soluble type preservatives). Whereas *Grevillea robusta* classified under “a” class, *Acacia mangium*, *Hevea brasiliensis*, *Melia dubia* and *Populus deltoids* “b” class. *Eucalyptus eurograndis* and *Eucalyptus tereticornis* classified under “c” class, *Acacia auriculiformis* and *Gmelina arborea* “d” class with red oil dye (oil type preservatives).

Three species of cane viz. *Calamus thwaitesii*, *Calamus dransfieldii* and *Calamus vattayila* were treated with CCB and Boric acid preservatives by vacuum pressure impregnation method following 3 different treatment schedules. Retention of the preservative was determined by weight gain basis. Qualitative analysis of the treated cane specimens were determined by spot test. The preservative content was determined quantitatively by chemical assay method. The results show that in green condition when the diameter of the specimens was bigger the absorption was lesser. In dried specimens the diameter does not make any difference in the absorption of the preservatives. The treatment schedules show that the green specimens can be successfully treated to the BIS recommended absorption, 8kg/m<sup>3</sup>, by vacuum pressure method



at 30 minutes initial vacuum followed by  $3\text{kg}/\text{cm}^2$  for 2 hours followed by final vacuum for 15 minutes. The absorption of Boric acid preservative was always higher than the CCB. In dried specimens the required absorption was achieved at 1 hour treatment schedule itself. The penetration tests show the complete penetration of both the preservatives through and through.

Under the study on effect of treatment with micronized copper preservative on the strength, treatability and durability of selected wood species, procured the timber and converted into planks for air-seasoning. Designed, got fabricated and installed the vacuum pressure treatment plant. A small laboratory vacuum system was developed for treatment of small blocks using preservative chemicals. Samples were treated with water as control for comparing with the chemically treated samples. Treatments of planks/wood samples with chemicals were carried out. Specific gravity studies were completed and shrinkage and certain mechanical properties evaluated.

In another study on screening of oil of *Pongamia pinnata* Linn., *Jatropha curcus* Linn. and *Simarouba glauca* D.C. for developing eco-friendly wood preservatives, literature survey was made. Seeds of *Pongamia pinnata* and *Jatropha curcus* were procured and oil was extracted. Incorporated copper metal in *Pongamia pinnata* and *Jatropha curcus* oils by refluxing with cupric oxide for 4 different time periods viz, 8, 16, 32 and 64 hours. Rubber wood was procured and converted into specimens. Specimens of rubber wood were given prophylactic treatment with boric acid. Under screening of certain plant extractives for developing ecofriendly wood preservatives literature survey was made. The barks of *Acacia auriculiformis*, *Acacia nilotica*, leaves of *Gliricidia sepium* were collected and extracted with 4 different solvents (Petroleum ether, ethyl alcohol, ethyl acetate and water). Incorporated copper metal into the extractives by refluxing with copper oxide for

4 different time periods viz, 4, 8, 16, and 32 hours. Rubber wood was procured and converted into specimens. Specimens of rubber wood were then given prophylactic treatment with boric acid.

Rubber wood was esterified with phenylisothiocyanate and dimensional stability, decay resistance and photo stability of the modified wood assessed. Unmodified and modified samples were exposed to a brown rot (*Polyporus meliae*) and a white rot (*Coriolus versicolor*) fungus for 12 weeks. Modified wood samples exhibited good dimensional stability and were very resistant to decay. However, phenylisothiocyanate modification of wood was not effective in decreasing photo-yellowing. Dimensional stability and photo-stability of rubber wood esterified with a series of fatty acid chlorides (Hexnoyl ( $\text{C}_6$ ), decanoyl ( $\text{C}_{10}$ ) and tetradecanoyl chloride ( $\text{C}_{14}$ ) has been investigated. Esterified wood exhibited good dimensional stability, degree of dimensional stability increased with increasing carbon chain length. As the chain length of acid chloride increases, thermoplastic property also increases which leave the surface of the wood softer. Fatty acid chloride treatment was only partially effective in inducing stability against UV light irradiation. Decay resistance of esterified wood was also evaluated. Unmodified and modified samples were exposed to a brown rot (*Polyporus meliae*) and white rot (*Coriolus versicolor*) fungus. Modified wood samples exhibited very good resistance to brown and white-rot fungi.

Attenuation constant (at microwave frequencies) increases with increasing moisture content in timber even above the F.S.P. in both directions-longitudinal and transverse. Therefore, relationship between attenuation content and moisture constant may be of practical importance for industries, to measure moisture content during the processing of timber. Relationship of ultrasonic velocity (measured by direct pulse



transmission method) has been established with each Modulus of Elasticity (MoE), Modulus of Rupture (MoR), Compressive Stress at Elastic Limit (CS at EL) and Maximum Crushing Strength (MCS). On the basis of developed regression models of ultrasonic velocity with strength properties, timber material may be sorted out/graded into the different grade (strength-wise). Ultrasonic velocity decreases with increasing moisture content in timber up to the Fibre Saturation Point (FSP) as well as above the FSP and ultrasonic velocity was found to be higher along the longitudinal direction than transverse ones (radial/ tangential) of timber. Generated data on defect, indicates that speed of ultrasound decreases significantly in the presence of structural irregularities (centre hollowness, cracks etc.) in timber. Centre hollowness/ cracks and its size detected successfully by ultrasonic technique in the log. Exponential transducers were fabricated to make testing more effective without couplant.

The data on old doors, used windows, used frames and shutters were evaluated both by conventional test method and ultrasonic method. The values obtained through ultrasonic method (NDT) were close to the values measured using conventional method which shows that the ultrasonic method which is a non-destructive method can be useful to find the service life of used structures and will give the guidance for reuse the same.

NIR methods have been developed for specific gravity, shrinkage, bending properties (MoE- modulus of elasticity, MoR- modulus of rupture and FS at LP – Fibre stress at limit of proportionality), and lignin and holocellulose estimation. The methods are now ready for use in place of conventional one. Wide variations in properties of 47 phenotypes of *E. tereticornis* were observed. Specific gravity had varied from 0.494 to 0.767 and similarly, other strength

properties, making a good case for further selection of material with desired traits. Lignin content varied from 26 to 32% and holo-cellulose content from 65-72%. Combination of different traits can be used for developing the material for further propagation. Development of NIR methods will help in reducing cost, time and efforts in assessing wood quality of Eucalyptus in future programmes. NIR is of great relevance for quick assessment of the properties. The advantage is that all the properties can be evaluated simultaneously on the same samples with no extra time and cost. This was not possible till now with conventional methods.

Under the study on constraints in the export of carved out wood products and its economical and social impact on the livelihood of dependent people in North India, literature regarding distribution of Wood Carving Industry, its economic contribution and identification of problems with focus on raw material procurement, manufacture of carved out wood products and their marketing was studied. Ten (10) wood carving centres have been selected throughout North India viz. Srinagar, Rajouri, Chamba, Kullu, Hoshiarpur, Amritsar, Saharanpur, Nagina, Udaipur and Jodhpur. Reconnaissance survey has been undertaken. Questionnaires have been developed in such a way so as to assess the economic condition, literacy level, specialization, working tools or machines (technology) used, number of working months, alternate source of income, type of working, and constraints in the development of skill, economic upliftment.

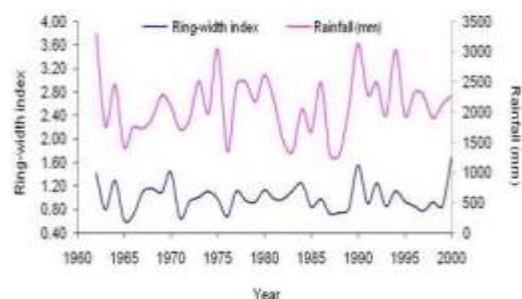
As a part of extension, regular surveys were conducted in timber depots and workshops to ascertain the powder post beetle problems and monitoring their occurrence in field. A field workshop was organized by IWST, Bangalore in association with Karnataka State Handicrafts Development Corporation Limited for the benefit of the handicraft artisans of Multicraft, Metugally,



Mysore on 25<sup>th</sup> March 2011. The meeting was attended by 71 wood craftsmen of Metugally who are living in Multicraft Complex and mainly engaged in production of wooden handicraft articles. It was a lab to land extension programme conducted for extending the newer findings on the methods of protection of wooden handicrafts. The methods to detect the pest attack and manage the problem were explained. It was emphasized that prevention is better than control. It was pointed out that by avoiding sapwood pest attack, can be avoided. Ecofriendly methods of wood protection and methods of curing of the infested wood were explained. Phosphine fumigation for curing the infestation was also demonstrated.

Gas permeability of five imported hardwood species - Gurjan- *Dipterocarpus* spp., Pyinkado- *Xylia dolabriformis*, Merbau-*Instia bijuga*, Red meranti- *Shorea* spp., and Balau-*Shorea* spp., was studied. Gurjan was found to be of the higher flow rates than the rest of the species of timber tested. Balau-*shorea* spp. was found to be the most impermeable species of timber and is highly refractory. Longitudinal permeability in balau and red meranti is extremely low and requires improvement. The permeability variations in longitudinal and transverse directions are considerably very large that signifies the complex nature of the hardwoods. Both longitudinal and transverse permeability varied between species of timber. In general, there is not much difference between radial and tangential permeability though the radial permeability for a given species tends to be slightly higher than tangential permeability. The timber species used for permeability study were evaluated for durability under local condition. The observations revealed that except gurjan all other species exposed to termites were found to be in sound condition even after three years of exposure.

Under the Investigation on Tree ring analysis of certain species in Western Ghats to monitor climate changes and its relevance to wood quality, the main objective was to infer available information on temperature fluctuations, rainfall, soil type, atmospheric disturbances to ring analysis and wood quality and test the sensitivity of the species to the changes in climate and develop chronologies based on growth rings or expressions of growth periodicity and vessel morphology in teak and *Myristica fatua*. Collected meteorological data and information on sites from Karnataka and Maharashtra. The sensitivity of teak wood (collected from Madikeri, Mundagod of Karnataka and Thane, Chandrapur from Maharashtra) to the changes in climate was studied. Cross dating and standardization of discs were carried out. Chronologies based on growth rings/expressions of growth periodicity and vessel morphology were developed from available information on temperature fluctuations, rainfall, soil type, atmospheric disturbances to ring analysis and wood quality.



Correlation between Rainfall and Ring-width Index  
Chronology of Teak Collected from Madikeri

For the assessment of wood quality, characteristics of *Melia dubia* Cav of Seedling Seed Orchard, the billets of same age but varying girth were received. The billets were divided into three girth classes (large, middle and small) to study wood quality parameters with respect to the growth rate i.e. girth. Accordingly, different anatomical, physical and mechanical properties were evaluated. From the studies it was found that there was not much significant variation in the



formation of heartwood while comparing to the three girth classes. The timber from trees of middle girth class was found to have higher specific gravity as compared to large and small girth class trees. The overall higher values in the shrinkage indicate that the timber should be properly seasoned by following proper kiln schedule. In air-seasoning, care must be taken by painting both the ends of timber so that defects like twist, cupping, crook, splits etc. can be avoided. The strength properties (compression parallel and perpendicular to grain and hardness) were found to have higher values for tree of middle girth class which confirms the hypothesis that higher the specific gravity higher the strength properties.

In an effort to study the performance of coatings on modified wood surfaces, work on standardization of reaction conditions of acetylation and benzylation for optimum weight gain was carried out. Stands for natural weathering were designed and got fabricated. Chemically modified wood specimens of rubber wood and Radiata pine were prepared for application of coatings and weathering exposure. The modified wood panels (benzoylated and acetylated) with average weight gains of 10-20% were prepared and were coated with a transparent and opaque polyurethane exterior paint. Coated and uncoated panels have been exposed to outdoor weathering and samples are being periodically examined for weathering deteriorations. Results show that modified wood performed very well as compared to unmodified specimens. Study on Grafting of UVA's (functionalized benzophenon) on wood surfaces carried out. The performance of UVA grafted wood specimens under accelerated weathering conditions is in progress.

In another study, chemical modification of wood (rubber wood, silver oak) using octanoyl and lauoryl chloride has been carried out. Chemical modification of wood using alkylene epoxides viz., propylene oxide and butylene oxide carried

out. Esterified/ etherified wood was characterized using FTIR and NMR spectroscopy. TGA analysis of esterified/ etherified wood was carried out. Study in thermo-plasticization of modified wood and evaluation of its properties is in progress.

Under utilization of *Bambusa bamboos* (L.) and *Dendrocalamus strictus* (Roxb.) as an alternative for wooden dunnage pallets, procured bamboo machineries (bamboo cross cutting, bamboo splitting and bamboo external knot removing machines). Studied on various physical properties such as moisture content, specific gravity and shrinkage, culm wall thickness and diameter were carried out. Study on mechanical properties is in progress. The objectives of these studies are to find the suitability of bamboo for dunnage pallets.

Under comparative study of clones of eucalypts and *Acacia* hybrid for handicraft sector, procured *Eucalyptus tereticornis* and *E. eurograndis* clones and studied specific gravity and shrinkage properties. Mechanical properties under green conditions were also studied. Air seasoning behaviour on small planks was also investigated. The properties are being evaluated to assess the wood quality of clonal material for handicraft sector.

Under the study on enhancing dimensional stability and durability of wood for flooring application by ecofriendly thermal processing, designed the micro-processor controlled vacuum heating oven. Procured and installed the equipments (vacuum oven and swellometer). Procured timber and converted into planks and kept for air seasoning. Heat treatment was carried out at different temperatures and durations under vacuum, nitrogen and inert environments and atmospheric pressure. Specific gravity and EMC (control and treated specimens) were determined. Mechanical properties of control and heat treated samples were also evaluated.



A new study to enhance the strength of finger joints through manipulating the L/P ratio of the profiled fingers has been initiated.

### 2.5.5 Pulp and Paper

Under the evaluation of alternative raw materials for pulp and paper making, the raw materials viz. *Melia composita* and *Prosopis juliflora* was provided by State Forest Department, Punjab. Procurement of *Gmelina arborea* from RFRI, Jorhat is under progress. The procured raw materials were subjected to debarking and chipping prior to pulping experiments. The procured raw materials viz. *Melia composita* and *Prosopis juliflora* was chemically analyzed for extractives, holocellulose, lignin and ash content as per TAPPI standard methods, in order to check the suitability of these raw materials for pulp and paper making. The analysis revealed that *Melia composita* possesses 2.75% extractives content, 67.40% holocellulose, 27.50% lignin, 3.50% ash content however it was 0.58% extractives content, 73.20% holocellulose, 28.00% lignin and 1.00% ash content in case of *Prosopis juliflora*. The species chemically analyzed possesses adequate amount of cellulose content required for paper making. Anatomical analysis in terms of fibre length, fibre diameter was carried out for *Prosopis juliflora* and *Melia composita*. In case of *Prosopis juliflora* the average fibre length at pith, middle and outer part was 778.4 $\mu$ , 852.8 $\mu$  and 890.0 $\mu$  respectively, however the average fibre length range of pith, middle and outer part varies from 600 $\mu$ -940 $\mu$ , 630 $\mu$ -1080 $\mu$ , and 690 $\mu$ -1120 $\mu$  respectively. The average fibre length of *Melia composita* at pith,

middle and outer part was 785.2 $\mu$ , 933.2 $\mu$  and 946.4 $\mu$  respectively, however the average fibre length range of pith, middle and outer varies from 570-1020  $\mu$  670-1220  $\mu$  and 660-1200  $\mu$  respectively. Kraft pulping of *Melia composita* and *Prosopis juliflora* is under progress.

In another study of biodeinking of waste paper, ten White rot and Brown rot fungi (*Schizophyllum commune*, *Trametes versicolor*, *Oligoporus placentus*, *Lenzites striata*, *Coprinus disseminatus*, *Trametes incerta*, *Funalia leonina*, *Oxyporus ravidus*, *Trichoderma viridae* and *Trametes lactiana*) were collected from the Forest Pathology Division, FRI for the screening of best cellulose producer. In addition to this, twenty one decaying wood samples were also collected from the wild for isolation of microbes. The ten identified white rot and brown rot fungi collected from the Forest Pathology Division, Forest Research Institute, Dehradun along with twenty one unidentified samples collected from the wild were screened for best cellulose producer on the basis of primary screening method e.g. plate zone assay. On the basis of plate zone assay, *Coprinus disseminatus*, *Trichoderma viridae*, Isolate No. 14 and Isolate No. 2 were found excellent cellulase producer. Screened microbes (*Coprinus disseminatus*, *Trichoderma viridae*, Isolate No. 14 and Isolate No. 2) were further screened on the basis of indirect plate zone assay method in order to check the activity of the enzyme. On the basis of standard screening methods, *Trichoderma viridae* has CMCase and FPase activity 1.4702 and 0.210 respectively; however, it was 1.3670 and 0.198 in case of *Coprinus disseminatus*. The mixed office waste paper was collected locally.