Forest Products Division

(Committed to research and development activities in wood utilization)

RESEARCH HIGHLIGHTS

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PROLOGUE

Organized research in India in the field of timber products originated in 1920. The erstwhile Directorate of Forest Products Research and the reorganized Forest Products Division at FRI, Dehradun have significantly contributed to the development of wood based Industries in India. The Division pursues basic and applied research in addition to routine investigations on different aspects of wood and wood products utilization which includes composite materials from lignocellulosic sources. To date, the Division has more than 2200 publications to its credit.

This publication tries to collate some of the important research highlights that would be useful to researchers and professionals working in the fields of wood science and technology and wood utilization.

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Research Highlights of Forest Products Division of FRI

The wood processing chain starts with saw milling and goes through seasoning, preservation, wood working and finishing of the product's surface. The Forest Products Division of the Forest Research Institute (FRI), Dehradun has been addressing all these aspects through its Research and Development activities for the past hundred and odd years. Before choosing a particular species for any product making, its suitability for that utilization needs to be known. This is achieved through the studies on mechanical and physical properties of wood. With the timber resources dwindling all over the word, the focus of the future is going to be the wood composites wherein huge savings on precious timber is anticipated. The following discussion is on the works carried out and being pursued at the Division in these fields. Ready references are given below each discussion.

SAW MILLING

Saw millers around the world have always strived for getting maximum recovery from their logs. Economic conversion of logs has been the point of interest to saw millers. Further, with the declining timber resources from forests, the thrust has been to the utilization of plantation timbers. These, with their rather short rotations have posed problems during conversion in the saw mill as well as during subsequent seasoning. Another important aspect studies was to develop special sawing methods for economic conversion of problematic plantation timbers like Eucalypts. There is also an interesting report on the minimal conversion losses in round bamboo compared to what one encounters while sawing low girth plantation timbers. An attempt was also made to assess employment generation through saw milling and wood processing in general. Details of some interesting basic works in these areas can be found in the following publications

- Rawat, B.S. and R.C. Bhatnagar (1973). A note on time motion studies in saw milling. *Indian Forester,* **99** (4): 218 – 234.
- Rawat, B.S. and K.L.Arora (1982). Economic conversion of logs – Part II. *Indian Forest Leaflet.* No.197.
- Rawat B.S. and K.L.Arora (1986). Economic conversion of logs Part – III. *Indian Forest Leaflet* No. 198.
- Rajput S.S. and K.L.Arora (1988). Ready reckoner tables for Economic Conversion of logs Part – IV. *Indian Forest Leaflet* No. 199.
- Sachin Gupta, H.T. Lalmuankima and V. S. Kishan Kumar (2008). Comparative study on losses during primary processing of bamboo and low girth timber logs *Indian Forester*, **134** (9), 1186-1192.
- Kishan Kumar V.S., Pandey C.N., Chetan Swaroop Singh and Vipin Chawla (2007). Enhancing recovery from *Eucalyptus tereticornis* through manipulation of sawing methods.. *Indian Forester*, **133** (2A), 132-136.
- Vimal Kothiyal and Kishan Kumar V.S. (2008). Potential of timber processing in employment generation. In Proceedings *of the National workshop on Role of Forestry in employment generation and rural development* held at FRI, Dehra Dun, 29-30 August

2006, 105-113.

SEASONONG OF TIMBER AND BAMBOO

Kiln seasoning:

Extensive data collected on the kiln drying behaviour of Indian timber was used to formulate seven kiln drying schedules for more than 200 species of commercially important timbers. These schedules have formed the basis for kiln drying of timber in the country. The steam heated internal fans type of kiln was adopted and tested for drying of Indian timbers and compared from available foreign designs. Three different designs with overhead fans, fans under timber stack and side-mounted fans were prepared to meet varied commercial requirements. It was entirely based on this work that a purely indigenous kiln equipment manufacturing industry got established in the country soon after Independence.

- Rehman, M. A. (1950). Types of seasoning kilns suitable for drying Indian woods. *Indian Forest Leaflet* No. 54 (Utilization) revised 1950.
- Sharma, S.N. and Pandey, C.N. (1990). A model for Indian Standard kiln drying schedules for timber based on diffusion theory of drying. *Indian Forester*, **116** (2), 121-130. Feb. 1990.
- Pandey, C.N. and Kambo, A.S. (1995). Drying schedules for *Eucalyptus camaldulensis*, based on diffusion theory of drying. *J. Timb. Develop. Assoc. India*, **41** (2), 26-31.

Improvement in air circulation and kiln profile of a steam heated kiln:

Non-uniform air circulation within the timber stack in kilns leads to large difference in drying rates and moisture contents in the dried stock, which necessitate protracted period of moisture equalization treatment towards the end of drying. The wastage of heat as also power consumption by fans needs to be reduced for improving kiln efficiency. Extensive investigations has been found that in its unmodified form the overhead fans system gives the most uniform distribution of air within the gaps of the stack., the variation along the height being only 19 % of the mean velocity. This can be further reduced to only 9 percent by proper profiling of the side-walls to yield taped plenum spaces instead of the conventional rectangular plenum spaces on either side of the stack. The side-mounted fans system gives a very poor distribution, variation being 60 to 115 percent with the normal clear gap between the fan and the stack. The variation can be reduced to a certain extent by increasing the clear spacing gap between the fan and the stack. The air circulation work has also yielded an unorthodox design of small kiln of 5.6 cubic meter (200 cft) stacking capacity with very uniform air distribution (variation of only 9 percent.) It requires only a single fan to be mounted at the end of the stack as compared to two fans required in the overhead fan design for identical capacity and dimensions of stack.

- Sharma, S. N., Prem Nath and Badoni, S. P., (1976). A study on the movement of wood. *Journal of Indian Academy of Wood Science*. Vol. 7, No. 2, July-December 1976.
- Sharma, S.N. and Jain, P. K. (1977). Air circulation in an overhead cross shaft internal fan kiln. *J. Timber Development Association of India*, **23** (4), 8-21.
- Pandey, C.N., (2001). "Systematization of kiln drying schedules for drying of commercial Indian Woods." Proceedings IUFRO wood drying conference, Tsukuba, Japan, 9-13 July, 2001.

The FRI solar heated kiln:

A solar heated kiln of 7.1 cubic meters (250 cubic feet) capacity was developed and has proved successful, because of its considerably low erection and operating costs as compared to steam-heated kilns. Experiments have shown that 2.5 cm planking of moderately refractory timbers can be solar dried from green to 12% moisture content within 16-20 days as against 8-12 days taken in steam heated kilns. In terms of economics, the cost of operation comes to within Rs.236-394 per cubic meter for planks compared to Rs.639-974 per cubic meter in steam kilns, and for this too the latter have to be operated on a large scale to be economical. Timber dried in the solar kiln has less warping and is comparable in quality to that dried in the steam kilns. In the last twenty years FRI has installed 20 solar kilns on turnkey basis for industries as well as forest corporations.

- Sharma, S.N., Nath, P. and Bali, B.I. (1972). A solar timber seasoning kiln. *J. Timber Development Association of India*, **18** (2), 10-26. (April 1972).
- Sharma, S.N., Prem, Nath and Badoni ,S.P. (1980). Commercial trial on a 7.1 Cu. M. Solar Kiln. Indian Forest Bulletin, (New series) No. 274, pp 47.
- Sharma S.N., Nath Prem and Badoni, S.P. (1982). A direct method for determination of energy savings by thermal insulation in a glasshouse type solar kiln. *J. Timber Dev. Association*, **28** (1), 25-30.
- Pandey, C.N., Jain, V.K. and Sanyal, S.N. (1992). Innovation in the FRI, solar kiln-design and performance study. *J. Ind. Acad. Wood Science,* **23** (2), 25-32.

Solar drying of veneers and minor forest produce:

Experiments carried out at FRI have demonstrated that solar drying of 1.5 mm veneers is possible within 2 hours from green to 8 percent moisture content. Solar air heaters having total absorber area of 10 sq. meter (111 sq. ft.) were connected in series and atmospheric air was sucked through these heaters at the rate of 0.1 cubic meter per sec (3.5 cft./sec). The air got heated from 30 to 110^{o}C in passage. The heated air was used for drying the veneers in a single pass. About 17 kg of water could be evaporated from 0.56 cubic meters (2 cft.) of veneers in 2 hours. The effluent air from the dryer still contained usable residual heat at 45-67^{o}C indicating that dryer capacity could have been further increased in progressive system

for complete utilization of the available heat. The Disciple has installed two Bidi Patta dryers for clients.

- Pandey, C.N., Singh, H.P., Chandra, Akash and Rath, T. (1986). Solar drying of Tendu (bidi) leaves. *Indian Forester*, **112** (11), 986-992.
- Kambo, A.S. and Pandey C.N., (2002): Performance evaluation of newly developed solar-cum-dehumidification kiln. *Journal of Timber Development Association of India*, **48** (3-4), 20-23.

Modified design Solar Kiln for drying of wood and other non-wood forest produce:

FRI has now developed a modified solar kiln design having a charge capacity of 250 cft for one-inch thick plank. The design consists of a super structure of timber frame raised on walls with single sheathed glass on the roof, south, east and west walls with 5.5 mm clear transparent glass. The improved chimney type vents in south wall help in recovery of heat loss during venting operation. The modified design kiln is equally efficient and approximately 30 % cheaper compared to old version. The solar kiln can also be used for drying seeds, *bidi* leaves, raw material of ayurvedic medicines etc.

- Upreti, N.K., M.C. Kukreti and R.P. Kandpal (2009). A cost effective solar kiln for wood seasoning. J. Timb. Dev. Ass. India, 55, 72-80.

Drying of round bamboo:

A systematic investigation on air and kiln seasoning behaviour of round bamboo of nine species was completed. The results showed that round bamboo of several species, except *Dendrocalamus membranaceous, Dendrocalamus hamiltonis, Bambusa arundinacea* and *Dendrocalamus strickus,* is liable to excessive cracking at the nodes and collapse in the inter-nodal portion both. Prophylactic preservative treatment done at the time of stacking was found to be the best procedure for seasoning of bamboo for ordinary purpose. For specialized uses, such as handicraft items like flower vases, table lamp stand, mugs etc. round bamboo of the species *Dendrocalamus giganteous* could be successfully seasoned by the chemical seasoning procedure. The additional costs of chemical treatment in this procedure were found to be quite tolerable for commercial production of such specialized items of handicrafts.

- Sharma, S.N., Tiwari, M.C. and Sharma, R.P. (1972). Chemical seasoning of bamboo in the round form for handicrafts. *J. Timber Development Association of India*, **18** (1), 17-23. (January 1972)
- Jain, V. K. and Kambo, A. S. (1991). A new approach to seasoning of round bamboo. *J. Ind. Acad. Wood Science*. Vol. 22 (1), 1991.
- Kishan Kumar V.S., N.K. Upreti and K. K. Dwivedi (2008). Effect of peeling on moisture reduction during forced air-drying of three round bamboos. Indian Forester, Vol.134, N0. 9:1222-1228.
- Upreti, N.K. Kishan Kumar, V.S. and Jain, V.K. (2005). Chemical seasoning of round bamboos for making value-added handicraft products. *ENVIS Forestry Bulletin*, Vol. 5: 43-47.

- Upreti, N.K., 2004. Chemical seasoning of round *Bambusa tulda*. *Journal of Timber Development Association of India*, **60** (3-4), 28-31.
- Sachin Gupta, C.M. Sharma and Kishan Kumar V.S. (2007). Role of Nodal shaving and End coating in drying of *Dendrocalamus strictus*. *J. Timber Development Association of India*, **53** (3&4), 30-39.

Sawing and seasoning of Eucalyptus:

Plantation grown woods like eucalyptus pose problems in producing standard quality sawn and seasoned timber. Major problems in utilization of small girth eucalyptus log is that of development of severe end-cracking on the freshly cross-cut ends logs during storage and tendency to warp and crack excessively during conversion of logs into planks. The seasoning behaviour of eucalyptus is characterized by slow rate of drying, collapse, tendency to split and high shrinkage and pronounced drying stresses due to steep moisture gradient. Adoption of radial and balanced tangential sawing yields planking materials that can be seasoned almost free from surface cracks and warp.

- Pandey, C.N., Gaur, B.K., Kanoji, H.C. and Chandra, Akash (1984). A new approach to seasoning of Eucalyptus hybrid (*Eucalyptus tereticornis*). *Indian Forester*, **110** (2).
- Sharma, S.N., Pandey, C.N. and Kanoji, H.C. (1988). Sawing and seasoning technique for *Eucalyptus tereticornis*, *J. Timb. Develop. Assoc. India*, **34** (4), 5-12.
- Chauhan S.S., N.K. Upreti and Anil Sethy, (2006). Drying Behaviour of some plantation-grown timbers in forced air-drying. Journal of The Indian Academy of Wood Science, New Series, 3 (1):62-66.

SDR Procedure for seasoning of Poplar.

Plantation grown wood like Populus deltoids poses problems in producing standard quality sawn and seasoned timber. Studies on air and conventional kiln drying behaviour revealed that though it is not difficult to dry, the material is prone to severe distortions like bow, crook and honeycombing. The reason for the tendency to warp is pre-dominantly due to juvenile nature of wood and presence of residual growth stresses. The major problem of this distortion degrade has been solved by adopting Saw-Dry-Rip (SDR) method of sawing and high temperature seasoning. Recent improvements in processing have enabled this species to be commercially used for several value added products such as pencil making, doors and window shutters, light furniture and for making quality packing cases etc.

- Pandey, C.N., Kambo, A.S. (1993). Sawing and seasoning of *Populus deltoides* by saw dry rip (SDR) process. *Wood News*, April-June 1993, 21-24.
- Pandey C.N. and Kambo, A.S. (2001): Properties and processing of *Populus deltoides* for producing quality sawn and seasoned timber. *Indian Forester*, **127** (2). Feb. 2001.

A technique of wood plasticization for making bentwood furniture:

Use of curved wood in furniture and housing is prevalent and is of key importance in many industries in India especially in those that manufacture furniture, sports goods, boats, ships and several decorative and utility articles. Steam has traditionally been used to soften wood for bending. Tests carried out earlier have indicated that only a few Indian timber species are amenable to steam bending. The steam bending technique has also limitations such as bending at sharp radius of curvature is not possible, long period is required for plasticization and drying of stock after bending etc. The work carried out at Forest Research Institute, Dehradun has shown that the above-mentioned limitations can be overcome by using vapour phase ammonia plasticization technique. This technique has enabled a wider choice of species for production of bentwood components for a variety of commercial products. The FRI has designed and developed a pilot scale unit for the plasticization of wood through vapour phase ammonia treatment for making bentwood furniture components and other utility and fancy bentwood articles.

- Sharma, S.N., Pandey, C.N., Kanoji, H.C. and Ram Mani (1988). Wood bending by vapour phase Ammonia and Plasticization. *Indian Forester*, **114** (11), 752-760. Nov. 1988.
- Pandey, C.N., Kanoji, H.C. and Ram Mani (1991). Trials on bending of vapour phase ammonia plasticized wood –II. *J. Timb. Develop. Assoc. India*, **32** (4), 5-12. Oct. 1991.
- Rao, Krishna., P.V., Pandey, C.N. and Kanoji, H.C. (1993). Rubber wood-A promising timber for bent wood articles. *J. Ind. Acad. Wood Science* **24**(1), 13-17.
- Pandey C.N., Joshi Neeraj and Kandpal R.P. (2002): Silver oak- A promising species for bentwood furniture. *Wood News*, Jan-March 2002, 14-17.
- Joshi, Neeraj and Pandey C.N. (2001): Trial on bending of plywood with vapour phase ammonia treatment and its effect on strength properties. *Journal of Timber Development Association of India*, **47** (3-4), 41-45.

- Pandey C.N. and Kanoji, H.C. (1998): Trials on bending of vapour phase ammonia plasticized *Paulonia fortunei* wood. *J. Timb. Develop. Assoc. India*, **44** (3), pp. 34-37.

Vacuum drying of timber:

Vacuum drying of timber is a new field of wood science in India. The technology has been commercialized in few developed nations. The vacuum kiln is costly affair as on date for Indian entrepreneurs due to absence of such indigenous equipment in the country. The technology is useful in the sense that it takes shorter time period to dry timbers to desired moisture content with lesser drying degrades compared to traditional technology of steam kiln. Work on vacuum press drying type kiln has been carried out on few species including Eucalyptus. A vacuum kiln of 60 cft capacity has been developed indigenously for fast and efficient drying of Indian timbers including plantation with a view to reduce drying time as well as drying cost as compared to traditional steam based drying. It is based on convection drying. The data collected on Chir pine (*Pinus roxburghii*) and Toon (*Toona ciliata*) validates the defect free faster drying of wood in vacuum.

- Jain, V.K. and Pandey, C.N. (1993) Studies on energy consumption and drying rate in vacuum drying process. *J. Ind. Acad. Wood Science* **24** (2), 57-62.
- Pandey C.N., Kambo, A.S. and Gandhi, B.L. (1999): Exploratory experiments on vacuum press drying of *Eucalyptus* wood. *Wood News*, Oct.-Dec. 1999, 37-41. Vol. 8, No. 4, Jan-March 1999.
- Kishan Kumar, V. S., Sachin Gupta, and Sharma, C. M., 2008. Studies on vacuum press drying of *Populus deltoides*. Indian Forester, 134(6): 835-842.
- Kishan Kumar, V.S., Sachin Gupta and C.M. Sharma (2008).Preliminary attempts to season *Tectona grandis* using vacuum press drying – possibility of much faster seasoning. In *Proceedings of Regional Workshop on Processing and Marketing of Teak Wood Products of Planted Forests* held at KFRI, Peechi during 25-28 September 2007, 284-288.

ENVIRONMENTAL FRIENDLY PRESERVATIVES

Environmental friendly zinc-borate preservative

All over the world search is going on to develop the eco-friendly wood preservatives to replace the hazardous wood preservatives. In the present paper zinc borate, an environmentally safe compound is studied to find its biocidal properties along with fixation in the wood. In F.R.I., some work has been done by way of diffusion and precipitating this compound within the wood by double treatment of borax followed by zinc chloride solution and was found significantly effective against termites. Results of biological and fixation tests have shown that it has some potential to be a future wood preservative which can be used for wooden joinery such as furniture, toys turnery and handicraft items.

- Singh, Govind and Indra Dev (2000). *J. Timb. Dev. Assoc. (India)* 46(3&4): 9-13.

The results on termite resistance and permanency of zinc-borate show that treatment of wood with borax followed by zinc chloride to allow precipitation of zinc borate, an insoluble compound in the wood could protect the wood form termites. Degree of protection achieved is low probably due to very low solubility of zinc-borate in the metabolic system of termites. Understanding of zinc-boron, zinc-boron-wood interactions are necessary for further improving the formulations. Since both Zn and boron are benign ions they have large potential for development of eco-friendly preservatives.

- Dev, I., Bagga, J.K., Misra, S.C. and Kumar, S. (1997). *J. Timb. Dev. Assoc. (India)* 43(2): 10-15.

Field performance of ammonical copper lignin complex A (CLC-A) treated wood after post-treatment processing.

Another study reported the effects of post-treatment processing of ammonical copper lignin complex-A treated wood on subsequent retention level of preservative and copper content.

Wrapping for 96 hours gave the best protection to wood in ground contact for 36 months, followed by steaming at 50 °C.

- S Tripathi (2009). Journal of Tropical Forest Science 21(4): 299–306

ZiBOC- A Potential Eco-friendly Wood Preservative of the future

Over the past decade, the wood processing industry has been increasingly involved in strategies to minimize the environmental impacts of treated wood. One sign of this is the dramatic increase in the use of preservatives based on inorganic metal oxides, which fix in wood. Among such preservatives the most common is chromated-copper-arsenate. In ASCU chromium and arsenic both are carcinogenic thus in the present study a new and fixed composition of three chemicals (Copper sulphate, Zinc chloride and Sodium borate) have been used to develop an environment friendly preservative. The formulation is amorphous and water insoluble and dissolved with the help of co-solvents. Fixation study of ZiBOC in Chir and Poplar exhibited only 23.6, 13.1 and 12.1 % leachability of Copper, Zinc and Boron in Chir and 53.5, 6.5 and 5 % leachability of respective metals in Poplar. Efficient fixation of Zinc, Boron in both the species and Copper in Chir was achieved. Efficacy against *Polyporous versicolor* (PV) and *Poria monticola* (PM) a white and brown rot fungus respectively showed that 0.50% concentration of salt (3.13 kg/m3) protected poplar completely against both the fungus as compared to control whereas PV caused 18%and PM caused 52.1% weight loss in control samples. In Chir, 0.2%(1.39 kg/m^3) and 0.1%(0.68 kg/m^3) concentration of salt protected blocks completely against PM and PV respectively as compared to control (54 and 11.4% weight loss caused by PM and PV).Accelerated field test after three months of installation reveals full protection of both the species against termite & fungus. Scanning electron micrograph revealed the difference of parent individual salts with the derived product. Thus, study is directed to develop synergistic biocidal compositions that combine a copper salt and inorganic biocide, removing arsenic and chromium.

- Sadhna Tripathi, J.K. Bagga and V.K.Jain (2005). THE INTERNATIONAL RESEARCH GROUP ON WOOD PROTECTION IRG/WP 05-30372 Paper included in the 36th Annual Meeting Bangalore, India 24-28 April 2005

PRESERVATIVES FROM NATURAL SOURCES

Neem leaves, a potential source for protection of hardwood against wood decaying fungus

Neem leaves are widely recognized for their insecticidal, pesticidal, fungistatic and fungitoxic ability. Neem leaves extractives prepared in various solvents such as petroleum ether, acetone, ethanol, methanol and hot water were tested at concentration levels of 0.5%, 1.0% and 1.5% against *Poria monticola, a* brown rot and *Polyporous versicolor*, a white rot by malt agar method. The extracts showing higher efficacy in the petri plate were then

subjected to soil block bioassays. The methanolic and ethanolic extract revealed high efficacy by inhibiting of the growth of both of the test fungus upto 98-99% at a very low concentration of 0.5%. While the acetone extract inhibited the growth of the brown and white rot upto 50 and 60% respectively, at its high concentration (1.5%). On the contrary the hot water and petroleum ether extractives promoted the growth of both the test fungus upto 100% at all the concentration levels. These results were observed in the petri plate by malt agar method. The extractives exhibiting higher efficacy in petri plate were then tested for their efficacy on poplar wood against the test fungus at a concentration levels of 1.5%, 3% and 4.5%. Blocks treated with the MeOH, EtOH and Acetone extracts of neem leaves reported a weight loss of 16%, 18% and 27% respectively against *Poria monticola* at a concentration level of 4.5%. While a weight loss of 21%, 22% and 26% was observed in the case of *Polyporous versicolor* at 4.5% concentration. Control samples exhibited a weight loss of 68 and 67% by both the fungus. Thus extractives treatments protected wood efficiently at laboratory scale. Qualitative estimation of the extractives revealed a high amount of phenolics and small amount of flavonoids in MeOH and EtOH extractives. Acetone extract showed small amount of phenolics and traces of flavonoids while the hot water extract contained a large amount of carbohydrate and slight presence of phenolics.

- Swati Dhyani, Sadhna Tripathi and V.K. Jain (2005). THE INTERNATIONAL RESEARCH GROUP ON WOOD PROTECTION IRG/WP 05-30370 Paper included in the 36th Annual Meeting Bangalore, India 24-28 April 2005.

Protection of hard and softwood through Neem leaves extracts and oil- A direction towards development of eco-friendly wood preservatives

Conventional wood preservatives like CCA and CCB are facing lot of criticism all over the world. It is essential to address the problem in view of environment protection. Eco-friendly wood preservatives may be considered as one option. The activity of alcoholic extract of neem against wood decaying fungi i.e. *Postia placenta* and *Trametes versicolor* in hardwood i.e. *Populus deltoides* and softwood i.e. *Pinus roxburghii* at different concentrations revealed 4 to 7 fold protection of wood over to control. 80-82% protection was observed in samples of hard and softwood treated with leaves extracts when subjected against wood destroying termite i.e. *Microcerotermes bessoni* in laboratory. Neem oil at various concentrations protected hard and softwoods efficiently against fungi i.e. upto 4 to7 fold over control. Hard and softwood samples treated with neem oil exhibited only 9-10% of weight loss by termites in laboratory whereas 95% damage was recorded in control samples. Present study shows that further work on neem oil and leaves extracts is required to develop potential eco-friendly wood preservative.

- Swati Dhyani and Sadhna Tripathi (2006). THE INTERNATIONAL RESEARCH GROUP ON WOOD PROTECTION IRG/WP 06-30394 Paper prepared for the 37th Annual Meeting. Tromsø, Norway 18-22 June 2006.

A review on organo metallic preservative from Mohwa oil, chir pine resin , cashew nut shell liquor and BNSL

Field data (accelerated test-yard tests) and toxicity studies indicate that the performance of Cu/Zn abietate is almost similar on Cu/Zn content basis with proprietary preservatives like Cu/Zn naphthenate in which naphthenic acid, an imported compound, is traditionally used as the base fatty acid. Development of wood preservatives from above raw materials of vegetable origin, which are abundantly available in the country at cheap price, has great potential.

- Jain, J.K and Satish Kumar (1991). *J. Timb. Dev. Assoc. (India)*. 37(4): 29-38.

<u>*Shorea robusta* Extractives</u>

The extractives of sal wood from different portions and at different heights were tested for their fungicidal toxicity against two brown rot and one white rot by filter paper disc method**.**

The results have shown that total extractives content varies in the order OHW>Top>1HW>SW but the fungicidal toxicity of all the extractives varies in the order Top>Middle>Bottom. Alcohol soluble extractives of the whole the tree, top to bottom and periphery to 1HW have fungicidal toxicity and inhibitory effect. These investigations are likely to have direct bearing on the formulation of new toxic compositions which are expected to free from any hazards during treatment of timber, handling of treated timber and finally their disposal after use.

- Gupta, Poonam and Indra Dev, (1999). *J. Timb. Dev. Assoc. (India)* 45(1&2): 16-24**.**

<u>Against sapstain</u>

Fungi which cause discoloration and disfigurement of wood in storage and in service are generally described as staining fungi. Their presence is a serious irritant in most uses like match logs, sports goods, artificial limbs etc. A continuous search for cost effective and environment friendly chemicals is being made around the world only chlorinated phenolic homologues turned out to be effective against sapstain. Environmentally safer formulations consisting of Reetha extract, copper lignin complex (lignin from black liquor of paper industry based), sodium fluoride, calcium hydroxide, copper sulfate were tested against *Alternaria alternata.* Reetha extract and copper lignin complex 'A' at 2% and 4% had completely checked growth of stains.

- Samani, A., Tripathi, S. and Gazwal, A.K. (2005). *J. Timb. Dev. Assoc. (India)* 51(1&2): 72-77.

<u>Eco-friendly preservative derived from copper chir pine rosin and CNSL</u>

A new formulation CRCNSL was prepared by reacting copper salts, rosin of *Pinus roxburghii* (chir) tree and Cashew nut shell liquid. The formulation CRCNSL contains copper

content 4-5%. It is soluble in powering; it keeps the wood in natural look. It is the safest eco-friendly broad-spectrum termite and fungi resistant formulation for joinery and furniture timber and very effective at 4.0 kg/m^3 retention level.

- Dev, I. and S.N. Nautiyal (2004). *J. Timb. Dev. Assoc. (India)* 50(1&2): 19-25.

Ipomea leaves- a natural source for wood protection against termites

Use of toxic pesticides may have an adverse effect on the quality of life in terms of toxicity to food chain as well as to human and wild life. The hazardous threat posed by the synthetic chemicals pesticides dictates the need to find out alternative past management strategy. Keeping in view of the toxicity of Ipomoea, leaves extractive in cheap solvent were tested against termite using semul (*Bombax ceiba*) as substrate. The extractive was found to be moderately resistant to prevent termite attack.

- Saxena P. and Dev, I. (2002). *J. Timb. Dev. Assoc. (India)* 48(1&2): 12-15.

VALUE ADDITION OF NON DURABLE WOODS

Value addition of eucalyptus through ammoniacal copper arsenite for improved service life.

A simple soak treatment in a new preservative system (Ammoniacal-Copper-Arsenite) has been developed which ensures good penetration (5-8 mm) and adequate absorption of the preservative (α 10 kg/m^3) in the heartwood. This development had helped to get proper service life from Eucalyptus timber even in high hazard areas, and thus increase its scope as utility timber.

- Dev, I., S.C. Pant, Prem Chand and Satish Kumar (1991). *J. Timb. Dev. Assoc. (India)* 37(3): 12-15.

Utilization of treated eucalyptus hybrid for joinery purposes

Eucalyptus joiners, with and without incisions at different depths, gave excellent performance with ACA treatment, after seven years of installation in field conditions. CCA and copper resinate, well known for efficacy could not perform well, which may be due to insufficient loading of preservatives in both the cases. The joineries were dipped for one week for treatment.

- Tripathi, S., Nautiyal, S.N. and Dev, I. (2005). *J. Timb. Dev. Assoc. (India)* 51(1&2): 3-12**.**

ACA and ACB treatment of plantation grown timber

Seven plantation species namely *Acacia tortilis, Casurnia equisetifolia, Melia azedarach, Paulownia fortunei, Populus deltoides, Eucalyptus hybrid and Prosopis chilensis* have been tested for their natural durability. It has been found that five species are non-durable and two i.e. *Eucalyptus hybrid* and *Prosopis chilensis* are moderately durable. Regarding treatability *Acacia tortilis*, *Casuarnia equisetifolia*, *Prosopis chilensis, Eucalyptus hybrid* fall in refractory class, *Melia azedarach, Paulownia* showed treatability class 'c' and *Populus deltoides* 'a'. In order to utilize non-durable class timbers emphasis is given to their treatment so that their life is increased for their proper utilization. All the species irrespective of treatability class may be treated with ACA/ACB wood preservative formulation by soaking or hot and cold process for the use in joinery.

- Dev, I. and Chauhan, K.S. (2004) *J. Timb. Dev. Assoc. (India)* 50(1&2): 53-62**.**

Protection of Eucalyptus during storage.

Considerable amount of sawn timber is degraded by insect and fungi during outside storage at saw mill yards and sale depots. The most susceptible stage for degradation is soon after the felling of trees. Such deterioration can be checked by giving prophylactic treatment with chemicals. Study suggests that creosote emulsion can be effectively used for protection of eucalyptus during storage for a period up to 24 months. Lime turmeric failed to protect against mold fungi but prevented fungal degradation up to 12-18 months storage.

- Dobriyal, P.B., Dev, I. (1997). *J. Timb. Dev. Assoc. (India)* 43(3): 14-17.

Natural durability of commercially important timbers and their performance improvement through preservative treatment.

Proper and economical utilization of any wood species can be suggested, only when its natural durability at different climatic zones and performance of preservative treatment for enhancing its durability are known in advance. Keeping this in mind sixteen species along with two reference species *Pinus roxburghii* and *Mangifera indica* have been tested at three different sites, Dehra Dun, Chakrata and Jodhpur. Nine species have been found to be non durable but after treatment their life has increased and are at par to durable species *Canarium euphyllum* gave poor performance in the lowest dose of CFO, *Cullinea excelsa* with lowest dose of ASCU and *Sapindus mangifera* with lowest dose of CFO and ASCU. The place wise analysis shows that there is difference within the lots of same species between species and different treatments for all places. The pooled analysis shows that there is different among the replications i.e. difference among the pieces of same species among species, among treatments, among places and all possible two factor interactions, however the three factor interactions is no significant.

- Dev, I., Pandey, R. and Chauhan, K.S. (2003). *J. Timb. Dev. Assoc. (India)* 49(2&3): 10-18.

Durability improvement of commercially important timbers

Proper and economical utilization of any wood species can be suggested, and its natural durability at different climatic zones and performance of preservative treatment for enhancing its durability are known in advance. Keeping this in mind eight species *Acacia Arabica, Adina cordifolia, Canarium strictum, Depterocarpus tubinatus, Dysoxylum malabaricum, Pterocarpus marsupium, Terminalia belerica, terminalia tomentosa* alongwith two reference species *Pinus roxburghii* and *Mangifera indica* have been tested at two different sites Dehra Dun and Jodhpur. Results have shown that the interaction between species and treatments are significant at 5% level for both sites and there is marked difference between test species with over all performance of check species for both sites. Maximum durability was given by creosote fuel oil mixture at highest retention C3 followed by C2 and is at par with highest retention of ASCU (A3).

In another study, the durability of treated and untreated specimen of 16 species along with two reference species and discussed. The study indicated that cold climate of Chakrata, being non congenial for fungus and termite, helped in increasing the service life of all species. The *T. nudiflora* and *B. serratta* were the poor performer species and statistically at par with check species Mangifera indica. The species *D. indicus, A. pindrow and P. morinda* which are reported to be non durable class as per F.R.I., Dehra Dun test yard data has shown a higher service life and behaved like a moderately durable class at Chakrata. All other twelve species remained to be durable class 1. The higher level of retention in both the preservatives have shown better results than lower retention.

- Dev, I., Pandey, R. and Chauhan K.S. (2001). *J. Timb. Dev. Assoc. (India)* 47(1&2): 27-33.

- Dev, I., Pandey, R. and Chauhan K.S. and Mittal, M.C. (2001). *J. Timb. Dev. Assoc. (India)* 47(3&4): 14-19.

Effect of ACA treatment on wood strength of Eucalyptus hybrid

The use of wood in building construction is one of the most important applications. Due to scarcity of such timbers and ban on felling of trees from natural forests plantation grown wood species have been promoted for different purposes including the building construction. Eucalyptus hybrid, one of such species has been recommended after developing the treatment method. The effect of ACA treatment on the mechanical properties of Eucalyptus hybrid has been studied and the results indicated that ACA has no adverse effect on the mechanical properties required for door shutter and frames.

- Bagga, J.K., Khanduri, A.K. and Dev, I. (2001). *J. Timb. Dev. Assoc. (India)* 47(3&4): 20-23.

TREATMENT SCHEDULES FOR FEW INDIAN HARD WOODS

Wood species have been categorized into five treatability classes according to their ease in getting preservative treatment. These classes are used as a guideline to treat wood under pressure. During pressure treatment, pressure, duration of pressure and solution concentration are regulated to get adequate loading and penetration. Woods belonging to different treatability classes thus need different treatment schedules. Work on poplar, hillock, babul, lampati, myrobalan, dhaman, hopea, machillis was carried out.

Percent voids filled increase with increasing pressure but this tends to taper of at 7.0 kg/cm^2 pressure for easy to medium treatability class wood species. For refractory species, better treatment is obtained at higher pressure. However, a similar trend is noticed with increase in pressure duration. While there is no effect of concentration in preservative solution uptake in most easy-to –treat wood species, refractory wood species tend to absorb less solution at higher concentrations.

This data coupled with distribution of preservative in different cell types can be used to frame pressure treatment schedules for different end uses.

- Jain, D.K., S.N. Nautiyal and Satish Kumar (1991). *J. Timb. Dev. Assoc. (India)*. 37(4): 23-28.

Preservative treatment of Green wood

An entirely different process following a schedule of fast fluctuating pressure was developed for treating easy to treat wood species in green condition with CCA type preservative. The results were compared with conventional full-cell pressure process using the same pressure and time periods. The Fast Fluctuating Pressure Process not only resulted in higher loading of the preservatives in wood but also provided a more uniform distribution of salts in pinewood.

- Kumar, S. and Kainth, P.S. (1996). *J. Timb. Dev. Assoc. (India)* 42(4): 5-9.

Durability and Preservation of Eucalyptus L. Hertier - A Review

Eucalyptus hybrid wood now available in plenty in all the states of the country is searching the market for its proper and economic use. The present paper reviews the work done on E. hybrid as well as other species of eucalyptus regarding durability, treatability and treatment processes.

- Dobriyal, P.B. and Indra Dev (1992). *J. Timb. Dev. Assoc. (India)*. 38 (2): 33-41

Treatability and Treatment Studies of *Prosopts chilensis*.

In order to utilize the *Prosopis chilensis* timber species grown in social forestry programme, treatment with preservative chemicals is essential to prolong its life. Work was carried out to determine the treatability class and method of treatment to desired level. The study indicated

that the *Prosopis chilensis* fall in treatability class 'D' i.e. refractory to treatment. A simple soak treatment in ammoniacal copper arsenite solution has been tried which ensured good penetration (40% area treated) with adequate retention recommended for joinery and furniture.

- Dev, I., S.C. Pant, P.S. Kainth and Prem Chand (1992). *J. Timb. Dev. Assoc. (India)*.38 (2): 47-50

WOOD UTILIZATION FROM ARTISANS POINT OF VIEW

To meet the growing demand of timber for increasing industrial activities in the country a large number of non-traditional wood species are being used. The small-scale industries meet their demand of such timber from local suppliers by local names. The experience and correspondence records of the industry show that the timbers supplied under trade or local names are not always found correct. Because of lack of standardization in trade names, a number of species have been kept under one trade name e.g. 12 different *Dipterocarpus* species under the trade name gurjan and 8 different *Michelia* spp. under champ. A rational nomenclature is therefore necessary to have optimal utilization of these wood species.

- Dobriyal, P.B. (1992). *J. Timb. Dev. Assoc. (India)*. 38 (1): 35-38.

Wood preservation for handicraft items- A review

Wood has been most preferred for the handicraft item because of its excellent anatomical structure and finishing properties. Durable wood species like teak, rosewood Shisham, sandal wood etc has been referred but now due to scarcity and high prices of these timbers, the handicraft industry has shifted to the use of easily available mango and rubber wood which are prone to insect and fungal attack, and thus quality of the products could not be maintained. Methods to make the products dimensionally stable and resistant to attack by biological degradation and a number of conventional and futuristic chemicals have been suggested to suit individual needs.

- Dev, I (2000). Protection of wood in Handicraft items. *J. Timb. Dev. Assoc. (India)* 46(1&2): 5-10.

FIRE RETARDANT CUM ANTISEPTIC FORMULATIONS FOR BAMBOO AND WOOD PROTECTION

Fire retardant-cum-antiseptic formulation for wood protection.

Fire retardant treatment of wood is very expensive because of high dosage of chemicals required. A loading of 48 kg/m^3 has been recommended irrespective of type of wood species, commodity and chemicals. Effectiveness of boric acid - borax mixture and ammonium phosphate fire retardants at different loadings was examined. The results indicated ammonium phosphate, effective at lower loadings than boric acid - borax mixture. A lower dosage of chemical is recommended for less hazardous areas.

- Dev, I., Ram Lal and Satish Kumar (1992). *J. Timb. Dev. Assoc. (India)*. 38 (3): 24-28

A review on fire retardant treatment of wood

Wood is a unique material found abundantly on earth requiring less energy for processing renewable in nature and available at reasonable rates. Primarily all timbers do catch fire but the amount of destruction varies depending upon the structure design, density, porosity, moisture content and nature of infiltrated chemical. Chemical treatment improves the fire resistance behaviour of timber, which makes it a versatile material. The present paper reviews the work done in India and abroad on the development of fire retardant chemicals and treatments for wood and other lingo cellulosic materials.

- Dev, I. (1993). *J. Timb. Dev. Assoc. (India)* 39(2): 23-32.

Fire retardant-cum-antiseptic formulation for ply wood protection

Ammonium sulphate, Ammonium phosphate, Boric acid, Borax, CCB, Zinc chloride, Magnesium phosphate, Magnesium sulphate were taken in different proportions and combinations and tested at 10% concentration in plywood. Combinations of Ammonium sulphate, Ammonium phosphate, Zinc chloride and Borax (2:2:3:3) and Magnesium pyrophosphate, Magnesium phosphate, Borax and Boric acid (3:3:2:2) were found best performing as per IS-5509. The cost of the formulations is Rs. 87 and 83 per kg while treatment was Rs. 2040-2330/m^3 at 24 and 28 kg/m^3 retention level.

- Samani, A, Tripathi, S and Lal, R. (2007). *J. Timb. Dev. Assoc. (India)* 53(1&2): 10-21.

Resistances of Chemically Treated *Bambusa arundinacea* against Fungi, Termite and Fire

Protection of *Bambusa arundinacea* against fire, fungi and termites by treatment with different compositions of fire retardants and the eco-friendly preservative ZiBOC were studied. Bamboo culms splits treated with 6 compositions at 15 % mass fraction were subjected to three tests, viz: flame penetration, flammability and rate of burning as per Indian Standard. Compositions of: 1. ammonium sulphate + Ammonium phosphate + ZiBOC ; 2. ammonium sulphate + ZiBOC; 3. ammonium phosphate + ZiBOC; 4. magnesium phosphate + magnesium pyrophosphate + ZiBOC; 5. magnesium phosphate + ZiBOC and 6. magnesium pyrophosphate+ ZiBOC at 15 % mass fraction were used. Retentions of different

chemical compositions, under test, in bamboo were in the range of 9-11.5 kg/m^3. Decay test against *Trametes versicolor* (white rot) exhibited that compositions 2, 3, 5 and 6 imparted significantly high protection (up to 95 % ; $p<0.05$) to bamboo blocks against white rot as compared to control . Approximately 43 %-67 % protection could be achieved to bamboo, treated with different compositions, over control, against *Oligoporus placentus* (brown rot). All specimens treated by compositions 2-6 were completely protected against termite after the 1st and the 2nd seasons of exposure except composition 4, where very slight attack of termite was seen after the 2nd season while control specimens were badly damaged. A few compositions had remarkable contribution toward protection of samples against fire.

- Sadhna Tripathi (2010). *Chemistry and Industry of forest products* ; 3(4)

WOOD FUMIGANTS

Chloropyrifos: A fumigant for protection of wood against decaying fungi.

Chloropyrifos is one of the most widely used active ingredients for pest control products in the world. In order to determine the efficacy of Chloropyrifos as a fumigant against wood destroying fungi, it was tested at different concentrations. 100% growth inhibition of *Oligoporus placentus* (brown rot) was achieved with 1.3% Chloropyrifos. Whereas, at 1.9% it had completely checked the growth of *Trametes versicolor* (white rot).

- Pant, H.; Tripathi, S. and Samani, A. (2007). *J. Timb. Dev. Assoc. (India)* 53(3&4): 40-49.

Chloropyrifos and lindane for wood protection against termites

A search into the literature indicates that light organic solvent type, preservatives (LOSP) hold a lot more promise than other types because there are clean to handle, can be applied easily to prefinished and prefabricated wood products including plywood and other board products. Considering the increasing advance in organic solvent type wood preservatives, a study was carried out I Wood Preservation Discipline of DFPR. Termite resistance tests on Lindane 20EC and Technical grade, and chloropyrifos were carried out in termite mound using wood as substrate to assess the comparative performance as insecticide. A dose of 1.00 kg/m^3 is considered effective for protection against termites for al the three products with a mean score of degradation less than 0.5 an accepted value for effective termite resistance.

Fungal decay resistance of wood fumigated with chloropyrifos

Disinfestation is the main purpose of fumigation and no subsequent and sustained protection for longer duration against risk of attack is afforded. The ideal fumigant is in fact, one which leaves treated commodity unchanged in all respect. Although the effectiveness of chloropyrifos as termiticide has been proven in laboratory and field test studies, no information is available concerning the fumigant action against wood degrading fungi. Chloropyrifos (O, O-diethyl [3, 5, 6-trichloro-2-pyridyl] phosphorothioate) was evaluated as

wood fumigant by soil block bioassay test. Soft wood *(Pinus roxburghii*) and hard wood (*Populus deltoides*) blocks fumigated with 5 different concentrations of chloropyrifos were subjected to wood-decaying fungi, white rot *(Trametes versicolor*) and brown rot (*Oligoporus placentus*). Results revealed that 4.9% concentration of chloropyrifos imparted more than 90% protection to the wood against white and brown rot. Laboratory results showed that chloropyrifos is very effective at all concentrations tested, providing more than 75% protection at lowest concentration tested i.e., 0.9%

- Himani Pant, Sadhna Tripathi (2010). International Biodeterioration & Biodegradation, 64: 665-669.

WOOD UTILIZATION IN COOLING TOWER AFTER PRESERVATIVE TREATMENTS

Suitability of Hard wood species for cooling tower.

Albizia procera, Albizia lebbeck, Boswellia serrata, Butea monosperma, Eucalyptus hybrid and *Populus ciliate* treated with CCA, ACC, CCB and BCCA were tested for suitability in cooling tower. None of the species could sustain the fungal attack in untreated form. While eucalyptus*, Albizia lebbeck* and *Albizia procera* behaved better than other species. However, none of the species could match the behavior of chir, the reference species.

- Kumar, S., Pant, S. C. and Bagga, J.K. (1996). *J. Timb. Dev. Assoc. (India)* 42(3): 25-29.

BAMBOO DURABILITY IMPROVEMENTS THROUGH PRESERVATIVE TREATMENTS

Field performance of treated bamboo]

Grave yard data on natural durability of *Bambusa polymorpha, Dendrocalamus strictus* and *Melocanna bambusoides* shows that none of the species is durable in ground contact. Treatment with creosote: fuel oil mixture proved to be the best wood preservative for enhancing the life of bamboo. The performance of CCA, ACC and CCB treated bamboos was almost equivalent. The performance of *Melocanna bambusopides* even after preservative treatment was not good, although this species has earlier been found to treat well.

- Kumar, S., Kainth, P.S. and Chauhan, K.S. (1998) *J. Timb. Dev. Assoc. (India)* 44(3): 17-24.

Ammonical copper arsenite treatment of round bamboo

The bamboo culms in round form which poses treatment problems in dry condition can be easily treated with ACA by soaking for 7 days to required retention with deeper and uniform penetration from the surface. Though by pressure method higher retentions can be achieved soaking method is more suitable in rural areas where Vacuum-pressure treatment facilities are not available.

- Dev, I., S.N. Nautiyal and Satish Kumar (1999). *J. Timb. Dev. Assoc. (India)* 45(1&2): 39-43.

Boucherie process

Treatment of wood, bamboo and other cellulosic products with preservative chemicals is essential to enhance their service life. The treatments to required doses and penetration can be done either in green condition or after drying to 12-18% moisture content by pressure method in water borne type preservatives. In green condition diffusion and Boucherie process have been recommended for wood planks and sleepers but poles and bamboos can be treated in full length by Boucherie process alone. In this article the Boucherie process in its modified forms for the treatment of round bamboo and poles have been discussed. The results of treatment with modified equipment have shown that longer treatment durations with lower concentration of the treating solution have given more uniform absorption throughout the length and cross section of treated poles.

- Shukla, K.S. and Dev, I. (2000). *J. Timb. Dev. Assoc. (India)* 46(3&4): 33-44

Performance evaluation of Borax: Boric Acid treated Green bamboo through new VAC-FRI and conventional processes

A number of processes have been developed for treating bamboo in green/dry, split and round form. However the latest breakthrough is achieved in treatment of bamboo and this new approach is much faster and more efficient while maintaining the economics of the treatment well within the reach to entrepreneurs one such a process VAC-FRI. ***D. strictus, B. nutans*, *B. arundinacea, B. balcooa*** and ***B. gigantius,*** species, known for structural and other uses were treated with 4% Borax: Boric acid by Boucherie, VAC-FRI, wick and diffusion processes. Natural durability and performance after treatment was evaluated under shade and ground contact. Results revealed that new process VAC-FRI is comparable to all other known conventional process.

- Sadhna Tripathi & S.N. Nautiyal (2006). THE INTERNATIONAL RESEARCH GROUP ON WOOD PROTECTION IRG/WP 06-40327 Paper prepared for the 37th Annual Meeting Tromsø, Norway 18-22 June 2006

Performance of *Dendrocalamus strictus* Treated with Combined Fire Retardant and Preservative Systems against Fire, Fungus and Termites

Dendrocalamus strictus was treated with six fire retardant and preservative compositions. Different combinations of fire retardant and new eco-friendly preservative ZiBOC were tested in the above species for protection against fire, fungus and termites. Bamboo culms treated with six compositions at 15% concentration, were subjected to three tests, viz: flame penetration, flammability and rate of burning as per Indian Standard. Compositions (1) Ammoniumsulphate +Ammonium phosphate + ZiBOC,(2) Ammonium sulphate+ ZiBOC , (3) Ammonium phosphate+ZiBOC ,(4) Magnesium phosulphate+ Magnesium pyrophosphate+ ZiBOC , (5)Magnesium phosphate+ ZiBOC and (6) Magnesium pyrophosphate+ ZiBOC at 15 % were taken for the study. Results revealed that 7.4 kgm-3was the lowest retention achieved by 6 no. composition while 19.90 kgm-3 was the highest retention achieved byno.1 composition. Treatment cost for Composition no.1 was

comparatively higher as compared to other treatments because of high retention and solubility of chemicals in acid. Whereas, lower cost was observed by Composition no.2 as the chemicals were water soluble. All compositions performed as per standard except Composition no.3 in flame penetration test. Statistical analysis revealed that Composition no. 4 performed best followed by no.2 and 1.Test against decaying fungus in laboratory and termites in mounds respectively exhibits significant protection by all compositions as compared to control.

- Sadhna Tripathi (2009). 8th World Bamboo Congress Proceedings (ISSN 2150-1165); 9: 26-35.

UTILIZATION OF INDUSTRIAL WASTE FOR WOOD PROTECTION

Utilization of black liquor of paper mill for wood protection against sapstain

The study was conducted on the efficacy of prophylactic treatment of black liquor of Star paper mill, with and without Copper sulphate, against sap stain fungus *Altenaria alternata* on *Populus deltoides* (Poplar). Spray treatments revealed complete protection of samples at 1% liquor + 3% Copper sulphate and 5% liquor + 3% copper sulphate under different experimental conditions, after 9 months of installation. Thus it suggests that complete protection of Poplar can be achieved for a longer duration by prophylactic treatment of black liquor and copper sulphate at various dilutions as compared to other known methods.

- Tripathi, S. and Chand, S. (2005). *J. Timb. Dev. Assoc. (India)* 51(3&4): 27-34.

WOOD WORKING AND JOINERY

After the processing of wood and before a product is made, the processed timber usually goes through a set of working operations. There are six basic wood working operations viz. planing, sanding, mortising, boring, moulding and turning. Each wood species responds differently to these operations. Based on the response of any wood species to these operations, working qualities are calculated for them and are compared with that of teak. This helps us in choosing suitable species for each job. The working quality indices of nearly 80 Indian species have been evaluated. In addition, works on joinery and other wood working operations were also carried out at FRI. Recently, research on finger jointing with a commercial finger shaper has also been initiated. A glimpse of some of these can be had from the following publications:

- Rawat, B.S., S.S. Rajput and B.C. Pant (1972). Working qualities of Indian timbers. *Indian Forester,* **98** (11): 669 – 696.
- Rawat, B.S., S.S. Rajput and B.C. Pant (1973). A study of power requirement in thickness planing. *Indian Forester,* **99** (1): 23 – 32.
- Rawat, B.S., S.S. Rajput and B.C. Pant (1974). Studies on working qualities of Indian timbers. *Holzforschung und Holzvertung*. **26** (2).

- Rawat, B.S. and S.S. Rajput (1975). On the qualitative evaluation of working qualities of Indian timbers. *Jour. of Timb. Dev. Assoc. (India)*. **21**(3): 8 – 10.
- Rawat, B.S., S.S. Rajput and B.C. Pant (1976). Studies on working qualities of Indian timbers. *Indian Forester,* **102** (1): 43 – 56.
- Rawat, B.S., S.S. Rajput and B.C. Pant (1977). Studies on working qualities of Indian timbers – IV. *Jour. of Ind. Acad. Of Wood Sci.* **8** (1): 7 – 16.
- *Rajput, S.S. (1977). A note on development of multi-coloured laminated decorative wood articles. Indian Forester, **103** (8): 550 – 556.*
- Rawat, B.S. and B.C. Pant (1980). Studies on working qualities of Indian timbers. *Indian Forester,* **106** (1): 60 – 78.
- *Guha, S.R.D. and S.S. Rajput (1981). Furniture and joinery industries in India. Jour. of Timb. Dev. Assoc. (India). **27** (4): 5 – 12*.
- Shukla, K.S. and B.C. Pant. (1983). Working qualities of some Indian timbers. *Indian Forester,* **109** (4): 222 – 236.
- Rajput S.S., B.C. Pant and S.L. Sharma (1983). Studies on working qualities of Indian timbers – VII. *Van Vigyan,* **21** (1&2): 16 – 25.
- Jaitly V.P., B.C. Pant and S.B. Gupta (1983). A note on working and finishing qualities of Eucalyptus species. *Indian Forester,* **109** (12): 917 – 925.
- Shukla K.S., R.C. Bhatnagar and B.C. Pant (1984). A note on working qualities and finish adaptability of rubber wood. *Indian Forester,* **110** (5): 490 – 496.
- Rajput S.S. and R.C. Bhatnagar (1984). Evaluation of machining qualities of particleboard. *Jour. of Ind. Acad. Of Wood Sci.* **15** (1): 33 – 36.
- Shukla K.S. and B.C. Pant (1985). Simple method for quantitative evaluation of surface smoothness of wood. *Indian Forester,* **111** (1): 28 – 35.
- Jaitly V.P., Avtar Singh and B.C. Pant (1985). A note on pattern knife for evaluating turnery properties of timber. *Indian Forester,* **111** (10): 802 – 811.
- Jaitly V.P., R.C. Bhatnagar and S.N. Nautiyal (1985). Machining qualities of particle boards. *Jour. of Ind. Acad. Of Wood Sci.* **16** (2): 71 – 74.
- Pant, B.C., K.S. Shukla and S.P. Badoni, (1989). Working qualities of Indian Timbers. Part – VIII. *Indian Forester.* **115**. (9): 644-660.
- Shukla, K.S., K.N. Pandey, B.C. Pant and S.P. Badoni (1989). Carving behaviour of some Indian timbers. A quantitative approach. *Jour. of Ind. Acad. Of Wood Sci*. **21**(2): 27-32.
- Shukla, K.S., S.P. Badoni and B.C. Pant, (1991). Working and Carving qualities of Indian timbers. *Wood News*. Oct. – Dec.: 29 – 34.
- Pant, B.C., K.S. Shukla and S.P. Badoni, (1992). Working qualities of Indian Timbers Part – IX. *Indian Forester*. **118** (8): 573 – 582.
- Pant, B.C., S.P. Singh Sachin Gupta, and C.M. Sharma (2002). Working qualities of some Indian Timbers Part – X. *Indian Forester*. **128** (8): 1021 – 1032.
- Pant, B.C., Sachin Gupta, S.P. Singh and S.P. Badoni (2003). Working and finishing qualities of some Andaman Timbers. *Indian Forester*. **129** (4): 479 – 488.
- Singh, S.P., Sachin Gupta and V.K.Jain (2006): Studies on carving quality of some Indian timbers. *The Indian Forester*, Vol. 132 No.8, 1019 – 1023.
- Kishan Kumar V.S., Sachin Gupta and Vimal Kothiyal (2011). Elasticity and rupture of finger jointed mango wood joined with two adhesives. Indian Forester, **137** (1), 88-93.

FINISHING ASPECTS

More and more emphasis was focused on the secondary processing aspects of plantation timbers in the recent years, which has significantly contributed in promotion of these species as an economical alternative to traditional woods. The simple, inexpensive, effective and environmental friendly technique of ammonia fumigation to upbring latent surface figures with prominent surface figures on less decorative timbers such as eucalypts, poplars, *Paulownia, gamari,* rubber wood, *gokul,* mango etc. was perfected to replace hazardous and harmful aniline finishes. The technique of using Moisture exclusion effectiveness (MEE) as an indicator for the moisture blocking capacity of finishes and measuring gloss as an indicator for comparing surface lusture of finished products have been successfully demonstrated. Some of the published literatures in this direction are listed below.

- Jaitly V.P., B.C. Pant and S.B. Gupta (1983). A note on working and finishing qualities of Eucalyptus species. *Indian Forester,* **109** (12): 917 – 925.
- Shukla K.S., R.C. Bhatnagar and B.C. Pant (1984). A note on working qualities and finish adaptability of rubber wood. *Indian Forester,* **110** (5): 490 – 496.
- Pant, B.C., Sachin Gupta, S.P. Singh and S.P. Badoni (2003). Working and finishing qualities of some Andaman Timbers. *Indian Forester*. **129** (4): 479 – 488.
- Studies on moisture resistance of a traditional and a commercial finish on mango wood at elevated temperature and high relative humidity. Kishan Kumar V.S., Keshav Kumar Upadhyay and Sachin Gupta. *J. Indian Academy of Wood Sciences*, **6** (1&2), 36-44, (2009).
- Role of different finishes in controlling moisture entry into strips of *Dendrocalamus strictus*. Kishan Kumar V.S., John and Sachin Gupta (2008). In *Proceedings of the international conference on "Improvement of Bamboo Productivity and marketing for Sustainable Livelihood"* held at New Delhi during 15-17 April 2008, 343-347.
- Effect of different number of coatings on gloss and in controlling moisture entry into mango wood. Sachin Gupta, Ambrish Sharma and V. S. Kishan Kumar. *Current Science*, **94** (9), 1128-30, (2008).
- Gloss and ammonia fumigation studies with film forming and penetrating types of finishes on poplar surface. Sachin Gupta, Prem Chandra, Brij Bhushan Mishra and Kishan Kumar V.S. *J. Indian Academy of Wood Sciences*, (N.S.), **4** (1&2), 53-59, (2007).
- A note on the performance of commercial glossy finishes on *Eucalyptus tereticornis* surface. Pandey, C.N., Vipin Chawla and Kishan Kumar V.S. *Indian Forester*, **133** (2A), 58-61, (2007).
- Badoni, S.P. (1987). Role of wood finishing in timber utilization. *Jour. of Timb. Dev. Assoc. (India)*. **33** (1): 5 – 14.
- Badoni, S.P., K.N.Pandey and K.S.Shukla (1990). A preliminary note on the moisture excluding efficiency of some pore filling treatment and polishing of *Terminalia manii* (Black chuglam). *Jour. of Timb. Dev. Assoc. (India)*. **36** (1): 13-17.
- Badoni, S.P., S.B. Gupta and K.S. Shukla (1990). Preliminary studies on Ammonia fuming of some Indian timbers. *Jour. of Timb. Dev. Assoc. (India)*. **36** (2): 24-30.

- Badoni, S.P., S.B. Gupta, K.S. Shukla and S.N. Sharma (1990). A note on staining *Populus deltoids* (poplar) using Ammonia Fumigation and aqueous *Terminalia alata* bark extract. *Jour. of Timb. Dev. Assoc. (India)* **36** (3): 20-25.
- Badoni, S.P., S.B. Gupta and K.S. Shukla (1991). A note on solar irradiation effect on colour of some Indian Timbers. *Jour. of Timb. Dev. Assoc. (India)* **37** (3): 27-33.
- Badoni, S.P. and S.S. Rajput (1997). Upgradation and utilization of secondary timber for furniture through Ammonia fumigation. Presented in First All India people's technology congress held at Calcutta on 21 – 23 Feb.: 37 – 39.
- Pant, B.C., Sachin Gupta, S.P. Singh and S.P. Badoni (2003). Working and finishing qualities of some Andaman Timbers. *Indian Forester*. **129** (4): 479 – 488.

WOOD COMPOSITES

BAMBOO MAT BOARDS

The influence of resin content and pressing conditions on the strength of board was studied. It is observed that lower the resin content, the more pronounced is the effect of pressing conditions on the strength of the resulting board. A resin content of 15% and a pressure of 28 kg/cm^2 are considered adequate. When strength properties of the board were plotted against the density the strength increased as a quadratic function of density. Tangentially cut strips were found better than those cut radially and the outer layers are better than the inner layers.

Another promising material that has been developed is a board with veneer faces and bamboo mat core. Saw dust treated with phenolic resin can also be sprinkled on the mats, which can be put together and pressed. Addition of saw dust enables the irregularities to be filled up, and if sprinkled on the two outer surfaces gives a mat appearance. Other fillers like coir pith, tamarind seed testa, cork dust etc., were also tried. The boards can also be made in corrugated form or moulded into any shape.

Cost of adhesives in bamboo board constitutes nearly 50% of the total cost of the bamboo board. Therefore, to effect economy in developing bamboo board, studies on the replacement of phenol in PF adhesive by indigenous cashew nut shell liquid (CNSL) were undertaken. Results were quite encouraging. Further, extension of PF resin by paddy husk gel (150%) shows a reduction in cost of production by 13-23% without adverse effect on properties of bamboo board.

- Shukla, K.S. and S.P. Singh (1994*). Composite Wood. Research and Development*, ICFRE–32.

Compressed Wood:

Prior to 1947, almost entire requirement of timber for textile shuttle blocks was met from imports. The timber species imported were cornel (*Cornus florida* Linn.), persimmon (*Diospyros virginiana* Linn.) and hornbeam (*Carpinus spp.*).

Keeping in view the interests of the textile and jute industry, studies on physical and mechanical properties of 38 indigenous wood species before and after compression have been undertaken to evaluate their suitability for this purpose.

Compression improved the strength and wearing qualities of timber, and density of 38 Indian timber species could be raised to lie in the range of 1.05 – 1.35 kg/cm^3 irrespective of their original density, suitable for wooden shuttle blocks for non-automatic looms.

Indigenous timbers tested viz., *Hardwickia pinnata, Albizia lebbeck, Melia dubia, Mitragyna parvifolia, Casuarina equisitifolia, Populus deltoides, Populus ciliata* and *Eucalyptus* hybrid meet the requirement for compressed wood block for shuttle manufacture.

- Shukla, K. S. and R.C. Bhatnagar. (1993). Compressed wood from some social forestry species. *J. Timb. Dev. Assoc*.(India), 39 (1): 5-8.

- Jain, N.C, M.K. Lala, K.K. Sharma and P.P. Gupta (1971). Compressed wood from Peeler cores of some Indian Timbers. *Research and Industry,* 16(1): 21-23.

- Jain, N.C. and R.C. Bhatnagar (1963). Compressed wood from Indian Timber. *Research and Industry*, 8 (3): 68-70.

DOOR WINDOW/SHUTTERS FROM LAMIANTED WOOD AND LVL FROM POPLAR

Poplar has been raised on large scale in the Northern parts of India and substantial quantities of timber is available for variety of uses. However, wood being light and lower in strength properties is not finding use in the manufacture of door/window shutters. A technology of utilize short dimension wood and improve physical and mechanical properties of poplar through laminated and simultaneous compression has been developed. 20 door shutters were made and fixed in Scientist Hostel for demonstration.

- Shukla, K. S. and Anil Negi (1998).Laminated veneer lumber (LVL) from poplar for door/ window shutter. ICFRE, BR-2, F.R.I.

- Shukla, K. S., Anil Negi and Ravindra Singh. (1997). Laminated Veneer Lumber (LVL) from *Populus deltoids*. *J. Timb. Dev. Assoc*. (India), 42 (3): 30-35.

- Shukla, K. S. (1997). Door / Window shutters from laminated poplar wood. ICFRE Brochure.

- Lala, M.K., H.K Bali and R.C. Gupta (1978). Studies on laminated wood. *Holzforschung und Holzverwertun,* 30 (3): 56-57.

RECONSTITUTED WOOD FROM LANTANA *(LANTANA CAMARA)*

Lignocellulosic material of lantana sticks are used for making reconstituted structural wood. Lantana is a weed, available in different parts of the country. It grows under varying conditions of climate and soil. Lantana thrives in moist areas of high rainfall exceeding 500 cm and also in comparatively dry localities with 75 cm rainfall per annum. It is drought resistant, light loving and tolerates moderate shades. It regenerates quickly after cutting.

Lantana sticks in green or wet condition with moisture contents of 60-80 percent are passed through counter revolving rollers. The material is fully destructured by narrowing the gap progressively between the alignment of the fibres in subsequent crushing till the material is crushed uniformly without disturbing the alignment of the fibres.

The destructured material is dipped in phenol formaldehyde resin (about 35 percent solid) in a tank without disturbing the fibre alignment so that the resin uptake is about 8 to 10 percent on solid basis. Resin uptake is controlled by adjusting the moisture content in crushed material, solid content of the resin and duration of resin treatment.

The resin treated material is then dried at a low temperature or sun drying to a moisture content of 6-8 percent.

The resin treated destructured material is formed into a pack of required dimension without disturbing the fibre alignment.

The packed material is then pressed in a cold press to consolidate the material and the final pressing is carried out in a hot press maintained at 140-150 ^{0}c at a pressure of 21-28 kg/cm^2 for about 30 minutes depending upon the density and thickness of the product required. The product is cooled in the press.

The board is taken out of the hot press and conditioned to equilibrium moisture content. The board is then planned, trimmed and polished according to the requirement.

The physical and mechanical properties of reconstituted wood developed from lantana compare favourably in most of the properties with durable timber like teak (*Tectona grandis*} and much better than medium density particle board. The product having the density in the range of conventional timber can be developed without much disturbing the alignment of fibres and thus retaining the directional strength properties of wood.

This product offers possibilities for use as a substitute for solid wood where directional strength properties are the main requirement as in structural timbers. It may be used for furniture, doors and window frames, beams and many loads bearing structure. It will help in substituting solid wood for various purposes and will ultimately help in conserving the forest resources.

- Singh, S.P., J.P. Singh, Anil Negi & S.S. Rawat, (2001).Reconstituted wood from *Lantana camara. J. Timb. Dev. Assoc*. (India), 47(1&2):42-46.

STRUCTURAL WOOD FROM BAMBOO AND LOPS AND TOPS OF EUCALYPTUS AND POPLAR:

Many new reconstituted wood products like particle board, fibreboard etc., have been remarkably successful in replacing solid wood for non-structural uses. However, they do not meet the requirements of timber for structural components.

Reconstituted products invariably involve steps of progressive reduction in size of wood raw material followed by alignment and bonding. It was considered that perhaps this

sequence itself is a factor inhibiting development of both a workable process and requisite structural properties. Therefore, a sequence has been evolved in which raw material is reduced partially to a conditions, as far as practicable, in which the elements remain interlocked and are in their highly aligned state and from which with the help of binder, wood can be reconsolidated to a desirable size. Reconstituted wood besides properties of parent wood has to a large extent directional strength properties.

In view of the shortage of wood raw materials, research was pursued at FRI to develop a destructured reconstituted wood utilizing bamboo, lops and tops of eucalyptus and poplar which has directional properties akin to solid wood.

Physical and mechanical properties of the reconstituted wood developed from bamboo, lops and tops of eucalyptus and poplar having about 9.0 percent resin and density comparable to teak were compared with teak. In most properties products is comparable or better than teak wood.

Reconstituted wood developed offers a potential for the substitution of solid wood for structural uses. This is a major break-through and offers immense possibilities of utilization of bamboo and branch wood. Further, it is expected to affect economy in the use of woody raw material, as there is negligible wastage in processing. The cost of adhesive involved is in the range (6-10%) generally used in particleboard.

- Shukla, K. S. and Anil Negi (1996). Reconstituted wood from *Eucalyptus hybrid. J. Timb. Dev. Assoc*. (India), 42(1): 5-8.
- Singh, S.P. (1995-96). Utilization of bamboo for structural used and other panel products. *J. Ind. Assoc. Wood Sci.* 26 and 27(1 & 2): 61-64.
- Shukla, K. S. and S.P. Singh (1994*). Composite Wood. Research and Development*, ICFRE – 32.
- Shukla, K. S. (1992). Reconstituted wood from poplar (Populus *deltoides*). *J. Timb. Dev. Assoc*. (India), 23 (1): 17-21.
- Shukla, K. S. and Janardhan Prasad (1988). Reconstituted wood from bamboo for structural uses. *Indian Acad. of Wood Sci*., 19 (1): 19-27.

STRENGTH PROPERTIES OF DIFFERENT TIMBER SPECIES

1. *Pinus radiata*

The species contain very high percentage of sap wood. The core of radiata pine is of low density. Juvenile wood surrounding the pith is commonly 100 to 125 mm in diameter which contains many knots and has inferior properties. From pith to outside, the density as well as properties increases. The central core is liable to twist, warp during drying. Therefore the central core of about 100 to 125 mm diameter may be avoided while using the timber for structural purpose. If the inner core is avoided the timber is suitable for use as door/window shutters, for use in furniture and cabinet and for use in packaging as a group III timber.

2.) Different clones of *Populus deltoides of different* ages

It has been observed that clones S7-C3 (7 yeras0, S7-C4 and G3 (10 years) and 290/84 (12 years) show better strength properties and specific gravity. Several clones meet the minimum requirement of strength not only for use as structural timber but also for door shutters,

furniture items and packing cases/crates. Clone G48 (10 years) has highest growth rate and most of the nail and screw withdrawal resistance values are also higher than other clones among the different clones of *Populus deltoides*.

Further reading

- Shukla, N.K., Khanduri, A.K., Lal, M. (1990) Physical and Mechanical properties of *Populus deltoides* "IC" from Haldwani. Van Vigyan, **28**(1 &2): 26-33.
- Shukla, N.K., Khanduri, A.K., Dangwal, M.N. (2000) Physical and Mechanical properties of different clones of *Populus deltoids*- An assessment. Indian Forester, **126** (1): 31-56.
- Jain V.K., Khanduri, A.K. (2003) Interclonal variation in strength properties of *Populus deltoides* from Haldwani (Uttaranchal). Indian Forester, **129**: 1069-1076
- Kothiyal V., Khanduri, A.K., Jain, V.K. (2005) Wood quality assessment of *Populus deltoids* clones from Haldwani, Uttaranchal. Indian Forester, **131**(1): 14-24.

3 Various Indian timbers

About 450 timber species have been evaluated for their physical and mechanical properties which forms the basis of their classification for various end uses. This data is published in various Indian forest records and as research articles. A list of publications where one can look for the physical and mechanical properties of various Indian timbers are given below.

- Anon. (1923) Mechanical, physical and structural properties of woods grown in India -Tests on small clear specimens. Scheme of operation Project No.1, Govt. Central Press, Delhi.
- Limaye, V.D., Seaman, L.N. (1933) The physical and mechanical properties of woods grown in India. Third Interim Report, Indian Forest Records (Economy Series), 18(10), Manager of Publications, Delhi.
- Negi, G.S., Bhatia, D.N. (1958) Physical and mechanical properties of woods tested at F.R.I., Dehradun Report X, Indian Forest Records (N.S.), Timber Mechanics 1(11), Manager of Publications, Delhi.
- Rajput, S.S., Rawat, N.S., Sharma, S.D. (1988) Suitability indices of Indian timbers-II. Indian Forest Records (N.S.), Timber Mechanics, 5(2), Controller of Publications, Delhi.
- Rawat, B.S. Rawat, N.S. (1960) Physical and mechanical properties of woods tested at the forest Research Institute, Dehradun, Report XI. Indian Forest Records (N.S.), Timber Mechanics 1(2) Manager of Publications, Delhi.
- Seaman, L.N. (1924) Interim Report on the Projects No.1 and 0 by the Section of Timber Testing including the results of the mechanical and physical test on certain of the commoner Indian timbers upto end of 1922. Indian Forest Records, 10(7), Govt. Central Press, Delhi.
- Seaman, L.N., Ranganathan, C.R. (1926) Second Interim report on the work under Project No.1 by the Section of Timber Testing including the results of the mechanical and Physical tests on certain of the commoner Indian timbers upto end

of 1924. Indian Forest Records (Economy Series), 12(3), Central Publications Branch, Calcutta.

- Sekhar, A.C., Bhatnagar, S.S. (1955) Physical and mechanical properties of woods tested at Forest Research Institute, Dehradun. Report IV. Indian Forest Records (N.S.), Timber Mechanics 1(3), Manager of Publications, Delhi.
- Sekhar, A.C., Bhatnagar, S.S. (1957) Physical and mechanical properties of woods tested at Forest Research Institute, Dehradun. Report V. Indian Forest Records (N.S.), Timber Mechanics 1(6), Manager of Publications, Delhi.
- Sekhar, A.C., Bhatia, D.N. (1957) Physical and mechanical properties of woods tested at Forest Research Institute, Dehradun. Report VI. Indian Forest Records (N.S.), Timber Mechanics, 1(7), Manager of Publications, Delhi.
- Sekhar, A.C., Sen, B.R., Bhatnagar, S.S. (1957) Physical and mechanical properties of woods tested at Forest Research Institute, Dehradun. Report VII, Indian Forest Records (N.S.), Timber Mechanics 1(8), Manager of Publications, Delhi.
- Sekhar, A.C., Bhatia, D.N. (1960) Physical and mechanical properties of woods tested at Forest Research Institute, Dehradun. Report VIII, Indian Forest Records (N.S.), Timber Mechanics 1(9), Manager of Publications, Delhi.
- Sekhar, A.C., Rana, R.S. (1957) Physical and mechanical properties of woods tested at Forest Research Institute, Dehradun. Report IX, Indian Forest Records (N.S.), Timber Mechanics 1(10), Manager of Publications, Delhi.
- Sekhar, A.C., Gulati, A.S. (1974) Cleavage properties of some Indian timbers. Indian Forest Buletin No. 269 (Timber Mechanics), Controller of Publications, Delhi.
- Shukla, N.K., Singh, K.R. (1987) Nail and screw holding power of Indian timbers. J. Ind. Acad. Wood Sci., 18(2): 57-68.
- Shukla, N.K., Rajput, S.S., Singh, K.R. (1990) Some studies on cleavage resistance in timber .J. Ind. Acad. Wood Sci., 21(2): 1-8.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of wood tested at the Forest Research Institute. Indian Forest Records, 7(1), T.M., ICFRE-9.
- Shukla, N.K., Singh K.R., Khanduri A.K., Lal, Krishan (1994) Physical and mechanical properties of *Cinnamomum cecidodaphne* and *Dysoxylum hamiltonii* from Arunachal Pradesh. J. Timb. Dev. Assoc. (India), 40(1): 14-26.
- Shukla, N.K., Khanduri, A.K., Singh, K.R. (1994) Physical and mechanical properties of *Diospyros melanonylon* and *Michelia champaca* from U.P. J. Timb. Dev. Assoc. (India), 40(2): 34-36.
- Shukla, N.K., Lal, M. (1994) Physical and mechanical properties of plantation grown *Tectona grandis* (Teak), J. Timb. Dev. Assoc. (India), 40(3): 38-49.
- Shukla, N.K., Guru R.D., Singh K.R., Khanduri, A.K., Lal, M. (1994) A note on physical and mechanical properties of some natural grown and plantation timbers. J. Ind. Acad. wood Sci. 25(1 & 2): 67-77.

- Shukla, N.K., Lal, M. (1995) Physical and mechanical properties of plantation grown *Anthocephalus chinensis* (kadam) from Dehra Dun (U.P.). J. Timb. Dev. Assoc. (India), 41(3): 15-24.
- Shukla, N.K., Singh, K.R. (1995) Physical and mechanical properties of *Populus deltoides* from U.P. and Haryana. J. Timb. Dev. Assoc. (India), 41(2): 14-25.
- Shukla, N.K., Singh, R.S. (1995) Physical and mechanical properties of *khaya senegalensis* (Khaya) from Wada Maharashtra). J. Timb. Dev. Assoc. (India), 41(4): 9-16.
- Shukla, N.K., Rajput, S.S., Lal, M. (1996) Strength variation in P*opulus deltoids*-study on bottom to top variation. J. Ind. Acad. Wood Sci., 27(1&2): 31-38.
- Shukla, N.K., Khanduri, A.K., Singh, K.R., Lal, M. (1996) Physical and mechanical properties of some plantation timbers from Maharashtra. J. Timb. Dev. Assoc. (India), 42(1): 25-42.
- Shukla, N.K., Dhiman, R.C., Rajput, S.S. (1997) Preliminary observations on strength properties of *Paulownia fortunei* – An exotic from China.Van Vigyan, 35(1): 41-45.
- Shukla, N.K., Rajput, S.S. (1997) Physical and mechanical properties of Haryana timbers. Van Vigyan, 35(1): 21-24.
- Khanduri, A.K., Shukla, N.K. (1998). Physical and mechanical properties of *Salix alba*-An assessment. J.Timb. Dev. Assoc. (India), 44(4): 22-30.
- Shukla, N.K., Lal, M. (1999) An assessment of physical and mechanical properties of *Ailanthus excelsa* from Haryana. J. Timb. Dev. Assoc. (India), 45(1&2): 25-32.
- Jain, J.D., Guru, R.D., Singh, R. (2000) Physical and mechanical properties of *Mangifera indica* (mango) and *Syzygium spp.* (jaman) from Dehradun, U.P. The Indian Forester, 126(9): 948-956.
- Khanduri, A.K., Panwar, P.S., Jain, J. D. (2000) An assessment of physical and mechanical properties of plantation grown *Grevillea robusta* (silver oak) and *Terminalia myriocarpa* (hollock). J. Timb. Dev. Assoc. (India), 46(3&4): 19-27.
- Khanduri, A.K., Lal, M., Jain, J. D. (2001) Physical and mechanical properties of *Acacia nilotica* (Babul) from Jabalpur. J. Timb. Dev. Assoc. (India), 47 (1&2): 34-41
- Khanduri, A.K., Jain, J.D. (2002) Strength properties of exotic timber-*Enterolobium timbouva* (Timbouva). J. Timb. Dev. Assoc. (India), 48 (1&2): 5-11.
- Jain, V.K, Uniyal, K.K., Shukla, N.K. (2002) Physical and mechanical properties of *Pinus caribaea* and *Pinus roxburghii* from Dehra Dun (Uttaranchal). J. Timb. Dev. Assoc. (India), 48 (1&2): 42-47.
- Jain,V.K., Khanduri, A.K., Panwar, P.S., Jain, J.D. (2002) Strength properties variation in Radial and Axial direction with a tree of *Cupressus cashmeriana.*Van Vigyan, 40(1-4): 87:98.
- Bhandari, R., Uniyal, K.K., Shukla, N.K. (2003) Physical & mechanical properties of M*elia azederach* from Dehradun (Uttaranchal). Van Vigyan, 41 (1-4): 87-94.

- Negi, Y.S., Lal, M., Jain , V.K. (2004) Strength properties variation of plantation teak with age, tree height and locality. J. Ind. Acad. Wood Sci., (NS), 1(1&2): 40-48.
- Kothiyal, V., Uniyal, K.K. (2005) Strength Properties of *Pinus patula* from Dehradun (Uttaranchal). J. Tim. Dev. Assoc. (India), 51(1&2): 36- 42.
- Kothiyal,V., Negi, Y.S., Uniyal, K.K., Panwar, P.S. (2008) Physical and mechanical properties of plantation grown *Leucaena leucocephala* (Subabul) from Andhra Pradesh and Dehradun. J. Indian Forester, 135(8): 1026-1038.

Plantation Timbers.

Plantation grown timbers have been tested for strength properties from different localities, which are useful for different end uses. The details of various such species studied can be found in the following list. The results thereof will help in better utilization of these species.

Acacia aneura

- Negi,Y.S., Jain J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute, J. Timb. Dev. Assoc. (India), 47 (3 &4): 27- 36.
- Shukla, N.K., Khanduri, A.K., Singh, K.R., Lal, M. (1996) Physical and mechanical properties of some plantation grown timbers from Maharashtra. J. Timb. Dev. Assoc. (India), 92(1): 25-42.

Acacia auriculaeformis

- Negi, Y.S., Jain J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 &4): 27-36.
- Shukla, N.K., Lal, M., Singh, R.S., Khanduri, A.K., (1990) Physical and mechanical properties of ***Acacia auriculaeformis, Fernandoa adenophylla*** and ***Melia aazedarch***. J. Timb. Dev. Assoc. (India), 36(2): 31-45.
- Shukla, N.K., Negi,Y.S. (1994) Physical and mechanical properties of wood tested at Forest Research Institute. Indian Forest Records Report XII, Vol 7(1), ICFRE-9.

Acacia benthami

- Negi,Y.S., Jain J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 &4): 27-36.
- Shukla, N.K., Khanduri, A.K., Lal, M. (1990) Physical and mechanical properties some exotic species, Indian Forester, 116(2): 140-147.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of wood tested at Forest Research Institute, Indian Forest Records Report XII, 7(1), ICFRE-9.

Acacia leucophloea

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute, J. Timb. Dev. Assoc. (India), 47 (3 &4): 27-36.
- Shukla N.K. ,Negi ,Y.S. (1994). Physical and Mechanical properties of wood tested at Forest Research Institute, Indian Forest Records(T.M.), Report XII, Vol 7(1), ICFRE-9.
- Shukla, N.K., Rajput , S.S. (1997) Physical and mechanical properties of Harayana timbers. Van Vigyan, 35(1), 21-29.
- Shukla, N.K., Verma, P.C., Lal, K., Lal, M., Sanyal, S.N. (1990) Physical and mechanical properties of plantation grown ***Acacia leucophloea, Acacia nilotica*** and ***Acacia tortilis*** from Mohindergarh (Harayana). J. Indian Forester, 116(10): 803-811.

Acacia mearnsii

- Gupta V.K., Kukreti, M.C. (1983) A note on physical and mechanical properties of ***Acacia mearnsii*** (Syn. *Acacia mollissima*) from Tamil Nadu. Indian Forester, 109(6): 395-400.
- Negi,Y.S. , Jain J.D.(2001). Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 &4): 27-36.
- Shukla N.K., Negi, Y.S. (1994) Physical and mechanical properties of wood tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.

Acacia melanoxylon **(Australian black wood)**

- Negi, Y.S., Jain J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 &4): 27-36.
- Sanayal, S.N., Saxena, R.C. (1981) Physical and mechanical properties of some Tamil Nadu Timbers. N.B.O. Journal 26(2): 33-42.
- Sekhar A.C**.**, Kukreti, M.C. (1977) A note on physical and mechanical properties of ***Acacia melanoxylon*** (Australian black wood) from Darrang Division Tezpur, Assam. Indian Forester, 103(1): 33-40.
- Sekhar, A.C**.**, Kukreti, M.C. (1979) A note on physical and mechanical properties of ***Acacia melanoxylon*** (Australian black wood) from Kodai Kanal, Tamil Nadu, Indian Forester, 105(9): 677-684.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of wood tested at Forest Research Institute, Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.
- Shukla, N.K., Verma, P.C., Aswal, S.S. (1987) Physical and mechanical properties of ***Acacia melanoxylon*** and ***Castanopsis indica.*** J. Timb. Dev. Assoc. (India), 33(3): 9-17.

Acacia nilotica

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute, J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at the Forest Research Institute, Indian Forest Records (T.M.), Report XII, Vol7(1), ICFRE-9.
- Shukla, N.K., Rajput, S.S. (1997) Physical, and mechanical properties of Haryana timbers, Van Vigyan, 35(1): 21-29.
- Shukla, N.K., Verma, P.C., lal, K., Lal M., Sanyal, S.N. (1990) Physical and mechanical of plantation grown ***Acacia leucoploea, Acacia nilotica and Acacia tortilis*** from Mohindergarh (Haryana). J Indian Forester, 116(10): 803-811.
- Tewari, M.C., Rajput, S.S. (1987) ***Acacia nilotica*** –Utilisation aspects. J. Timb. Dev. Assoc. (Indai), 33(2): 28-32.

Acacia tortilis

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4):27-36.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute, Indian Forest Records (T.M.), Report XII, Vol. 7(1), ICFRE-9.
- Shukla, N.K., Rajput, S.S. (1997) Physical and mechanical properties of Haryana timbers, Van Vigyan, 35(1): 21-29.
- Shukla, N.K., Sangal, S.K. (1986) Preliminary studies on strength properties of some exotic timbers, Indian Forester, 112(5):459-465.
- Shukla N.K., Verma, P.C., Lal, K., lal M., Sanyal, S.N. (1990) Physical and mechanical properties of plantation grown ***Acacia leuphloea, Acacia nilotica*** and ***Acacia tortilis*** from Mohindergarh (Haryana). J. Indian Forester, 116(10): 803-811.

Agathis robusta

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute, J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Sekhar, A.C., Shukla, N.K., Gandhi, B.L. (1974) A note on the strength properties of some exotic species, Van Vigyan, 12(1-4): 1-7.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute, Indian Forest Records (T.M.), Report XII, Vol. 7 (1), ICFRE-9.

Ailanthus excelsa

1. Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute, J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.

Anthocephalus chinensis (Kadam)

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute, J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Lal M., (1995). Physical and mechanical properties plantation grown ***Anthocephalus chinensis*** (Kadam) from Dehradun (U.P.). J. Timb. Dev. Assoc. (India), 1(2): 15-24.
- Shukla, N.K., Rajput, S.S., Lal M. (1994) A note on the axial and radial variation of strength of ***Anthocephalus chinensis*** (Kadam), J. Ind. Acad. Wood Sci., 25(1&2): 57-62.

Araucaria bidwillii

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Sekhar, A.C., Shukla, N.K., Gandhi, B.L. (1974) A note on the strength properties of some exotic species. Van Vigyan, 12 (1-4): 1-7.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.

Araucaria cunninghami

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. *J. Timb. Dev. Assoc*. (India), 47(3&4): 27-36.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Sangal, S.K. (1986) Preliminary studies on strength properties of some exotic timbers. *Indian Forester*, 112(5): 459-465.

Azadirachta indica

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Rajput, S.S. (1997) Physical and mechanical properties of Haryana timbers. Van Vigyan, 35(1): 21-29.

Casuarina cunninghamiana

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Khanduri, A.K., Lal, M. (1990).Physical and mechanical properties of some exotic species, Indian Forester, 116(2):140-147.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute, Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.

Casuarina equisetofolia **(Australian beefwood)**

- Limaye, V.D., Seaman, L.N. (1933) The Physical and mechanical properties of woods grown in India, Third Interim report on project 1. Indian Forest Records (Economy series), Vol. XVIII part X, Manager of Publication Delhi.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.

Casuarina glauca

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Khanduri, A.K., Singh K.R., Lal, M. (1996). Physical and mechanical properties of some plantation grown timbers from Maharashtra. J. Timb. Dev. Assoc. (India), 92(1): 25-42.

Cinnamomum Camphora **(Cinnamon)**

- Gupta, V.K., Negi,Y.S. (1982) A note on physical and mechanical properties of ***Cinnamomum Camphora*** (Cinnamon) from new forest, Dehradun (U.P.), Indian Forester, 108(6): 438-443.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Guru, R.D., Singh R.S., Khanduri, A.K., Singh, K.R., Lal, M. (1994). A note on physical and mechanical properties of some natural grown and plantation timbers. J Ind. Acad. Wood Sci, 25(1&2): 67-77.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute, Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.

Cryptomeria japonica **(Suji) (dhupi)**

- Limaye, V.D., Seaman, L.N. (1933) The physical and mechanical properties of woods grown in India, Third interim report on project 1. Indian Forest Records (Economy series) Vol. XVIII part X, Manager of Publication Delhi.
- Seaman, L.N., (1924) Interim reports on the work under projects No.1 and No.0 by the section of timber testing including the results of the mechanical and physical tests on certain of the commoner Indian timbers upto end of 1922,Indian Forest Records, Vol X, Part VII, Government Central Press, Delhi.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute, J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Sekhar, A.C., Bhatnagar, S.S. (1955) Physical and mechanical properties of wood tested at Forest Research Institute. Indian Forest Records (N.S.), Report IV, Timber Mechanics, Vol. 1(3). Manager of Publications, Delhi.
- Sekhar, A.C., Bhatnagar, S.S. (1955) Physical and mechanical properties of wood tested at Forest Research Instuute, Indian Forester, 81(7): 420-423.
- Shukla, N.K., Lal M. (1985) Physical and mechanical properties of ***Cryptomeria japonica*** (Suji) from Kalimpong division (West Bengal). J Timb. Dev. Assoc. (India), 32(1): 11-18.
- Sekhar, A.C., Rajput, S.S. (1970) Comparative studies on the physical and mechanical properties of conifers in India, J. Ind. Acad. Wood Sci., 1(2): 109-118.
- Shukla, N.K., Negi, Y.S.(1994) Physical and mechanical properties of woods tested at Forest Research Institute, Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.

Cupressus cashmeriana

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute, *J.Timb. Dev.Assoc.* (India), 47(3 & 4):27-36.
- Shukla, N.K., Khanduri A.K., Singh K.R., Lal, M. (1996) Physical and mechanical properties of some plantation grown timbers from Maharashtra. *Timb.Dev.Assoc.* (India),92(1):25-42.
- Shukla, N.K., Negi, Y.S. (1994) Physical and Mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Sharma, R.R. (1981) Physical and mechanical properties of ***Cupressus Cashmeriana*** from Dehra Dun, Van Vigyan, 19(2):54-33.

Cupressus lusitanica

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J.Timb. Dev.Assoc. (India), 47(3 & 4):27-36.

- Shukla, N.K., Negi, Y.S.(1994) Physical and mechanical properties of woods tested at the Forest Research Institute, Indian Forest Records (T.M.),Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Sangal, S.K. (1986) Preliminary studies on strength properties of some exotic timbers, Indian Forester, 112(5): 459-465.

Eriobotrya japonica

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Shukla, N.K., Khanduri, A.K., Lal, M. (1990) Physical and mechanical properties of some exotic species. Indian Forester, 116(2):140-147.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute, Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.

Eucalyptus camaldulensis

- Jain, V.K., Arora, K.L. (1995) Moisture content, specific gravity and shrinkage variation with radial and axial position within a tree of ***Eucalyptus camaldulensis.*** *J. Timb. Dev. Assoc.* (India), 41(1):22-37.
- Kamala, B.S., Kumar, P., Sudheendra, R. (1995-96) Assessment of strength properties of 10 year old ***Eucalyptus camaldulensis.*** J. Ind. Acad. Wood Sci., 26 &27 (1&2):71-75.
- Kumar, P., Pandey, C.N., Kamala, B.S., Jain, J.C. (1981) Studies of the physical and mechanical properties of *Eucalyptus camaldulensis* (Eucalyptus) from Karnataka. J. Ind. Acad. Wood Sci., 12(2):49-54.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Rajput, S.S., (1983) Physical and mechanical properties of Eucalyptus grown in India. J Indian Forester, 109(12):933-943.
- Shukla, N.K., Rajput, S.S., Lal, M. (1989) Some studies on variation of strength along tree height in ***Eucalyptus.*** J, Ind, Acad. Wood. Sci., 20(1):31-36.

Eucalyptus citriordora

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4):27-36.

- Shukla, N.K., Gandhi, B.L., Sangal, S.K. (1981) A note on the physical and mechanical properties of some ***Eucalyptus*** species from Tamil Nadu. J. Timb. Dev. Assoc. (India) 27:26-29.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. *Indian Forest Records* (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Rajput, S.S. (1983) Physical and mechanical properties of Eucalyptus grown in India. J Indian Forester, 109:933-943.

Eucalyptus eugeniodes

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Sanyal, S.N., Saxena, R.C. (1981) Physical and mechanical properties of some Tamil Nadu Timbers. N.B.O. Journal, 26(2):33-42.
- Sekhar, A.C., Sen, S.R., Bhatnagar, S.S. (1957) Physical and mechanical properties of woods tested at Forest Research Institute, D.Dun. Indian Forest Records (N.S.), Report VII, Timber Mechanics, Vol. 1(8) Manager of Publications, Delhi.
- Shukla, N.K., Gandhi, B.L., Sangal, S.K. (1981) A note on the physical and mechanical properties of some ***Eucalyptus*** species from Tamil Nadu. J. Timb. Dev. Assoc. (India) 27:26-29.
- Shukla, N.K., Negi, Y.S.(1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Rajput, S.S., (1983) Physical and mechanical properties of Eucalyptus grown in India. J Indian Forester 109(12):933-943.

***Eucalyptus globulus (*blue gum)**

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Seaman, L.N., (1924) Interim report on the work under projects No.1 and No.0 by the section of timber testing including the results of the mechanical and physical tests on certain of the commoner Indian timbers up to end of 1922. Indian Forest Records, Vol X, part VII, Government Central Press, Delhi.
- Shukla, N.K., Gandhi, B.L., Sangal, S.K. (1981) A note on the physical and mechanical properties of some ***Eucalyptus*** species from Tamil Nadu. J. Timb. Dev. Assoc. (India) 27:26-29.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.

- Shukla, N.K., Rajput, S.S. (1983) Physical and mechanical properties of Eucalyptus grown in India. J Indian Forester 109(12):933-943.

Eucalyptus hybrid

- Jain, J.C. (1969) A note on Eucalyptus hrbrid as timber. *Indian Forester*, 95(1):29-32.
- Kothiyal, V., Shukla, S.R., Sudheendra, R., Kamala, B.S., Rao, R.V. (1998) Assessment of wood quality of ***Eucalyptus*** hybrid. J. of Trop. Forest products, 4(2):166-173.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Rajput, S.S., Shukla, N.K., Lal, M., Khanduri, A.K., (1992) Physical and mechanical properties of ***Eucalyptus*** hybrid from Punjab and Haryana. J. Timb. Dev. Assoc. (India), 37(2): 31-38.
- Sanyal, S.N., Saxena, R.C. (1981) Physical and mechanical properties of some Tamil Nadu Timbers, N.B.O. Journal, 26(2): 33-42.
- Sekhar, A.C., Rajput, S.S., Rawat, N.S. (1968) A note on the Physical and mechanical properties of ***Eucalyptus*** hybrid (Mysore gum). Van Vigyan, 6(1&2): 3-11.
- Shukla, N.K., Gandhi, B.L., Sangal, S.K. (1981) A note on the physical and mechanical properties of some ***Eucalyptus*** species from Tamil Nadu. J. Timb. Dev. Assoc. (India) 27: 26-29.
- Shukla, N.K., Khanduri, A.K., Singh K.R., Lal, M. (1996) Physical and mechanical properties of some plantation grown timbers from Maharashtra. J. Timb. Dev. Assoc. (India), 42(1): 25-42.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Rajput, S.S. (1983) Physical and mechanical properties of Eucalyptus grown in India. J Indian Forester 109(12): 933-943.
- Shukla, N.K., Rajput, S.S., Lal, M. (1988) Some studies on variation of strength properties from pith to periphery in ***Eucalyptus*** hybrid. J. Ind. Acad. Wood. Sci, 19 (1): 39-46.
- Shukla, N.K., Rajput, S.S., Lal, M., Khnaduri, A.K. (1991) Studies on effect of age on strength of ***Eucalyptus*** hrbrid. J. Timb. Dev. Assoc. (India), 37(2): 19-24.
- Shukla, N.K., Rajput, S.S., Lal, M., Khnaduri, A.K. (1994) Studies on the variation of strength along the tree height in ***Eucalyptus*** hybrid from Punjab. J Timb. Dev. Assoc. (India), 40(1):27-31.

Eucalyptus pilularis

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Gandhi, B.L., Sangal, S.K. (1981)A note on the physical and mechanical properties of some ***Eucalyptus*** species from Tamil Nadu. J. Timb. Dev. Assoc. (India) 27: 26-29.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Rajput, S.S., (1983) Physical and mechanical properties of Eucalyptus grown in India. J Indian Forester 109(12): 933-943.

Eucalyptus propinqua

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Gandhi, B.L., Sangal, S.K. (1981) A note on the physical and mechanical properties of some ***Eucalyptus*** species from Tamil Nadu. J. Timb. Dev. Assoc. (India), 27: 26-29.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Rajput, S.S., (1983) Physical and mechanical properties of Eucalyptus grown in India. J Indian Forester, 109(12): 933-943.

Eucalyptus saligna

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Rajput, S.S., (1983) Physical and mechanical properties of Eucalyptus grown in India. J Indian Forester, 109(12): 933-943.

Eucalyptus tereticornis

- Benny, A.G., Bhat, K.M. (1994) Strength properties of ***Eucalyptus tereticornis*** grown in wet and dry localities of Kerala. J. Ind. Acad. Wood Sci. (India), 25(1-2): 47-50.
- Bhat, K.M., Thulasidas, P.K. (1997) Physical and mechanical properties of ***Eucalyptus grandis*** and ***E.tereticornis*** grown in Kerala. Indian Forester, 123: 297-302.

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. *J. Timb. Dev. Assoc.* (India), 47(3&4): 27-36.
- Shukla, N.K., Gandhi, B.L., Sangal, S.K. (1981) A note on the physical and mechanical properties of some ***Eucalyptus*** species from Tamil Nadu. J. Timb. Dev. Assoc. (India) 27: 26-29.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Rajput, S.S., (1983) Physical and mechanical properties of Eucalyptus grown in India. J Indian Forester, 109(12): 933-943.
- Shukla, N.K., Rajput, S.S., (1997) Physical and mechanical properties of Haryana timbers. Van Vigyan, 35(1): 21-29.
- Shukla, N.K., Rajput, S.S., Lal, M. (1989) Some studies on variation of strength along tree height in ***Eucalyptus.*** J, Ind, Acad. Wood. Sci., 20(1): 31-36.

Fernandoa adenophylla

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Lal, M., Singh, R.S., Khanduri, A.K. (1990) Physical and mechanical properties of ***Acacia auriculaeformis, Fernandoa adenophylla and Melia azedarch,*** J. Timb. Dev. Assoc. (India), 36(2): 31-45.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.

Fraxinus uhdei

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. *J. Timb. Dev. Assoc.* (India), 47(3 & 4):27-36.
- Sekhar, A.C., Shukla, N.K., Gandhi, B.L. (1974) A note on the strength properties of some exotic species. Van Vigyan, 12 (1-4): 1-7.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.
- Shukla, N.K., Sangal, S.K. (1980) A Preliminary note on the physical and mechanical properties of ***Fraxinus uhdei*** grown at new forest, Dehradun, (U.P.). J. Indian Forester 106(9): 641-643.

Gleditsia triacantha

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Sekhar, A.C., Shukla, N.K., Gandhi, B.L. (1974) A note on the strength properties of some exotic species. Van Vigyan, 12 (1-4): 1-7.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.
- Shukla,N.K., Rawat, N.S. (1972) Some preliminary investigations on strength properties of plantation grown timbers symposium on man made forestry in India, June 8 to 10, 1972, pp32-36.

Gmelina arborea (gumhar)

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute, J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Limaye, V.D., Seaman, L.N. (1933) The physical and mechanical properties of woods grown in India, Third Interim report on project 1. Indian Forest Records (Economy series) Vol XVIII part X, Manager of Publication Delhi.

Grewia optiva

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Guru, R.D., Khnaduri, A.K., Singh, R.S. (1990) Physical and mechanical properties of *Quercus dilatata* and *Grewia optiva.* J. Timb. Dev. Assoc. (India), 36(4): 15- 26.
- Shukla, N.K. Rajput, S.S. (1993) Physical and mechanical properties of timber from Himachal Pradesh. Van Vigyan, 31: 68-75.

Grevillia robusta (Silver Oak)

- Kamala, B.S., Kothiyal, V., Sharma, S.K., (2000) Assessment of wood quality of ***Grevillia robusta*** from Bangalore, Karnataka. Journal Indian Forester, 126(6): 625-633.
- Khanduri, A.K., Panwar, P.S. and Jain, J.D. (2000) An Assessment of physical and mechanical properties of plantation grown ***Grevillia robusta*** (Silver oak) and ***Terminalia myriocarpa*** (hillock). J. Timb. Dev. Assoc. (India), 46(3&4): 19-27.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Sekhar, A.C., Rajput, S.S. (1964) Physical and mechanical properties of ***Grevillia robusta*** (Silver oak). J. Soc. Ind. For., 4(4): 125-129.

- Shyamasundar, K., Jagadeesh, H.N. (1994) Evaluation of properties of plantation grown ***Grevillia robusta*** (Silver Oak) for structural uses. J. Ind. Acad. Wood Sci, 25(1-2): 33-40.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.

Hevea brasiliensis **(rubber wood)**

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Sanyal, S.N., Dangwal, M.N. (1983) A short note on the physical and mechanical properties of *Hevea brasiliensis* in Kiln-dry condition from Kottayam, Kerala. J. Timb. Dev. Assoc. (India), 29(1):35-38.
- Shukla, N.K., Lal, M. (1985) Physical and mechanical properties of ***Hevea brasiliensis*** (rubber wood) from Kerala. J. Timb. Dev. Assoc. (India), 31(2):27-34.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.

Hopea Shinkeng

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.
- Shukla, N.K., Rawat, N.S. (1972) Some preliminary investigations on strength properties of plantation grown timbers, symposium on man made forestry in India, June 8 to 10, 1972, pp32-36.

Juniperus phoenicea

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. *J. Timb. Dev. Assoc.* (India), 47(3&4): 27-36.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.

- Shukla, N.K., Rawat, N.S. (1972) Some preliminary investigations on strength properties of plantation grown timbers, symposium on man made forestry in India, June 8 to 10, 1972, pp32-36.

Khaya senegalensis (Khaya)

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Sangal, S.K. (1986) Preliminary studies on strength properties of some exotic timbers. Indian Forester, 112(5): 459-465.
- Shukla, N.K., Singh, R.S. (1995) Physical and mechanical properties of ***Khaya senegalensis*** (Khaya) from Wada, Maharathstra. J. Timb. Dev. Assoc (India), 41(4): 9-16.

Leucaena leucocephala

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Shukla, N.K. (1982) A preliminary note on strength properties of ***Leucaena leucocephala*** from Lalkua, Tarai Bhabar forest Division (U.P.). Indian Forester, 108(3): 226-229.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Sangal, S.K. (1986) Preliminary studies on strength properties of some exotic timbers. Indian Forester, 112(5): 459-465.

Melia azedarch (Persian lilac)

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Rawat, B.S., Rawat, N.S. (1960) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (Timber Mechanics), Report XI, Vol 1(12).
- Shukla, N.K., Lal, M., Singh, R.S., Khanduri, A.K. (1990) Physical and mechanical properties of ***Acacia auriculaeformis, Fernandoa adenophylla*** and ***Melia azedarch.*** J. Timb. Dev. Assoc. (India), 36(2): 31-45.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Rajput, S.S. (1997) Physical and mechanical properties of Haryana timbers, Van Vigyan, 35(1): 21-29.

Melia composita (Malabar neem)

- Kothiyal, V., Kamala, B.S., Sudheendra, R. (1998) Assessment of strength properties of Branch wood of ***Melia composita*** (Malabar neem) from Karnataka. The proceedings of national seminar "*Plantation timbers and bamboo*" held on 23-24 July 1998 at IPIRTI, Bangalore.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.
- Shukla, N.K., Rawat, N.S.(1972) Some preliminary investigations on strength properties of plantation grown timbers, symposium on man made forestry in India, June 8 to 10, 1972, pp32-36.

Millingtonia hortensis

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. *J. Timb. Dev. Assoc*. (India), 47(3 & 4):27-36.
- Sekhar, A.C., Shukla, N.K., Gandhi, B.L. (1974) A note on the strength properties of some exotic species. Van Vigyan, 12(1-4): 1-7.
- Shukla, N.K., Khanduri, A.K., Lal, K., Lal, M., Singh, R.S., (1990) Physical and mechanical properties of some exotic species. Indian Forster, 116(2): 140-147.
- Shukla, N.K., Negi, Y.S.(1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.

Paulownia fortunei

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Negi, Y.S., Shukla, N.K. (1999) Some studies on the strength properties of ***Paulownia fortunei.*** J. Timb. Dev. Assoc. (India), 45(3-4): 28-34.

Pinus caribaea

- Jain, V.K., Uniyal, K.K., Shukla, N.K., (2002) Physical and mechanical properties of ***Pinus caribaea*** and ***Pinus roxburghii*** from Dehradun (Uttaranchal). J. Timb. Dev. Assoc. (India), 48(1-2):42-47.

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Shukla, N.K.., Khanduri, A.K., Singh, K.R., Lal, M. (1996) Physical and mechanical properties of some plantation grown timbers from Maharashtra. Timb. Dev. Assoc. (India), 92(1): 25-42.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.
- Shukla, N.K., Sangal, S.K. (1986) Preliminary studies on strength properties of some exotic timbers. Indian Forester, 112(5): 459-465.

Pinus Kesiya (Khasi pine)

- Bali, B.I., Singh, K.R., Lal, M. (1984) A note on the physical and mechanical properties of ***Pinus Kesiya*** (Khasi pine) from phek Division, Nagaland. J. Timb. Dev. Assoc. (India), 30(4): 10-14.
- Bali, B.I., Singh, K.R., Sharma, R.P. (1985) A note on the physical and mechanical properties of ***Pinus Kesiya*** (Plantation grown) khasi pine from Orissa. J. Timb. Dev. Assoc. (India), 31(4): 13-19.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.

Pinus patula

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Sekhar, A.C., Rajput, S.S. (1970) Comparative studies on the physical and mechanical properties of conifers in India. J. Ind.Acad. Wood Sci, 1(2): 109-118.
- Shukla, N.K., Rawat, N.S.(1972) Some preliminary investigations on strength properties of plantation grown timbers, symposium on man made forestry in India, June 8 to 10, 1972, pp32-36.
- Sekhar, A.C., Shukla, N.K., Gandhi, B.L. (1974) A note on the strength properties of some exotic species. Van Vigyan, 12 (1-4): 1-7.
- Shukla, N.K., Negi, Y.S. (1994) Physical and Mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Sangal, S.K. (1986) Preliminary studies on strength properties of some exotic timbers. Indian Forester, 112(5): 459-465.

***Pinus roxburghii* (Chir)**

- Jain, V.K., Uniyal, K.K., Shukla, N.K. (2002) Physical and mechanical properties of *Pinus caribaea* and *Pinus roxburghii* from Dehradun (Uttaranchal). J. Timb. Dev. Assoc. (India), 48(1-2): 42-47.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Sekhar, A.C., Rajput, S.S. (1970) Comparative studies on the physical and mechanical properties of conifers in India. J. Ind. Acad. Wood Sci*,* 1(2): 109-118.
- Shukla, N.K., Khanduri, A.K., Singh, K.R., Lal, M. (1996) Physical and mechanical properties of some plantation grown timbers from Maharashtra. J. Timb. Dev. Assoc. (India), 92(1): 25-42.
- Rajput, S.S., Gupta, V.K. (1980) A note on the effect of pinholes on strength of timber. Indian Forester, 106(5): 372-376.
- Rajput, S.S., Gupta, V.K., Lohani, R.C. (1990) A study on the influence of pin holes on strength of *Pinus roxburghii*. J. Timb. Dev. Assoc. (India), 36(3): 37-42.
- Shukla, N.K., Rajput, S.S. (1993) Physical and mechanical properties of timber from Himachal Pradesh. Van Vigyan, 31: 68-75.

Populus deltoides

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Shukla, K.S., Bhatnagar, R.C.(1989) A note on the effect of compression on strength properties of ***Populus deltoids*** and ***populus ciliate.*** J. Timb. Dev. Assoc (India), 35(1): 17-20.
- Shukla, N.K., Khanduri, A.K., Dangwal, M.N. (2000) Physical and mechanical properties of different clones of ***Populus deltoids***-an assessment. Indian Forester, 126(1): 31-56.
- Shukla, N.K., Khanduri, A.K., Lal, M.(1990) Physical and mechanical properties of ***Populus deltoids*** 'IC' from Haldwani (U.P.).Van Vigyan, 28(1-2): 26-33.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.
- Shukla, N.K., Rajput, S.S. (1997) Physical and mechanical properties of Haryana timbers. *Van Vigyan*, 35(1): 21-29.
- Shukla, N.K., Rajput, S.S., Singh, K.R.(1991) A note on variation of density and strength properties from pith to periphery in ***Populus deltoids*.** J. Indian Acad. Wood Sci*.,* 22(1): 1-6.
- Shukla, N.K., Sangal, S.K. (1986) Preliminary studies on strength properties of some exotic timbers. Indian Forester*,* 112(5): 459-465.

- Shukla, N.K., Singh, K.R. (1995) Physical and mechanical properties of ***Populus deltoids*** from U.P. and Haryana. J Timb. Dev. Assoc. (India), 41(2): 14-25.

Prosopis cineraria

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Physical and mechanical properties of Plantation-grown ***Prosopis cineraria , Prosopis juliflora, and Tamarix articulata*** from Mahendergarh (Haryana). J. Timb. Dev. Assoc. (India), 35(4): 37-48.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.
- Shukla, N.K., Rajput, S.S. (1997) Physical and mechanical properties of Haryana timbers. Van Vigyan, 35(1): 21-29.

Prosopis Juliflora

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Sanyal, S.N., Saxena, R.C. (1980) Physical and mechanical properties of some Maharasthra Timbers. N.B.O. Journal, 25(2): 1-5.
- Sanyal, S.N., Saxena, R.C. (1982) Physical and mechanical properties of some Maharasthra Timbers. N.B.O. Journal, 27(2): 1-6.
- Sanyal, S.N., Saxena, R.C. (1982) Physical and mechanical properties of ***Prosopis juliflora.*** Indian Forester, 86(8): 485-87.
- Shukla, N.K., Khanduri, A.K., Lal, M. (1990) Physical and mechanical properties of some exotic species. Indian Forester, 116(2):140-147.
- Shukla, N.K., Khanduri, A.K., Lal, K., Lal, M. (1990) Physical and mechanical properties of Plantation-grown ***Prosopis cineraria, Prosopis juliflora, and Tamarix articulata*** from Mahendergarh (Haryana). J. Timb. Dev. Assoc. (India) 35(4): 37-48.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.
- Shukla, N.K., Rajput, S.S. (1997) Physical and mechanical properties of Haryana timbers. Van Vigyan, 35(1):21-29.

Quercus dilatata **(Indian Oak)**

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.

- Shukla, N.K., Guru, R.D., Khanduri, A.K., Singh, K.R. (1990) Physical and mechanical properties of ***Quercus dilatata*** and ***Grewia optiva*****.** J. Timb. Dev. Assoc. (India), 36(3): 15- 26.
- Shukla, N.K., Rajput, S.S. (1993) Physical and mechanical properties of timber from Himachal Prdaesh. Van Vigyan, 31: 68-75.

Quercus serrata

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Shukla, N.K., Guru, R.D., Singh, R.S., Khanduri, A.K., Lal, M. (1994) A note on physical and mechanical properties of some natural grown and plantation timbers. J. Ind. Acad. Wood Sci, 25 (1&2): 67-77.

Robina pseud-acacia **(Black locust)**

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol 7(1), ICFRE-9.
- Shukla, N.K., Singh, K.R., Singh, R.S.,(1986) A note on the physical and mechanical properties of ***Robina pseud-acacia*** **, Fraxinus** spp. and **Ailanthus** spp. from Srinagar (J and K). Indian Forester, 112(2): 139-151.

Salix alba

- Khanduri, A.K., Shukla, N.K. (1998) Physical and mechanical properties of ***Salix alba***-assessment. J. Timb. Dev. Assoc. (India), 44(4): 22-30.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.

Tamarix articulata Syn.T.aphylla **(Frash)**

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute, J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Shukla, N.K., Khanduri, A.K., Lal, M., Lal, K., Sanyal, S.N. (1989) Physical and mechanical properties of Plantation-grown ***Prosopis cineraria, Prosopis juliflora, and Tamarix articulata*** from Mahendergarh (Haryana). J. Timb. Dev. Assoc. (India) 35(4): 37-48.

- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. *Indian Forest Records* (T.M.), Report XII, Vol 7(1), ICFRE-9.
- Shukla, N.K., Rajput, S.S. (1997) Physical and mechanical properties of Haryana timbers. Van Vigyan, 35(1): 21-29.

Tecomella undulata

- Kamala, B.S., Kumar, P., Sharma, S.K., Shukla, S.R., Sudheendra, R., Rao, R.V. (1999) Evaluation of wood quality of ***Tecomella undulata*** grown under a social forestry programme. Journal of Tropical Forest Products, 5(2):204-208.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3&4): 27-36.
- Shukla, N.K., Guru, R.D., Singh, R.S., Khanduri, A.K., Lal, M. (1994) A note on Physical and mechanical properties of some natural grown and plantation timbers. *J. Ind. Acad., Wood Sci,* 25 (1&2): 67-77.

***Tectona grandis* (Teak)**

- Bali, B.I., Singh, K.R. (1983) A note on the physical and mechanical properties of ***Tectona grandis* (Teak)** from Gorakhpur Division Uttar Pradesh. *J*. Timb. Dev. Assoc. (India), 29 (1): 25-34.
- Limaye, V.D., Seaman, L.N. (1933) The Physical and mechanical properties of woods grown in India, Third Interim report on project. 1. Indian Forest Records (Economy series) Vol XVIII part X, Manager of Publication Delhi.
- Nair, K.R., Mukerji, H.K. (1960) A statical study of the variability of physical and mechanical properties of ***Tectona grandis*** (Teak) grown at different localities of India and Burma and the effects of the variability on the choice of the sampling plan. Indian Forest Records, N.S. (statistical) ,Vol 1(1),1957.
- Negi, G.S., Bhatia, D.N. (1958) Physical and mechanical properties of woods Tested at FRI. Indian Forest Record (N.S.), Report X, Timber Mechanics, Vol1 (11). Manager of Publications, Delhi.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. *J. Timb. Dev. Assoc*. (India), 47(3 & 4):27-36.
- Pearson, R.S. (1911) Note on the relative strength of natural and plantation grown teak in Burma. Forest Bulletin no.3.
- Pearson, R.S. (1913) A further note on the relative strength of natural and plantation grown teak in Burma. Forest Bulletin no.14.
- Rajput, S.S., Shukla, N.K., Lal, M. (1991) Some studies on the variation of strength properties of ***Tectona grandis*** from Mizoram. J. Timb. Dev. Assoc. (India), 37(2): 33-38.

- Rajput, S.S., Shukla, N.K., Sharma, R.R (1983) Some studies on the comparison of strength of sapwood and heartwood of teak and kokko. J. Timber Dev, Assoc. (India), 29(4): 24-30.
- Rawat, B.S. Rana, G.S.(1962) A note on Teak from Andamans. J. of the society of Indian Foresters ,Vol. 2(1): 26-28.
- Sanyal, S.N., Bali, B.I. Singh, K.R., Sharma, B.D. (1987) A note on Physical and mechanical properties of plantation grown ***Tectona grandis*** (Teak) from Tanjavur district,Tamil Nadu. J. Timb. Dev. Assoc .(India) ,33(4): 15-22.
- Sanyal, S.N., Saxena, R.C. (1980) Physical and mechanical properties of some Maharasthra Timbers. N.B.O. Journal, 25(2): 1-5.
- Sanyal, S.N., Saxena, R.C. (1980) Physical and mechanical properties of some Maharasthra Timbers. N.B.O. Journal, 27(2): 1-6.
- Seaman, L.N., Ranganathan, C.R.(1926) Second Interim Report on the work under Project No.1 by the section of timber testing including the results of the mechanical and physical tests on certain of the common Indian Timber up to end of 1924. Indian Forest Records (Economy series), Vol. 12(3).
- Sekhar, A.C., Bhartri, R.K., Rawat, M.S. (1960) Comparative studies on natural and plantation teak. Indian Forest Bulletin No.227 (New Series).
- Sekhar, A.C., Rana, R.S. (1957) Physical and mechanical properties of woods tested at Forest Research Institute, D.Dun. Indian Forest Records (N.S.), Report IX, Timber Mechanics Vol. 1(10).
- Sekhar, A.C., Rawat, B.S. (1966) Physical and mechanical properties of teak from different localities in India and Neighbouring areas. Indian Forest Records (Timber Mechanics), Vol 1(13).
- Shukla, N.K., Lal M., (1994) Physical and mechanical properties of plantation grown ***Tectona grandis*** (Teak) from Mizoram. J Timb. Dev. Asso . (India) ,40(3): 38-49.

Terminalia myriocarpa **(Hollock)**

- Khanduri, A.K., Panwar, P.S. and Jain, J.D. (2000) An Assessment of physical and mechanical properties of plantation grown ***Grevillia robusta*** (Silver oak) and ***Terminalia myriocarpa*** (hillock). J. Timb. Dev. Assoc. (India), 46(3&4), 19-27.
- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Sanyal, S.N. and Gaharwar, K.S. (1981) Physical and mechanical properties of some Assam timbers. Indian Forest Records (Timber Mechanics), N.S. Vol 4(1).
- Sekhar, A.C., Bhatnagar, S.S. (1955) Physical and mechanical properties of wood tested at Forest Research Institute. Indian Forest Records (N.S.), Report IV, Timber Mechanics, Vol 1(3).Manager of Publications, Delhi.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.

Thuja orientalis

- Negi, Y.S., Jain, J.D. (2001) Physical and mechanical properties of plantation grown timbers tested at Forest Research Institute. J. Timb. Dev. Assoc. (India), 47(3 & 4):27-36.
- Shukla, N.K., Khanduri, A.K., Lal, M. (1990) Physical and mechanical properties of some exotic species. Indian Forester, 116(2): 140-147.
- Shukla, N.K., Negi, Y.S. (1994) Physical and mechanical properties of woods tested at Forest Research Institute. Indian Forest Records (T.M.), Report XII, Vol7 (1), ICFRE-9.

NONDESTRUCTIVE TESTING

Wood is a biological natural product widely used for different constructional purposes on the basis of their strength or quality, which is affected by the presence of natural as well as biological defects. Besides these physical and mechanical properties of wood not only vary species to species but also vary within species due to various wood parameters. In the present scenario, scarcity and high cost of timber has drawn attention of the users to select a good quality timber for a specific application. It can be decided on the basis of different properties of timber and timber products. Therefore, in recent years, considerable interest has developed in determining the strength properties of timber through non-destructive techniques, as these are less time consuming, economical in comparison to destructive test methods and also may be applied in situ for quality assessment which are based on different concepts. Among several NDT methods, vibration testing technique (ultrasonic) is employed to evaluate the elastic properties, quality assessment and defect detection of timber. Research work in this field was carried out at FRI to assess quality of timber and defect detection especially hollowness or multiple cracks at the centre of timber disc. An ultrasonic testing technique has been able to successfully identify artificially created defects (hollowness or multiple cracks) at the centre of the timber disc (*Cedrus deodara, Tectona grandis* and *Dalbergia sissoo*). This technique may also be used for defect detection in log in the field, as equipment is easy to transport at the place of testing site.

WOOD QUALITY ASSESSMENT USING NEAR INFRARED SPECTROSCOPY

Near infrared (NIR) spectroscopy in terms spectra of electromagnetic waves ranging from 800 to 2500 nm has been mainly used for the nondestructive measurement of organic materials such as agricultural products or foods. However, it shows great potential in all facets of material assessment (for example, polymer, textile, pharmacy, petrochemical, etc.) including timber and composite wood. NIR is a fast-growing field that has broad implications in relation to wood quality and, ultimately, tree improvement. In the case of wood or forest products, NIR spectroscopy should be widely used in a state where not only the cellular structure but also its bulky shape is retained. It is as a promising technique to analyze the physical state of such materials as well as the chemical composition. NIR spectroscopy is high through put low cost technique for rapid assessment of solid wood properties.

Forest Products Division, Forest Research Institute, Dehradun is engaged in developing NIR based application method for assessing mechanical properties (strength properties), physical properties (specific gravity and density), and chemical properties (lignin cellulose estimation) of plantation timbers. Work is in progress for eucalyptus sp., poplar sp, subabul, sissoo. Work is also in progress to use NIR as an identification tool.

- Kothiyal, V. and Raturi, A. (2011). Estimating mechanical properties and specific gravity for five-year old *Eucalyptus tereticornis* having broad moisture content range by NIR spectroscopy (In press with *Holzforschung*)