

Potentials of tree improvement and tissue culture for paper and alike industries.

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SUMMARY

Forests are the main natural resources for the wood based industries in general, and paper and pulp industries in particular all over the world. Bamboos were once the main raw material for paper and pulp but due to their over exploitation and shortage, now-a-days eucalyptus or mixture of different species is the practice. The choice of the species depends on wood qualities, availability of raw material and economic considerations. To make the venture profitable wood qualities and sustainable supply of the raw material are the most important factors out of other technical and managerial inputs. Already there is a big gap in demand and supply of these products due to various constraint. Thus, genetic improvement of wood properties and production of quality raw material on mass scale, proportionate to the demand, assumes a great importance and calls for immediate measures to solve the problems of shortages of quality material. Forest genetics and tissue culture techniques have the potential and can play a pivotal role in immediately solving these crucial problems by application of simple already tried methods. It is need of the time that paper industries and other wood based industries should follow the line of other countries and establish their own research and development establishments and allocate seperate funds for tree improvement and quality raw material production programmes. Methods and case history of two institutions are provided in the paper to show the gains obtained through these studies.

Introduction

Forests are the main natural resources for the wood based industries in general, and paper and pulp industries in particular all over the world. Bamboos were once the main raw material for paper and pulp but due to their over exploitation and shortage, now-a-days eucalyptus or mixture of different species is the practice. The choice of the species depends on wood qualities, availability of raw material and economic considerations. To make the venture profitable wood qualities and sustainable supply of the raw material are the most important factors out of other technical and managerial inputs. Already there is a big gap in demand and supply of these products due to various constraint. Thus, genetic improvement of wood properties and production of quality raw material on mass scale, proportionate to the demand, assumes a great importance and calls for immediate measures to solve

the problems of shortages of quality material. Forest genetics and tissue culture techniques have the potential and can play a pivotal role in solving these crucial problems by application of simple already tried methods. More sophisticated techniques can be developed simultaneously to further augment the genetic base which is also essential for future needs. It is need of the time that paper industries and other wood based industries should follow the line of other countries and establish their own research and development wings and allocate seperate funds for tree improvement and quality raw material production programmes. As a geneticist and tree breeder I can assure the profits are going to be amazing and unbelievable. Aracruz paper

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mill in Brazil is the burning example of the current times for improving the yields of *Eucalyptus grandis* to 70 cubic meter/ha/yr. by the application of genetics and propagation techniques. Similarly this Institute has the potential and capability to help in this direction quite substantially as already such programmes are under way though in a humble way at Genetics and Tree Propagation, and Cellulose and paper division. The requirements of wood are tremendous. Therefore, concerted research efforts and financial inputs are essential to fulfil the national commitments.

Genetics of Wood

Research has shown that most wood qualities, as well as tree form and growth characteristics that affect wood are inherited strongly enough to obtain rapid economically important gains through genetic manipulation. The differing wood properties have a significant effect on the quality and yield of pulp and paper products and on strength and utility of solid wood products. Wood properties are related to product quality. Wood is notably non-homogeneous, both within and among trees of a species as well as among species and geographical sources. Genetic manipulation of wood in a breeding programme can result in a higher proportion of desired wood. This is one of the most useful improvements that can be made for wood qualities. The easier and more consistent conversion of uniform raw materials results in cheaper production of higher value final product (Zobel, 1983). In general tree improvement programme that have wood production as their goal should include knowledge of the manipulation of wood qualities.

Wood Breeding - Wood Properties

The question always arises about which wood properties should be changed. Even though nearly all wood properties that have been studied respond satisfactorily to breeding, each having different economic value and importance. Therefore, it is necessary to determine the most important wood property and not to try to include everything.

Wood specific gravity or wood density is most important characteristic for nearly all wood products (Einspahr et al., 1969, Barefoot et al., 1970). In some programmes fibre or tracheid length are also included. Both the characteristics have strong inheritance patterns,

and changes in them can have a significant effect on the final product. For certain special products, other wood properties can be of great importance, especially for quality hardwoods in which grain or colour may be key characteristics.

The wood of softwoods and hardwoods are varied and different but general principles related to wood and breeding strategies for two groups are same; but details can be grossly different. Specific gravity is not a single wood characteristic but is a combination of characteristics, each of which has a strong inheritance pattern of its own. Combined they determine what is called *specific gravity* (Van Buijtenen, 1964). Despite its complexity, specific gravity is considered to be a single property in most breeding programmes. Specific gravity is primarily determined by three different wood characteristics namely, amount of summer wood, cell size and thickness of cell wall, which has a strong inheritance pattern. Therefore, specific gravity is of key importance because it has major effect on both yield and quality of the final product (Barefoot et al., 1970) and because it is strongly inherited (Zobel, 1961, Van Buijtenen, 1962, Harris, 1965).

Variation Pattern in Wood

It is essential to have a good knowledge of wood variability if its quality and yield are to be manipulated. In addition to well recognised wood differences among species, variability in wood also occurs as follows :

- (1) Within a given tree—Juvenile and mature wood.
- (2) Among trees of the same species.
- (3) Sometimes, between populations of a species growing in a single locality.
- (4) Frequency, between populations of a species growing in different geographic areas.

The natural variability available among species and within species is key factor for the genetic improvement of the tree species for wood qualities. The fact that such variation exist in nature further adds to the necessity of undertaking vigorous studies to harness the goals for increasing wood yields qualitatively and quantitatively through genetic manipulation of the desired traits linked with end uses.

Genetic Relationships Among Wood Properties

Many of the different wood qualities are genetically independent one from another : thus, one can have a thick walled trachieds and high specific gravity trees that are either short or long fibred.

Some wood qualities are interdependent, such as specific gravity and wall thickness. These are often correlated, some times strongly. This is true of many of the morphological characteristics of cells, such as size wall thickness, lumen size, and other factors such as the chemical characteristics of cell morphology. Thus, when one of these is changed, the other wood properties will also be affected. A prime example is compression or tension woods that are closely associated with variation in cell size, structure and chemistry.

Because of the general independent inheritance of factors that affect the major wood properties, it is possible to "tailor make" the kind of wood desired. Programmes have been developed with *Pinus taeda* in the Southern United States to produce kinds of woods that are best for newsprint, paper board, bags and boxes, writing paper, and other wood products.

Effect of Growth Rate on Wood Properties

The relationship of growth rate to wood qualities is very important, it has been much studied and it is confused as is shown by many contradictory results in the literature. It is very complicated because of the many factors that effect both wood and tree growth. As Larson (1962) stressed, anything that affects the physiology and growth of a tree can also influence the kind of wood that is formed. Only limited information is available on the relationship of growth rate and wood in tropical hardwoods. Because of the confusion, it is difficult to make definitive statements about the relationship of wood to growth rate. Though, some believe that a fast growth rate causes low specific gravity in *Abies* and *Picea* (Stairs, 1969; Ollesen, 1976). In Poplars Mutibaric (1967) found a slight decrease in wood specific gravity with increased ring width, whereas for black cherry (*prunus serotina*), Koch (1967) found no relationship between growth and wood specific gravity. A major reason for the contention that growth rate is strongly and inversely correlated

with specific gravity evolved from a failure to recognise within - tree variation. The wood of young wide-ringed trees has been compared frequently with the narrow-ringed wood from older trees, or the wide ringed wood at the centre of the tree has been compared with the narrow-ringed wood at some distance from the pith. The key point is that if two trees are growing under the same environmental conditions but exhibit widely different growth rates, the faster growing tree may have either higher or lower specific gravity than does the slow grower.

Effect of Fertilization on Wood Qualities

As the use of supplemental nutrients becomes more widespread, there is an increasing concern about the effect that fertilization will have on wood qualities. One general reaction that has been observed and is documented for the hardpines and Douglas fir is that heavy nitrogen fertilization results in a lowering of specific gravity for about a period of 5 years (Posey, 1964). Some times phosphorus fertilization will reduce the high specific gravity values that are common to trees grown under strong deficiencies of this element.

One of the most desired benefits from fertilization is to make the wood of trees more uniform than when grown under normal conditions. This improved uniformity can be quite marked. In *Pinus taeda*, Posey (1964) found that high nitrogen fertilization reduces the gravity of inherently low specific gravity of high density trees is greatly reduced. This is of special importance to the tree breeder because the improvements gained by breeding for high specific gravity can be partially nullified if a heavy nitrogen fertilization is used.

Mode of Propagation and Wood Qualities

Most of the tree species are propagated through seed for raising plantations. Because trees are heterozygous genetically it causes lot of segregation resulting in ununiform population which reduces the genetic gains of yield per ha per annum. But if the selected or experimentally produced superior genotypes are multiplied through vegetative propagation, viz, rooting of cuttings or tissue culture then the genetic gains of production can be retained which has been confirmed in the case of *Eucalyptus grandis* by Aracruz Celuloses

in Brazil using asexual approach by raising plantations with rooted cuttings.

Based on the information collected from the literature on the breeding behaviour of wood properties and their relationship to different environmental factors vis-a-vis genetic control of wood traits and variability available in nature following tree improvement strategy is suggested :

Selection of plus trees having required wood properties linked with their end use from the natural populations or plantations of chosen species. The parameters should be defined accordingly before starting selection work. As the survey of literature shows that lot of variability is available in the nature in wood characteristics of the trees.

Provenance selection : It is documented that variation in wood properties exists when samples are drawn from different geographical sources of the species.

Germ plasm banks : Variety of genotypes are required to be collected and assembled at one place to have a wide spectrum of variability for different wood traits having economic value. Exotic collections should also be included in these banks. Experimentally synthesised new genotypes can also be assembled in these germ plasm banks. This will help in widening the genetic base of the species and their availability at one place to be utilized for breeding programmes.

Establishment of seed production areas : Best plantations should be marked and managed through cultural practices for better seed production to meet the interim seed requirement till the seed orchards become productive. Simultaneously these areas should be treated by removing the inferior trees and retaining only uniform superior trees to convert the area into seed stand. These areas can also serve for collecting vegetative material for clonal multiplication by asexual propagation.

Establishment of seed/seedling orchards : Plus trees should be utilized to establish seed/seedling orchards depending on the species. Plus trees should be selected based on the wood qualities associated with other favourable characteristics for improved wood production.

Simultaneously, progeny trials should also be laid down to know the genetic worth of the trees. This will help in further improvement of the wood traits and give information on the breeding behaviour and other genetic parameters. Heritability, general and specific combining ability if crosses are can also be worked out.

Laying out of multilocal trials : Multilocal field trials of provenances, plus trees, other selected and experimentally produced genotypes should be laid out to assess their performance by recording observations on growth, wood properties, yield, disease resistance and other traits. This will also help in getting information on genotype-cum-environment interactions.

Genetic engineering/biotechnology : Studies on genetic engineering/biotechnology will help in increasing the variability for further selections and for improvements in specific traits through mutation breeding and polyploidy breeding techniques. Haploidy breeding and male sterile lines can also help in the genetic improvement of trees much faster than the conventional methods alone.

DNA transplant, somatic hybridization can help in transferring the genes from donor species to recipient species eliminating sexual pathway for quicker improvement of species for required traits.

Vegetative propagation : Rooting of cuttings or tissue culture techniques can help in producing replicas of the parent types on mass scale to retain the superiority of genotypes and eliminate segregation which is observed if propagated through seed.

Hybridization : Interspecific and intraspecific hybridization can be practised to exploit heterosis and for creating "tailor make" genotypes and recombinants for further selection to help in making genetic base wider.

Case history of works carried out at Aracruz, Brazil and FRI (ICFRE), Dehradun are briefly reported here to show the gains obtained through these studies.

Tree Improvement Programme at Aracruz (Brazil) in *E. grandis* for Paper

Aracruz celuloze in 1978 had the world's largest single-line bleached pulp operation, boasting a rated capacity of some 4,00,000 tons/yr of bleached eucalyptus market pulp. Its entire wood needs were provided by its own forests all located within a short distance of the mill. During, 1984 after minor investments to remove bottlenecks, the capacity of Aracruz was about 460,000 tons/yr. This has been possible largely due to the tree improvement work associated with asexual propagation. Aracruz made selections of phenotypically superior trees of *Eucalyptus grandis* from which cuttings were taken at the harvest stage of seven years and following characteristics were taken into account :

- (1) The selected tree must have volume of more than 1m³ including bark and free of diseases and insect damage.
- (2) Selected tree must be straight and have small limbs. This enhances self-pruning and avoids tension in the wood, usually associated with thick branches and crooked trees.
- (3) Bark should be smooth, not rough and brown.
- (4) The crown should be well-shaped, having a large leaf volume which gives better and earlier shade, so suppressing competitive vegetation.

The selected trees were felled and the wood of each was analysed for basic density, which should be from 500-600 kg/m³, for pulp yield, and should exceed 50% based on the wood's dry weight, and for bark content, which should be less than 10%. Equally important is the coppicing ability of the tree stump. Rooting capacity of cuttings derived from stump sprouts should exceed 70%. Rooted cuttings from the selected trees must be tested for their genetic suitability. The remets obtained are tested in different soils to reconfirm the characteristics in the rooted cuttings of the selected trees. The assessment is made after half rotation (between three and four years) and the best clones are then propagated for multiplication. These are subsequently planted in large areas from clonal test areas called clonal multiplication areas, which

provide sprouts for operational rooted cutting production.

The morphological and anatomical analysis of the wood from cuttings of selected trees include, fibre length, wall thickness, specific gravity and cellulose yields. Brief results of the gains achieved after the application of tree improvement methods and vegetative propagation in *E. grandis* at Aracruz (Brazil) are given below in the table.

ARACRUZ'S FORESTRY PROGRAM : THE RESULTS

	Initial forest (seven years old)	Today's forest (seven years old)	Change by quantity	%change
YIELD (m³/ha/yr)				
Minimum	26	54	+ 28	+108
Maximum	53	113	+60	+113
Average	33	70	+37	+112
PULPWOOD CHARACTERISTICS				
Density range	300-900	500-600	—	—
Average density (kg/m ³)	460	575	+115	+25
Pulp yield (%)	48	51	+ 3	—
PULP CONTENT				
(kg cellulose/m ³ s CC)238	293		+ 55	+23
SPECIFIC CONSUMPTION				
(m ³ s CC/ton cellulose)4.20	3.41		—0.79	—19
FOREST PRODUCTIVITY				
(ton cellulose/ha/yr) 7.85	18.45		+10.6	+135
MILL CAPACITY				
(1,000 tons/yr)	400	460	+60	+15

Tree Improvement programme at the Division of Genetics and Tree Propagation, Forest Research Institute in Eucalyptus for Paper and Pulp

Experimentally produced hybrids at this Division in eucalyptus have shown hybrid vigour. The hybrids are 3-5 times superior in growth/yield in comparison to their parent species. The hybrids are *E. tereticornis* × *E. camaldulensis* (FRI-4), *E. camaldulensis* × *E. tereticornis* (FRI-5) and reciprocal hybrids of × *E. citriodora* × *E. torelliana*.

The wood properties of *E. citriodora* × *E. torelliana* were tested at the age of 6.5 years by taking cores by increment borer. The results have shown that specific gravity of hybrids was in the range of 0.5619 (F1 *E. torelliana* × *E. citriodora*) and 0.6161 (F1 *E. citriodora* × *E. torelliana*); whereas the specific gravity of parent species was 0.6599 (*E. torelliana*) and 0.9253 (*E. citriodora*). This shows that the hybrids have improved upon specific gravity properties in comparison to parent species. Similarly properties of wood fiber were also improved as can be seen from the table below :

Wood properties of Eucalyptus F1 hybrid (*E. citriodora* × *E. torelliana*) at age of 6.5 years.

Material	Specific Gravity	Fibre length	Wall thickness	Lumen diameter
			(in milli microns)	
1. F1 Cit. × tore.	0.6161	1291.4	4.70	6.55
2. F1 tore. × cit.	0.5619	1168.0	4.15	10.65
3. <i>E. citriodora</i>	0.9253	970.8	6.66	8.15
4. <i>E. torelliana</i>	0.6599	1069.8	5.46	8.91

Tissue culture protocol for hybrids have successfully been standardized for their clonal multiplication and for testing their performance in field.

Two examples given above have shown that tree improvement if coupled with vegetative propagation can give very high returns.

Studies on the genetic improvement of other species like Poplar, Acacias, Gmelina, Albizia, Pinus, Leucaena, Prosopis, Azadirachta and Bamboos etc., are also being conducted in this Division.

To conclude it is stressed that potentials of tree improvement and asexual propagation should be exploited for the improvements of wood qualities which have genetic controls. This calls for concerted and collaborative research and financial inputs.

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