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RESEARCH ARTICLE

PULPWOOD WOOD CHARACTERIZATION OF SCREENED EUCALYPTUS GENETIC RESOURCES

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Abstract: The tree farming is ecologically as well as economically more viable than traditional agriculture. Investment in tree plantations always remained relatively low in India, in spite of the fact that the existing forests cannot continue to meet our wood requirements. However, realizing the existing problem, the expenditure on afforestation has increased enormously from fifth five year plan onwards but still the results on the land are not encouraging and we have not been able to increase area as well as the forest productivity to the desired level. The misery caused to the entire nation due to unprecedented ecodegradation is enormous and warrants immediate remedial measures. To counteract the impending crisis, use of fast growing tree species managed with intensive cultural operations especially in tree farming have opened up new vistas in wood biomass production. Against this backdrop, the current study was planned to screen and identify superior genotypes of Eucalyptus for higher pulp yield. Eleven eucalyptus genotypes were subjected for pulp quality analysis. The clone EC 48 has been characterized for wood quality towards its amenability for pulp and paper industries and the results are very encouraging. The clone expressed the Pulp yield of 48%, Kappa number 19.3 and Lignin content of 23.20% which expressed superiority over the local seed sources. Similarly, this clone expressed acceptable strength properties viz., Burst index (5.0 K Pa m2 g -1), Tear (8.20 m Nm2 g -1) and tensile index (80.0 Nm g-1) which are again proved superior. Considering the pulp quality, the genotypes EC MTP 48, EC MTP 47 and EC MTP 41 proved superior and this study recommends the suitability of EC MTP 48, EC MTP 47 and EC MTP 41 for pulpwood plantation programme.

Keywords: Agriculture, Eucalyptus, Pulpwood, Genetic resources

INTRODUCTION

The biological diversity of forests and their ecological function are the heritage of mankind. These forests are most important and remarkable natural resources which play a very important role in the economic prosperity and ecological stability of the country. The forests of the country are shrinking under acute socio economic pressure and the foresters are at the cross roads. India's forests till recently are being denuded at an alarming rate of 1.5 million ha per year and has fortunately come down to rapidly with the enactment of the Forest Conservation Act, 1980. Currently, the forest area in the country is around 24.62 per cent and in the state of Tamil Nadu it is around 20.31 per cent which is low against the mandated requirement of 33.0 per cent. Not only is the forest wealth of the country is poor but its productivity in terms of MAI is also one of the lowest. The MAI of Indian Forest is a meager of 1.6 m^3/ha compared to the global average of 2.1 m^3 /ha. The less forest area coupled with the low productivity of Indian forest has ushered in a total mismatch between the demand and supply of both domestic and industrial wood requirement besides creating environmental disequilibrium and de stability.

India due to its burgeoning population is under tremendous pressure to meet the ever-growing multifarious demands for wood and wood products. The demand for pulp and paper is one such thing. Today, there are about 580 mills in India with 20 in the large scale sector and 560 in the medium and small scale sector. During 2020's, the *per capita* consumption of paper was 13 -15 kg, but still lower compared to the global average of 58 kg. Hence, the fortune of paper industry can be closely linked to the buoyancy in the economic development of a country. Today, pulp for papermaking is produced mostly from wood fibres (more than 90%) which contain many different chemical substances viz., cellulose, hemi cellulose, lignin and extractives. The rest is produced from non-wood fibres like bagasse, straw and bamboos. Forest plantations constitute about 3.8

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per cent of the total forest area. Productive forest plantations, primarily established for wood and fibre production, account for 78 per cent of forest plantations, and protective forest plantations, primarily established for conservation of soil and water accounts for 22 per cent.

An availability of adequate raw materials is one of the major constraints for the development of paper industry. The rapidly changing economic, technological and regulatory environment has affected the progress of Indian paper industry due to the poor availability of cellulose raw materials. Amongst the cellulosic raw materials, bagasse, straw and waste paper have inherent drawbacks of limited and scattered availability of suitable technology for conversion into higher-grade pulp. This makes quite imperative to have a sustainable supply of forest based raw materials, which account for 45 per cent of raw materials used (Sarada *et al*., 2000). The country has just one per cent of world's forest coverage but supports 16 per cent of the world's population (Mall, 1998). For wood-based industries, industrial plantation is the only answer.

The raw material requirement will shoot up further, as the paper consumption figure is bound to increase with all round development hence there is an increasingly growing demand to grow quality pulpwood through plantation. Depletion of forest areas in the country has badly hit the supply of fibrous raw material to the industry and hence great importance has been given to raise fast growing species for use as raw material for paper and cellulose industries (Salkia *et al*., 1991and Tomar, 2015).

The *Eucalyptus* have revolutionised the productivity and profitability of the plantations in many states of the country. However, these clones were developed taking only into consideration the yield of plantation and not the wood quality particularly in terms of cellulose, kappa number and strength properties. Increase in one per cent cellulose content will have tremendous impact in the overall paper production. However, studies pertaining to screening wood quality specific clones coupled with increased yield are dismally modest and thus needs intensive investigation. Against these backdrops, the current investigation has been designed in to elicit information to determine physical, chemical and strength properties of wood pulp of *Eucalyptus* clones.

MATERIALS AND METHODS

Eleven superior eucalyptus were collected from existing seed source evaluation trial at Forest College and Research Institute, Mettupalayam. From each species, a billet of each 1 m length and 50-60 cm girth were collected, debarked and chipped separately and screened. The screened chips were used for pulping experiments. Some chips were converted into dust for proximate chemical analysis. Based on the initial screening study in the laboratory, the wood samples were subjected to analysis of physical and chemical properties. The pulping experiments were also carried out to find out its suitability for papermaking. The physical characteristics such as bulk density, basic density and moisture content of wood chips are estimated. For the chemical properties analysis, the billets of individual tree species were chipped in pilot chipper; air dried and converted into wood meal. The wood dust passing through 40 mesh but retained over 60 mesh was subjected to analysis for moisture, ash, hot water soluble, one per cent NaoH soluble, AB extractive, acid insoluble lignin, pentosans, hollocellulose as per TAPPI methods (TAPPI, 1980). The strength properties such as pulping, identification of kappa number, pulp brightness, paper sheet preparation, paper strength measurement, tensile strength, tearing strength, bursting strength measurement were analyzed as per standard method (TAPPI, 1980).

RESULTS AND DISCUSSION

Physical properties of wood chips

The analysis of physical properties of wood studied had exhibited variation among the *Eucalyptus* genetic resources investigated. The moisture content varied between 9.76 per cent (EC MTP 47) and 10.97 per cent (EC MTP 50). The wood density of *Eucalyptus* pulp wood is possibly one of the most influential factors controlling the strength and several other physical characteristics of the paper sheet. It is relatively simple and inexpensive property to determine, even in unsophisticated environments. The bulk density exhibited wide variation and maximum density was recorded by EC MTP 48 (Table 1). This variation among tested genotypes may be due to the differences between early and late wood which could have created variation between and within trees (Malan and Arbuthnot, 1995). The bulk density of the entire culm of bamboo indicated the variation between nodes and internodes samples (Ahmad and Kamke, 2005). Similarly significant difference was observed among *Eucalyptus* species in basic density which ranged between 446 kg m^{-3} (EC MTP 41) and 542 kg m^{-3} (EC MTP 48). These results are in consonance with the observation in *Eucalyptus globulus* (Santos *et al*., 2004) and *Eucalyptus* species (Hamza, 1999; Rock wood *et al*., 2008). The wood density properties are of major importance for the production of quality pulp and paper. The amount of wood needed to produce one tone of air dried pulp is calculated from the density and pulp yield (Storebraten, 1990).

A wide variation in wood and fibre properties of different tree species was reported. Persson (1975) found that differences in diameter growth have major impact on basic density of wood. Basic density is again highly correlated with late wood content (Bergstedt and Olsen, 2000). Similarly the variability exhibited in most physical properties studied among different *Eucalyptus* in the current study also thus attests the results of earlier findings. But it is important to understand the exact relationship between wood density and other fibre characteristics of the test clones that have an effect on pulp and paper quality.

Chips classification results revealed that accept chips for cooking are around 82.8 per cent and dust is around 0.5 per cent. This is the accepted size for pulping. The heat transfer and chemical penetration during pulping may be uniform in all cases. Pape (1999) found higher basic density in Norway spruce trees stands thinned from above than that thinned from below due to the lower density in dominant trees than in codominant and suppressed trees. Johanson (1993) did not find such a difference in the basic density level between tree classes. This might be probably due to the young material used as indicated by Pape (1999). However, in the current study the basic density exhibited wider variation which might be due to species or differences between early and late wood formation as reported by Malan and Arbuthnot (1995).

Chemical properties

The proximate chemical analysis gives an idea of potentiality of raw material for paper making. The chemical analysis in terms of ash content ranged between 0.32 (EC MTP 48) and 0.54 (EC MTP 1) (Table 2). The chemical investigation carried out in wood pulp of *Morus alba* recorded high ash content of 1.2 per cent (Guha and Madhan, 1962a). Similar observations of high ash content were reported in many species *viz*., *Ailanthus excelsa (*Guha and Pant, 1981); *Populus eupratica* (Chaturvedi, 1997) and *Acacia mangium* (Saepuloh, 1999). However, all the selected eucalyptus in the current study exhibited lower ash content which thus lends a scope for utilization as pulp wood.

The alcohol-benzene solubilities of wood constitute the waxes, fats and resinous matter. In the current study, the extractives were in the range between 1.1 (EU MTP 1, EU MTP 2 and ET MTP 29) and 1.4 (EU MTP 14, EU MTP 47 and EC MTP 48) and potential differences were recorded among the genotypes selected. Similar variation in alcohol-benzene extractives were observed among various clones of *Eucalyptus tereticornis* (Rao *et al*., 1999), wherein the extractives ranged between 1.06 and 1.35. Among the chemical properties, holocellulose is very important because it is a measure of total carbohydrate content of the wood (Tappi, 2001). The holocellulose constituting cellulose and hemicellulose is the major portion of fibrous raw material. The holocellulose content in the study ranged between 71.6 (S.O) and 75.2 (EC MTP 48) and other *Eucalyptus* species recorded in between these. The result indicated the superiority of EC MTP 48 as a source of raw material for paper industry.

The content of pentosans ranged between 13.0 per cent (EC MTP 47) and 18.5 per cent (S.O) and acid soluble lignin was found to be in the range of 23.0 per cent (EC MTP 47) to 25.7 per cent (S.O). Such variation in the content of pentosans of *Acacia mangium* (Saepuloh, 1999) and *Neolamarkia cadamba* (Vennila and Parthiban 2021) were also evident which corroborate the results of current findings.

The overall chemical analysis revealed that the EC MTP 48 is most superior among ten eucalyptus and one seed source tested which could be used for commercial deployment for clonal plantation establishment.

Kraft pulping and kappa number

Kraft pulping generally involves the removal of most of the extractives, approximately 80 per cent of the lignin and 50 per cent of the hemicellulose from the cellulose fibres using alkali (Smook, 1992). For the production of high quality paper, the pulp is further bleached to remove the residual lignin, which is responsible for turning the paper yellow through oxidation and light absorption. The lignin and extractives contents of wood are traits that are fast being recognized as having importance in minimizing the costs and environmental impacts of kraft pulping. The optimization of chemical requirement for any industry is a prerequisite in order to reduce the pollution hazards. The current investigation on optimization carried out with 20 kappa pulp using different chemical additions. The unbleached pulp yield ranged between 44.17 (S.O) and 48.38 per cent (EC MTP 48) and potential differences were recorded among *Eucalyptus* genotypes tested (Table 3). The pulp yield was maximum in EC MTP 48 coupled with minimum kappa number. The earlier studies in *Eucalyptus globulus* (Miranda and Pereira, 2002; Santos *et al*., 2004) indicated wide variability in terms of bleached and unbleached pulp yield and it was found that both provenance and site had a highly significant effect on pulp yield. Hence, the variation in the pulp yield of current study might be due to variation in the genotypes used.

Kappa number is an important factor, which decides the presence of lignin. Higher the lignin more will be the bleaching process and less will be the pulp yield. Hence, the higher pulp yield coupled with less kappa number (<20) recorded in the present investigation recommends three clones *viz*., EC MTP 48, EC MTP 47 and EC MTP 41 as potential genotypes for incorporation in the industrial wood plantation programme.

Strength properties of bleached pulp

The results of the strength properties at 300 ml CSF for each pulp are given in Table 3. The best strength properties in terms of tensile index, burst index and tear index were recorded by three genotypes *viz*., EC

MTP 48 (80.0 Nm g^{-1}, 5.0 K Pa m^2 g^{-1}, 8.2 m Nm^2 g^{-1}), EC MTP 47 (78.0 Nm g^{-1}, 4.4 K Pa m^2 g^{-1}, 8.0 m Nm^2 g^{-1}) and EC MTP 41 (78.0 Nm g^{-1}, 4.7 K Pa m^2 g^{-1}, 8.0 m Nm^2 g^{-1}) respectively. The strength properties of paper are directly associated with cellulose and interfibre bonding. The genotype EC MTP 48 recorded high holocellulose and low lignin content due to increased pulp yield and is good for interfibre bonding and pulp strength. Similar variations among tree species for various strength properties were also recorded between *Eucalyptus tereticornis* and *Eucalyptus grandis* (Patil *et al*., 1997). Within the species, the strength properties varied due to age but in the current study variation occurred among clones of same age which indicated the variation might be due to genotype. It was reported that improvement in burst and tensile index with decreasing freeness in *Eucalyptus tereticornis* (Patil *et al*., 1997). The best strength properties *viz.* burst, tear, tensile was attained by pulps of 14-15 years age groups in case of *Eucalyptus*. However, in the current study satisfactory levels of strength properties was achieved even in five years of growth which indicated that the genotype tested in the current study could be harvested even in five years as against seven years of current practice by the state forest department.

Table 1. Physical characteristics of different *Eucalyptus* genotypes

Clones	Moisture content (%)	Bulk density (OD basis) (kg m^{-3})	Basic density (OD basis) (kg m^{-3})	Chips classification (%)				
				+ 45 mm	+ 8 mm (over thick)	+7 mm (accept)	+ 3 mm (pin chips)	-3 mm (dust)
EU MTP 1	10.49	260**	499**	Nil	6.1	80.1	13.2	0.6
EU MTP 2	10.76*	270**	510**	Nil	5.9	78.5	14.8	0.8
EU MTP 8	10.90*	230	455	Nil	5.7	80.4	13.5	0.4
ET MTP 14	10.61	249	469	Nil	6.2	77.8	15.4	0.6
ET MTP 29	10.47	236	452	Nil	5.2	80.9	13.5	0.4
EC MTP 41	10.22	234	446	Nil	6.5	82.6	10.1	0.8
EC MTP 47	9.76	270*	510**	Nil	4.4	82.8	12.4	0.4
EC MTP 48	9.98	284**	542**	Nil	6.5	81.8	11.3	0.4
EC MTP 50	10.97**	245	540**	Nil	7.2	79.9	12.1	0.8
EC MTP 53	10.49	240	540**	Nil	5.8	81.5	12.3	0.4
S.O (Control)	10.29	220	455	Nil	8.3	78.6	12.8	0.3
Mean	**10.44**	**249**	**493**					
SEd	0.13	0.83	0.82					
CD (0.05)	0.27	1.66	1.65					
CD (0.01)	0.35	2.22	2.20					

Table 2. Proximate chemical composition of different *Eucalyptus* genotypes

Clones	Ash content (%)	Solubility in		Alcohol benzene extractive (%)	Acid insoluble lignin (%)	Pentosans (ash corrected) (%)	Holocellulose (%)
		Hot water (%)	1 % NaOH (%)				
EU MTP 1	0.54**	3.0	12.9	1.10	24.3	13.4	73.1
EU MTP 2	0.45	2.9	12.2	1.10	24.9**	13.7	73.1
EU MTP 8	0.53**	2.8	12.5	1.20	24.6*	13.2	73.3
ET MTP 14	0.43	2.8	12.8	1.40**	24.2	13.8	73.7
ET MTP 29	0.34	2.7	14.3**	1.10	24.3	13.9	73.4
EC MTP 41	0.43	2.9	13.5	1.20	24.5	13.3	74.6**
EC MTP 47	0.46	3.4	12.2	1.40**	23.0	13.0	74.8**
EC MTP 48	0.32	2.7	12.9	1.40**	23.2	14.4	75.2**
EC MTP 50	0.53**	3.7**	13.8*	1.30**	24.4	14.8**	73.2
EC MTP 53	0.48**	2.7	12.7	1.30**	24.3	14.6*	73.2
S.O (Control)	0.38	3.6**	14.0*	1.20	25.7**	18.5**	71.6
Mean	**0.44**	**3.02**	**13.07**	**1.25**	**24.31**	**14.24**	**73.56**
SEd	0.02	0.02	0.29	0.01	0.14	0.17	0.18
CD (0.05)	0.03	0.03	0.58	0.02	0.27	0.33	0.36
CD (0.01)	0.04	0.04	0.78	0.03	0.36	0.44	0.48

Table 3. Comparison of different Eucalyptus genotypes with respect yield and strength

Species	Chemical charge for 20 kappa	Kappa Number	Unbleached pulp yield (%)	Strength properties at 300 ml CSF		
				Tear index (m Nm^2 g^{-1})	Tensile index (Nm g^{-1})	Burst index (K Pa m^2 g^{-1})
EU MTP 1	17	20.56	45.06	7.5	74.0	4.3
EU MTP 2	17	20.30	46.84	7.7	61.0	3.4
EU MTP 8	17	20.26	44.65	7.5	70.0	4.1
ET MTP 14	17	20.38	44.28	7.6	77.0	4.6
ET MTP 29	17	20.80	46.51	7.7	67.0	4.3
EC MTP 41	17	20.30	47.35	8.0	78.0	4.7
EC MTP 47	17	20.48	47.38	8.0	78.0	4.4
EC MTP 48	17	19.30	48.38	8.2	80.0	5.0
EC MTP 50	17	20.64	47.02	7.9	71.0	4.1
EC MTP 53	17	20.90	46.91	7.8	78.0	4.2
S.O (Control)	17	21.00	44.00	7.8	72.0	4.5
Mean	**17**	**20.45**	**46.22**	**7.79**	**73.27**	**4.33**
SEd		1.00	1.84	0.37	3.44	0.13
CD (0.05)		2.09	3.86	0.77	7.17	0.28
CD (0.01)		2.85	5.26	1.05	9.78	0.38

CONCLUSION

In a holistic perspective, considering all physical, chemical and strength properties, all the genotypes subjected for analysis were found to be suitable as a source of pulpwood. However, considering the pulp yield and kappa number coupled with strength properties, the superiority of the EC MTP 48, EC MTP 47 and EC MTP 41 as a source of pulpwood was evident and hence the above three genotypes are recommended for clonal deployment towards establishment of industrial wood pulpwood plantations.

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