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Melia Dubia – A Potential Short Rotation Wood Species For Pulp and Paper Industries

Abstract

Four tropical tree species viz., Cassia siamea, Anthocephalus cadamba, Melia dubia and Leucaena leucocephala along with Eucalyptus tereticornis were subjected to physical and chemical analysis coupled with pulping characteristic studies in order to evaluate their feasibility as alternate pulpwood. The physical and chemical analysis of wood indicated that the lignin content was moderate for all the tree species which proved their suitability as pulp wood. The tree species differ significantly in holo cellulose content which is an essential factor for paper production. Considering this factor, the superiority of Melia dubia was evidenced due to maximum holo-cellulose content when compared to all other species. The pulping results indicated that Melia dubia exhibit high pulp yield and low kappa number at similar chemical and black liquor analysis conditions. The strength properties of pulp also indicated the superiority of Melia dubia in terms of tensile, burst and tear properties. Considering all these parameters, the new species Melia dubia is found to be an ideal pulpwood for papermaking. Further, successful results with respect to pulp yield, chemical requirement, bleaching response and strength properties were also obtained during plant scale trials. Hence these studies clearly prove that Melia dubia is an ideal alternate pulpwood species amenable to high density and short rotation forestry.

Key words: *Melia Alternate pulpwood Short rotation forestry.*

Introduction

The biological diversity of forests and their ecological functions are a heritage of mankind. These forests are extremely important and remarkable natural resources which play an important role in the economic prosperity and ecological stability of the country. The forest cover of our country is constantly

shrinking under acute socio economic pressure leaving the foresters at cross roads. Not only is the forest wealth of our country poor, but its productivity in terms of MAI is also one of the lowest. The MAI of Indian Forests is a meager 0.5 - 0.7 m^3/ha compared to the global average of 2.1 m^3/ha. The less forest area coupled with low productivity of Indian forests has resulted in a total mismatch between demand and supply of both domestic and industrial wood requirements, besides creating environmental disequilibrium and de-stability. (*Parthiban et al* 2014).

Today, there are about ***750 paper*** mills in India with 35 in the large scale sector and 715 in the medium and small scale sectors. The current *per capita* consumption of paper is 10 kg which is lower when compared to the global average of 48 kg. Today, pulp for papermaking is produced mostly from wood fibres (more than 70%) which contain many different chemical substances viz., cellulose, hemi cellulose, lignin and extractives. The rest is produced from non-wood fibers like bagasse, straw and bamboos. Unavailability of adequate raw materials is one of the major constraints for the development and sustainability of the 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. The raw material requirement will increase further, as the paper consumption figure is bound to increase. Depletion of forests in our country has adversely affected the supply of fibrous raw material to the industry and hence greater importance has to be given to raise fast growing species for use as raw material for paper and cellulose industries (Salkia *et al*., 1991).

Pulp and paper industries in our country predominantly use Eucalyptus and Casuarina and to a smaller extent, various other pulp wood species. These species have exhibited both success and failure due to erratic adaptability coupled with poor productivity under marginal lands (Parthian *et al*., 2004). There is also a threat due to the epidemic nature of pests and diseases which has resulted in poor growth and severe damage to plantations. This, in addition to the promotion of industrial wood plantations in farm lands, has demanded an inventory of tree species amenable for cogeneration of wood and food in the same unit of land in which the existing pulpwood species do not support the compatibility after one year of plantation establishment. Under such circumstances, there is a need to identify and screen alternate pulpwood species with superior pulp wood quality coupled with high productivity and amenability for agro-forestry system.

Melia dubia Species Description

Taxonomically this species belongs to the order Meliales; family: Meliaceae; sub-family: Meliodeae. It is called as Malai Vembu in Tamil and bears Malabar Neem as its trade name. It is a fairly large, handsome deciduous and fast growing tree upto 20-25 m height and 1.2-1.5 m in girth, with straight cylindrical bore of about 9-12 m. The tree is leafless for a short period from December to February after which new leaves begin to appear until March. The flowers appear in April and are soon replaced by bunches of ovoid drupes, which ripen in the cold season from October to February.

The tree is a moderate to light demander at a young stage, but pushes up vigorously in moist deciduous forests. It coppices well and in addition produces root suckers. The species can be propagated through seed, but it has low germination percentage; therefore, tree improvement requires development of vegetative propagation techniques. Semi-hard wood cuttings of shoot portions are considered to be good materials for rooting purposes.

It is believed that *Melia dubia* originated in India. However, the exact origin is uncertain. In the eastern Himalayas it is found in Sikkim, north Bengal, upper Assam, Khasi hills and the hills of Orissa. In the peninsular region it is found from Ganjam hills in the north to Tirunelvelli in the southeast and from the Konkan coast all the way to the south. Outside India, it is found in Sri Lanka, Malaysia, Java, China and Australia. Due to its wide distribution, the tree is capable of withstanding wide range of climatic conditions. The tree can be

cultivated in arid, semi-arid and semi- moist areas. The species has multifarious uses from plywood, matchwood and dendro power to pulpwood due to its unique anatomical features. However, the species has not been exploited fully to its potential by the wood based industries in our country.

Materials and methods

Wood:

The experimental method for the present study consists of identification of wood species collected from four year old trees of different tropical species found in Ooty region of Tamilnadu in south India. The species are viz., *Cassia siamea, Anthocephalus cadamba, Melia dubia and* ***Leucaena leucocephala*** and *compared with Eucalyptus tereticornis*. From each species, a billet of each 1 m length and 50-60 cm girth were collected. The billets were debarked and chipped separately and screened.

The screened chips (6-8 mm) were subjected to proximate chemical analysis and used for pulping experiments. The pulping experiments were carried out at standard pulping conditions to find out its suitability for papermaking.

Physical and chemical analysis:

The physical characteristics such as bulk density, basic density and Proximate analysis results such as moisture, ash, hot water soluble, 1% NaOH soluble, Alcohol-Benzene extractive, Acid insoluble lignin, pentosans, hollocellulose evaluated as per TAPPI methods are presented in Table-1.

Table 1. Physical and chemical characteristics of woods chips

Parameters	***Cassia siamea***	***Anthocephalus Cadamba***	***Melia dubia***	***Leucaena leucocephala***	***Eucalyptus tereticornis***
Bulk density (OD basis kg/m^3)	268	180	250	250	240
Basic density (OD basis kg/m^3)	530	385	530	526	520
Proximate analysis					
Ash %	0.78	0.85	0.72	0.70	0.65
Acid insoluble lignin %	27.3	25.3	24.7	26.7	25.8
Pentosans (ash corrected) %	16.0	15.2	15.5	17.0	14.8
Solubility :					
Hot water %	6.6	5.4	3.8	4.2	4.0
1% NaOH %	16.2	14.7	15.0	16.7	15.4
Alcohol benzene %	4.7	3.2	3.3	2.9	3.0
Hollo cellulose (ash corrected) %	68.7	68.2	72.0	70.2	71.0

The pulping experiments were carried out in a laboratory CCL digester by taking 300 gm OD chips with same alkali concentration at a temperature of 165°C. The Pulping results such as kappa number, pulp yield, brightness and black liquor analysis were analyzed as per standard methods. The results are given in Table-2.

The Bleaching studies were carried out with ECF bleaching sequence (Do EOP D1) for pulp brightness of 86 % ISO brightness. Pulp strength properties were evaluated at different freeness level using PFI mill for refining. The strength properties computed at 300 ml CSF are presented in Tables - 3 & 4

Results and Discussion

The physical and chemical properties (proximate analysis data) shown in table-1 reveal that the chemical composition of Melia dubia is not significantly different from other raw materials.

Physical properties

The bulk density exhibited wide variation from 180 kg m^{-3} for *Anthocephalus cadamba* to 268 kg m^{-3} for ***Cassia siamea*** in the current study. Similarly a significant difference was observed between species in terms of basic density which ranged from 385 kg m^{-3} (*Anthocephalus cadamba*) to 526 kg m^{-3} (*Leucaena leucocephala*). The wood *Melia dubia* has better bulk density (250 as against 240 kg m^{-3} for Eucalyptus Hybrid) and higher basic density. When compared to other wood species, Melia *dubia* has comparable ash with low lignin content. With respect to solubility in hot water and NaOH, it is low which supports better yield. The holocellulose (cellulose and hemicellulose) content is higher when compared to all other species which also results in higher yield and better strength.

Chemical properties:

The proximate chemical analysis gives an idea on the potential of a raw material for paper making (Rao *et al*., 1999). The alcohol-benzene solubility of wood constitutes the waxes, fats and resinous matter. The data obtained indicated that the extractives were in the range of 2.9 (*Leucaena leucocephala*) to 4.7 (*Cassia siamea*) and differences were recorded in other species as well. Similar variations in alcohol-benzene extractives were observed for various clones of *Eucalyptus tereticornis* (Rao *et al*., 1999). Among the chemical properties, holocellulose is very important because it is a measure of total carbohydrate content of the wood (Tappi, 2001). The holocellulose content in the study ranged between 68.2 (*Anthocephalus cadamba*) and 73.0 (*Melia dubia*) with other species recorded in between these. The results indicate the superiority of *Melia dubia* as a source of raw material for paper industry.

Such variability among the various clones of *Eucalyptus w*as also evident (Rao *et al*., 1999) which thus lend support to the current investigation. The chemical analysis in terms of ash content ranged between 0.70 (*Leucaena leucocephala*) and 0.85 (***Anthocephalus cadamba***). However in the current study, the solubilities in one per cent NaOH and alcohol benzene were very low, which indicates the suitability of all the tree species investigated in the current study as a source of pulp wood. The chemical analysis particularly for hollocellulose, pentosans and lignin content of wood chips revealed that *Melia dubia* is the most superior among the four species tested.

Pulping Experiments

The Kraft pulping is carried out in laboratory CCL digester, electrically heated, with Poly ethylene glycol as heating medium with the following conditions

Chemical added as Na_2O	%	:	17
Bath Ratio		:	1 : 3
TAA in White liquor	gpl	:	88
Sulphidity of White liquor	%	:	20.0
Cooking Temperature	°C	:	165
Cooking time	min	:	90
H Factor		:	1100

The cooked pulp is washed and screened. The total pulp yield, screened pulp kappa number and

brightness are determined. The results are presented in Table-2. Then the bleaching studies are carried out with ECF bleaching sequence to the brightness level of 87% ISO. Bleached pulp strength was evaluated at different freeness levels and presented at 300mL CSF was computed and shown in Table-3.

Unbleached pulp yield and kappa number

The current investigation on optimization is carried out with 20 kappa pulp using different chemical additions. Finally all pulping was carried out at same chemical dosage (17% as Na_2O). The unbleached pulp yield ranged between 45.0 (Eucalyptus Hybriod) and 50.0 (*Melia dubia*). The pulp yield was higher in *Melia dubia* coupled with lower kappa number at same chemical concentration. Brightness of unbleached pulp from *Melia dubia* is also better (31%) when compared to Eucalyptus hybrid (28%). Kappa number is an important factor, which decides the presence of Residual lignin. Higher the lignin more will be the bleaching chemical demand. Hence, the higher pulp yield (50% and above) coupled with less kappa number (<20) recorded in the present investigation indicates ***Melia dubia*** as a potential alternate pulpwood species.

Table 2. Pulping results of different hardwood species

Species	Chemical as Na_2O (%)	Unbleached pulp yield (%)	Screen rejects (%)	Screened pulp yield (%)	Kappa number	Brightness % ISO
Cassia siamea	17	46.5	1.10	45.4	30.4	28.0
Anthocephalus cadamba	17	44.8	0.20	44.6	21.4	30.5
Melia dubia	17	50.2	0.20	50.0	19.5	31.0
Leucaena leucocephala	17	49.5	0.10	49.4	19.5	29.0
Eucalyptus tereticornis	17	45.2	0.20	45.0	21.0	28.0

Table 3. Comprison Of Yield & Stregnth Of Various Wood Species

Wood Species	Chemical Charge as Na_2O (%)	Unbleached pulp yield (%)	STRENGTH AT 300 ml CSF		
			Tensile index Nm/g	Tear index $mN.m^2/g$	Burst index $kPa.m^2/g$
Cassia siamea	17	46.5	58.0	6.5	3.7
Anthocephalus cadamba	17	44.8	66.0	6.2	4.2
Melia dubia	17	50.0	72.0	8.8	4.7
Leucaena leucocephala	17	49.5	67.0	7.0	4.4
Eucalyptus Hybrid	17	45.0	67.0	8.0	4.3

Strength properties of bleached pulp:

Bleaching experiments were carried out for each pulp in ECF bleaching sequence. The strength properties of all species are presented in Table 3 for comparison. The strength properties of any manufactured paper in terms of tear, burst and tensile factors are very important for paper quality (Anon, 1982). The strength and optical properties of bleached pulp of Melia dubia and Eucalyptus hybrid at various freeness levels are presented in Table 4 & 5. It was observed that initial freeness for the pulp was 560 ± 10 ml CSF. The refining energy required to get 300 ml CSF was around 3800 revolutions in PFI mill. for all cases.

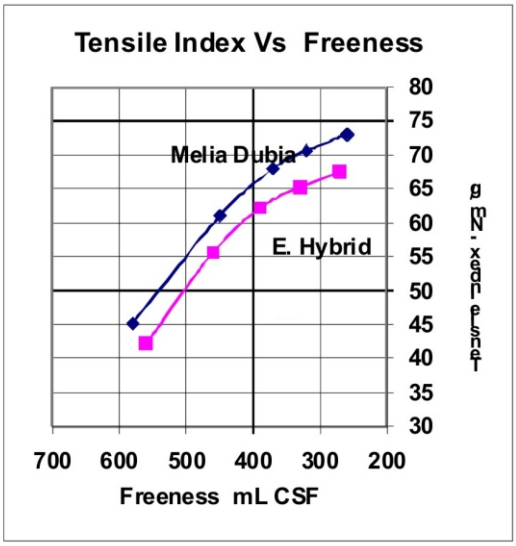
Table - 4 Strength Propertites of Melia Dubia Bleached Pulp At Various Freeness Leverls

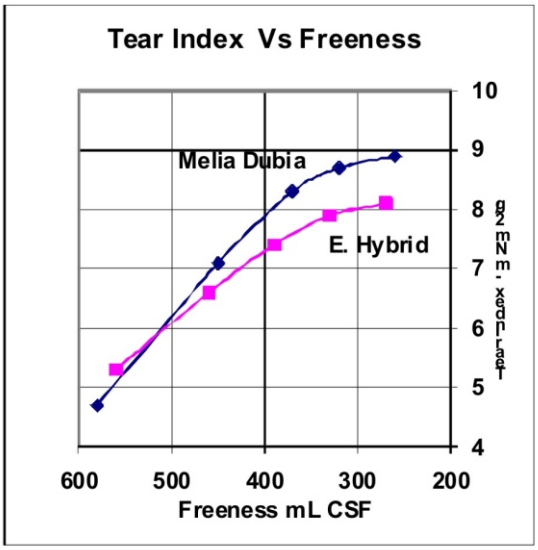
S.N	PFI Revolution	unit	0	1000	2000	3000	4000
1	Freeness	ml CSF	560	460	370	320	260
2	Bulk	cc/g	1.98	1.82	1.73	1.62	1.54
3	Tensile index	Nm/g	45.2	61.0	68.0	70.6	73.0
4	Tear index	$mN.m^2/g$	4.7	7.1	8.3	8.7	8.9
5	Burst index	$kPa.m^2/g$	2.1	3.7	4.4	4.7	4.8
6	Brightness	% ISO	86.8	85.2	84.4	84.3	84.0
7	Opacity (ptg)	%	84.2	83.6	82.7	81.8	81.0
8	Sc. coefficient	m^2/kg	48.4	46.5	45.5	45.2	45.0
9	Yellowness	%	9.6	9.7	9.8	10.0	10.0
10	Viscosity	cPs	11.4				

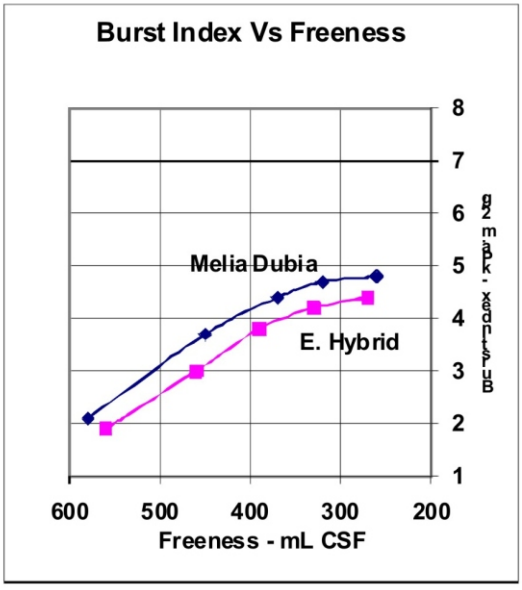
Table - 5 Strength Propertites of Eucalyptus Hybrid Bleached Pulp At Various Freeness Leverls

S.N	PFI Revolution	unit	0	1000	2000	3000	4000
1	Freeness	ml CSF	560	460	390	330	270
2	Bulk	cc/g	2.03	1.81	1.70	1.63	1.52
3	Tensile index	Nm/g	42.2	55.6	62.2	66.2	68.6
4	Tear index	$mN.m^2/g$	5.3	6.6	7.4	7.9	8.1
5	Burst index	$kPa.m^2/g$	1.9	3.0	3.8	4.2	4.4
6	Brightness	% ISO	86.8	85.2	84.4	84.3	84.0
7	Opacity (ptg)	%	85.2	83.2	82.8	82.2	81.6
8	Sc. coefficient	m^2/kg	54.3	51.2	48.6	47.3	46.6
9	Yellowness	%	9.8	10.2	10.5	10.6	10.7
10	Viscosity	cPs	10.3				

BLEACHED PULP STRENGTH PROPERTIES of MELIA DUBIA and E. HYBRID AT VARIOUS FREENESS LEVELS







STRENGTH AT 300 ML CSF

	Melia Dubia	E. Hybrid
Tensile Index - Nm / g	72	67
Tear Index - $mN.m^2/g$	8.8	8.0
Burst Index - $kPa.\ m^2/g$	4.7	4.3

The bleached pulp of *Melia dubia* recorded the best strength properties in terms of tensile index, burst index and tear index with values of 72 nm/g, 4.7 kpa /m^2/g and 8.8 mN.m^2/g respectively (Fig.1) The comparison of pulping results for yield and strength properties of all the species revealed that *Melia dubia* is superior compared to *Eucalyptus tereticornis.* The strength properties viz., tensile index, tear index, burst index are also found be better in case of *Melia dubia*. This might be due to superior fibre characteristic that may be present in the species. This, besides the chemical requirement to achieve 20 kappa in this species is lower when compared to Eucalyptus hybrid. Good bleaching response might have also contributed to improved

strength properties. Among these strength properties, tearing strength depends upon fibre length, width etc. Hence, the maximum tearing strength burst index and tear index in *Melia dubia* must be due to superior fiber characteristics.

Planttrial Results

Plant trials were conducted by using 30-40% of Melia dubia in our total consumption of wood chips per day along with regular Hybrid wood to confirm these findings. The plant scale results are given below.

Productivity and economics of ***Melia dubia***

Melia dubia is one of the fastest growing species in varied agro climatic zones. The species is a good coppice and amenable to a minimum of 2 coppice rotations. The species can be harvested and utilized after two years, for paper production. The systematic introduction in farm lands with density under 2500 plants per ha will yield an average of 100 tonnes in two years and a maximum of 175 tonnes with intensive management. Seshasayee Paper and Boards has introduced for the first time in the country, Melia based pulpwood contract farming and has extended a minimum support price of Rs.3500 / tone at farm site. This has attracted several farmers in the region towards Melia cultivation. As of now, the industry in association with Tamil Nadu Agricultural University, has promoted over 3000 acres of Melia plantations across the state of Tamil Nadu.

Conclusion

Melia dubia was tested both in a laboratory and at an industrial scale towards its amenability for paper production. The study indicated that compared to Eucalyptus and other hard woods, the species *Melia dubia* is significantly superior in all aspects of physical, chemical and strength properties thereby proving its suitability for pulp and paper production. Moreover the species is a fast grower and could be harvested within 24 months for paper production compared to the 3 – 5 years rotation for existing species. Most importantly, the species exhibited significant adaptability in agro forestry system resulting in more number of farmers being attracted towards *Melia* cultivation. In a holistic perspective, *Melia dubia* can be an ideal raw material for the paper industry due to its superior pulping quality coupled with amenability towards short rotation forestry.

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Particulars	Unit	Trial - 1	Trial - 2	Trial - 3
Chemical Addition as Na_2O	%	17	17	17
Cooking Temperature	C	162	162	162
H-Factor		650 - 700	650 - 700	650 - 700
Kappa Number		18.8 - 21.0	17.4 - 20.8	18.3 - 22.0
Unbled pulp Brightness	% ISO	29 - 32	30 - 32	30 - 32
Bleached Pulp Brightness	% ISO	85 - 87	85 - 87	85 - 87
Viscosity	cPs	10.3	10.7	10.5
Tensile Index	Nm/g	70.0	69.0	71.0
Tear Index	$mN.m^2/g$	8.4	8.3	8.5
Burst Index	$kPa.m^2/g$	4.5	4.6	4.4

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Acknowledgement:

The authors thank the Management of M/s Seshasayee paper and boards limited, Tamilnadu for granting permission to publish the paper in IPPTA Annual Seminar held at Hyderabad in Mar 2015.