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Pulpwood Characterization on *Thespesia populnea* for Industry at different age Gradation

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ABSTRACT

The study was carried out at Forest College and Research Institute, Tamil Nadu, India using five different age gradations *viz.* two, three, four and five year old *Thespesia populnea* wood samples. About one metre length billets from the felled sample trees were collected from each tree for analysis of pulpwood properties. The billet was debarked, cleaned and labelled for analysis. Four age gradations of *T. populnea* were subjected to physical and chemical analysis in order to recommend suitable rotation age for pulp and paper production. Considering physical properties *viz*. bulk and basic density, all the age gradations were moderate to high in range which indicated their suitability as pulp wood. In the chemical analysis, the lignin content was significant parameter which was also moderate for all the age gradations and hence proved their suitability. The different age gradations of *T. populnea* differ for holocellulose which is essential factor for paper production. Considering this factor, among the four age gradations investigated, the superiority of five year old wood was evident due to maximum holocellulose content. The differences in anatomical characteristics *viz.,* fibre length, fibre diameter, fibre wall thickness and fibre lumen width for two, three, four and five year old *T. populnea* wood samples, respectively, were investigated. Fibre length, fibre diameter and fibre wall thickness showed significant increment with respect to increase in age but lumen width decrease with age increases.

1. Introduction

Forest are not just tree, but part of an ecosystem that interlinks life, economics and societies. Forest provides a multiplicity of environmental services. The demand and supply gap of timber, fuel wood and fodder is widening. At the same time industries like pulp and paper, match and plywood requires wood based raw materials. The National Forest Policy (1988) suggested that the wood based industries will have to make their own arrangements for the supply of raw materials. Most of the government forest polices and acts stresses on the conservation of existing natural vegetation and not for its exploitation. Hence, the importance of industrial plantations gained momentum across the country, to meet out the industrial raw material needs.

So to fulfil the domestic and industrial needs the only solution is implementation of the schemes like Joint Forest Management, agroforestry, industrial plantation, *etc*. hence we can achieve our need as well as increase the forest cover. To develop agroforestry and industrial plantation, require fast growing and multipurpose trees *Thespesia populnea* is one of the fast growing and multipurpose tree. Oudhia (2007) reported plant height is rapid in the first few years (0.5–1.5 m year^{-1}), but slows down at 7–10 years of age. Stem diameter growth is 1–3 cm year^{-1}. Flowering begins when the tree is only 1–2 years old. Friday and Okano (2006) reported the tree is suitable for dry locations because it develops a long taproot in porous soils; it may tolerate a dry season of up to 8 months. It thrives on sandy coastal soils as well as volcanic, limestone and rocky soils with a pH of 6.0-7.4. It tolerates heavier soils, soil salinity and occasional inundation, but does not grow on permanently inundated soils.

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2. Materials and Methods

The investigations were carried out in the laboratory of Forest College and Research Institute, Mettupalayam; Research and Development Laboratory, Seshasayee Paper and Boards Limited, Erode. The wood samples were subjected to analysis of physical and chemical properties which are essential to find out the suitability of the wood sample for pulpwood. The pulping experiments were also carried out to find out its suitability for papermaking at different age gradations.

2.1 Laboratory analysis

The wood samples were subjected to analysis of physical and chemical properties which are essential to find out the suitability of the wood sample for pulpwood in NAIP: Pulp wood Testing Laboratory, Department of Tree Breeding, Forest College and Research Institute, Mettupalayam.

2.2 Physical properties for pulpwood

Bulk density and basic density was determined using the displacement method (Haygreen and Bowyer, 1982). Moisture content of wood chips was determined after drying it at 100 + 5 ºC for 48 h. The billets collected across the age gradation were chipped in pilot chipper and air-dried for 24 hours. The wood chips were passed through different sieves (50 mm, 10 mm, 5 mm and 2 mm) as per TAPPI methods (TAPPI, 1980) for Chips classification.

2.3 Chemical properties for pulpwood

The billets of individual tree species were chipped in pilot chipper; air-dried and converted into wood meal in a laboratory pulp disintegrator. The wood dust of sample was prepared using Wiley mill and 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).

2.4 Anatomical characteristics of Thespesia populnea under different age gradation

Three samples each of dimension 2 x 2 x 2 cm^3 were sliced out separately from the heartwood and sapwood regions of *T. populnea.* From these wood samples thin microscopic sections of size 15 to 20 µm were taken using *'Leica* SM 2000 R Microtome'. Temporary slides were made by staining these sections with safranin stain and subjected to measurements and photography using Image analysis system (Motic). Measurement of various parameters was done using the Motic software. For each parameter study, three wooden cubes were taken from three different aged trees (one cube each from inner, middle and outer region) from each tissue type *viz*. sapwood and heartwood. One section each was taken from the three cubes. Temporary slides were prepared and the sectioned images studied using an image analyser. Observations were recorded on at least three fields on each section. Maceration of the wood samples was done using Jeffrey's method (Sass, 1971).

2.5 Fibre morphology - Fibre length

Fibre length (µm) was measured from macerated wood samples by measuring both end of the fibre through Motic Image Analysis Software.

2.6 Fibre diameter

Diameter (µm) of the fibre was measured from macerated wood samples by measuring cross sectional area through Motic Image Analysis Software.

2.7 Fibre wall thickness

Wall thickness (µm) of the fibre was measured from macerated wood samples by measuring thickness of the fibre wall cross sectional area through Motic Image Analysis Software.

2.8 Fibre lumen width

Lumen width (µm) of the fibre was measured from macerated wood samples by measuring width of the lumen at cross sectional area through Motic Image Analysis Software.

$$\text{Slenderness ratio} = \frac{\text{Fibre length}}{\text{Fibre diameter}}$$

(Varghese et al. 1995)

$$\text{Flexibility Coefficient} = \frac{\text{Fibre lumen width}}{\text{Fibre diameter}} \times 100$$

(Wangaard, 1962)

$$\text{Runkel ratio} = \frac{2 \times \text{Fibre wall thickness}}{\text{Fibre lumen width}}$$

(Runkel, 1949)

$$\text{Rigidity Coefficient} = \frac{\text{Fibre wall thickness}}{\text{Fibre diameter}}$$

(Tamolang and Wangaard, 1961)

The values were then compared to those of softwoods and hardwoods to assess the suitability of the plant raw materials for paper production.

2.9 Statistical analysis

The data were subjected to statistical scrutiny through an analysis of variance and treatment differences were tested by 'F' test (Panse and Sukhatme 1978). The stage wise data were analyzed separately in single factor analysis, using AGRES software.

3. Results and Discussion

3.1 Physical properties of wood chips

The physical properties of wood particularly basic density, bulk density and wood moisture content are highly essential. The influence of moisture content and its effect on dimensional stability are studied as a basic concern when using any forest products. It is not usually desirable to use the material that experiences rapid moisture changes because moisture affects the physical and mechanical properties of wood materials (Anon, 1992; Ahamad and Kamke, 2005). The wood density of 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. In the current study, the physical properties studied had exhibited variation in different age gradation wood samples in *T. populnea* (Table 1). The highest basic density (494.60 kg /m^3) and bulk density (278.00 kg /m^3) and lowest moisture content (10.67 per cent) was observed in five year old wood samples of *T. populnea*, the lowest basic density (428.30 kg/m^3), bulk density (227.00 kg /m^3) and highest moisture content (12.17 per cent) were recorded in two year old wood sample. This results showed that basic density and bulk density of *T. populena* wood increases with age while moisture content decreased with increase in age of the tree. Mcdonough et al. (2011) reported that *Pinus taeda* wood had higher specific gravity for 22 year old wood sample (0.50) and lower specific gravity for 13 year old wood sample (0.46). Similarly Izekor et al. (2010) reported the mean density values, based on oven-dry weight and volume were 480, 556 and 650 kg m^{-3} for 15, 20 and 25-year old *T. grandis* wood. Shukla et al. (2007) reported that the average standard specific gravity was highest in 13 year old trees (0.62) followed by 12 year (0.60) and 8 year old trees (0.57) in *Acacia auriculiformis*. Similar results were reported among various Eucalyptus species for basic density which ranged between 425 kg per m^3 and 542 kg per m^3 (Vennila, 2009).

The wood density properties are of major importance for the production of quality pulp and paper. The amount of wood needed to produce one ton of air dried pulp is calculated from the density and pulp yield (Storebraten**,** 1990). Therefore the high density recorded in the five year old *T. populnea* wood sample play a significant role in production of air dried pulp. Chips classification results revealed that five year old wood sample of *T. populnea* yielded the accepted chips (+7 mm) for cooking which was around 83.00 per cent and dust is only 0.40 per cent. This is the accepted size for pulping due to the optimal chips classification. The heat transfer and chemical penetration during pulping may be uniform in all cases. Hence the optimal chip classification found in five year old wood sample of *T. populnea* is acceptable for paper industries.

3.2 Chemical properties of wood chips

The proximate chemical analysis gives an idea of potentiality of raw material for paper making (Rao et al. 1999). The chemical analysis in terms of ash content recorded was highest in two year old sample (1.29 per cent) of *T. populnea* and lowest in five year old sample (0.87 per cent) which implies that ash content decreases with the increase in the age of the *T. populnea* wood. Goel and Behl (1996) recorded variation in ash content with relation to the age of the tree. The highest wood ash was observed in all the treatments in *Terminalia arjuna* (5, 10- and 15-year-old trees) as compared with that in other tree species in respective ages. The ash content decreased by 1 per cent and 1.6 per cent in *Acacia nilotica* and *Prosopis julifora*, respectively for 15-year old trees as compared to 5-year old trees. High content of ash will have negative impact on the chemical recovery process and, therefore, could constitute a serious drawback (*Khiari* et al. 2010). Similar results were also reported by several workers (Amaducci et al. 2000; Diaz et al. 2007; Lopez et al. 2008). Hence the low ash content reported in five year old wood sample of *T. populnea* indicated that *T. populnea* at five years could be harvested for paper industries as it is congenial for chemical recovery method (Table 2). All of the soluble material comes under the category of extractives, and these are totally undesirable in pulp and paper making. The water and alcohol-benzene soluble substances affect the pulp yield, paper quality and drainage characteristics of paper machine. In the present study two year old *T. populnea* wood sample recorded lowest solubility in alcohol benzene extractive, hot water and one per cent NaOH as compared to other age gradations and the five year old wood sample registered highest solubility in alcohol benzene extractive, hot water solubility and one per cent NaOH. The lower extractives will create lesser pitch problems and also proved more homogeneity in paper sheet (Kasiviswanathan, 1998).

Table 1. Physical characteristics of *Thespesia populnea* wood chips at different age gradations

Age in Years	Moisture (%) as received	Bulk density (OD basis) (kg m^{-3})	Basic density (OD basis) (kg m^{-3})	Chips classification (%)				
				+ 45 mm	+ 8mm (over thick)	+ 7 mm (accepts)	+ 3 mm (pin chips)	3mm (dust)
2	12.17	227.00	428.30	Nil	5.10	77.60	16.50	0.80
3	11.73	245.00	456.50	Nil	5.40	77.80	16.20	0.60
4	11.25	262.00	479.70	Nil	6.20	79.00	14.40	0.40
5	10.67	278.00	494.60	Nil	6.60	81.00	12.00	0.40
Mean	11.45	253	464.77	-	5.82	78.85	14.77	0.55
SEd	0.19	3.92	7.30	-	0.20	1.34	0.50	0.09
CD(0.5)	0.53	10.89	20.28	-	0.40	2.98	1.12	0.27

Table 2. Chemical composition of *Thespesia populnea* wood samples at different age gradations

Age in Years	Ash	Solubility in			Acid insoluble lignin	Pentosans (ash corrected)	Hollocellulose (ash corrected)
		Hot water	1 per cent NaOH	Alcohol benzene			
2	1.29	3.5	11.20	2.64	26.51	13.90	70.33
3	1.05	3.9	11.75	3.01	27.94	14.20	70.15
4	0.95	4.20	12.93	3.85	29.15	15.55	69.85
5	0.87	5.50	14.10	4.27	30.23	16.45	69.14
Mean	1.04	4.27	12.49	3.44	28.45	15.02	69.86
SEd	0.0192	0.0626	0.1932	0.0504	0.4491	0.2361	1.1462
CD (0.05)	0.0533	0.1738	0.5365	0.1400	1.2468	0.6557	3.1823

One per cent NaOH solubility, which measure low molecular weight carbohydrates, lower in two year old (11.20 per cent) *T. populnea* sample compared to five year old sample (14.10 %). This indicated that *T. populnea* pulp resistance to degradation due to light, heat and fungal decay is low in first year wood sample and high in five year wood sample (Table 2). The holocellulose results showed that the studied pulp resources were found to be significantly different. Two year old *T. populnea* was found to be superior for its holocellulose value (70.33 per cent) followed by three, four and five year old sample. This result showed that *T. populnea* is suitable for pulpwood from second year onwards. Similar results were observed in *Pinus taeda* at different age gradation (Mcdonough et al. 2011) and in *Anthocephalus cadamba* at different heights of the tree (Lal et al. 2010). Low lignin content was reported in two year old (26.51 per cent) *T. populnea* compared to five year old (30.23 per cent) sample which recorded the highest lignin content. Low lignin content of a ligno-cellulosic material reduces pulping time and chemical change compared to those of other non-wood raw materials (Lopez et al. 2008; Diaz et al. 2007). Furthermore, higher contents of lignin are predicted to consume more chemicals (Khristova et al. 2005). This result established that younger age trees of *T. populnea* are also suitable for paper industry considering lignin content as a parameter (Table 2).

3.3 Anatomical properties of wood chips

Regarding wood anatomical properties, the observations were made on fibre morphology from their corresponding analysis. Relationships in wood fibers can be a complex mixture of direct and indirect links which determine the pulping properties. There is considerable evidence in the wood profile study of *T. populnea* which suggest that fibre morphology appears to be influenced by age. *T. populnea* may be recommended for pulp and paper making from the age of five year based on the fibre morphology. However based on elaborate study on physical and chemical properties of four age gradations, it is concluded that the profitable age of harvest for pulp wood is five years (Table 3).

Conclusion

In a holistic perspective, the result of the current study apparently indicates that *T. populnea* is amenable for pulp and paper industry due to superior pulp yield and quality.

Table 3. Fibre morphology of *Thespesia populnea* at different age gradations

Sl. No	Anatomical properties	Age in years						
		2	3	4	5	Mean	SEd	CD(0.05)
1.	Fibre Length (μm)	579.58	621.25	739.58	788.33	682.185	10.3744	28.8045
2.	Fibre Diameter (μm)	36.20	37.65	38.01	38.42	37.57	0.6023	1.6350
3.	Fibre Wall Thickness	6.5	7.32	7.75	8.95	7.63	0.1149	0.3189
4.	Fibre Lumen Width	23.20	22.37	22.15	20.52	22.06	0.3717	1.0320

The productivity also indicated that *T.* populnea is fast growing trees with multifarious utility extend greater scope of its utility for various wood based industries. We recommended five year rotation for *T.* populnea for pulp and paper industry among the four age gradations studied. However, it is necessary to determine the growth rates and productivity of this species under different ecological conditions and its optimum planting wood density.

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