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COMPARISON FOR PHYSICO-MECHANICAL PROPERTIES OF FARM-GROWN *EUCALYPTUS CAMALDULENSIS* DEHN. WITH CONVENTIONAL TIMBERS

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Abstract

This paper deals with physical and mechanical wood quality properties of farm-grown *Eucalyptus camaldulensis* Dehn. in comparison to conventional timbers i.e., *Dalbergia sissoo* Roxb., *Acacia nilotica* Del. and *Cedrus deodara* Roxb. Tests were conducted using standardized, defect-free test specimens as per corresponding mechanical property. The mean values of wood density, static bending-MOR, maximum compressive strength parallel to grain and perpendicular to grain, maximum tensile strength, impact bending and nail holding capacity of *E. camaldulensis* were recorded as 0.681 g cm^{-3}, 1046 kg cm^{-2}, 88 kg cm^{-2}, 56 kg cm^{-2}, 610 kg cm^{-2}, 578 kg cm^{-1}, 129 kg cm^{-1}, respectively. Findings of our study suggest that *E. camaldulensis* wood can be used as an appropriate substitute of hard/soft woods due to their short supply. Feasible strategies need to be promoted for its efficient and versatile utilization in various usable sectors.

Introduction

Wood is a natural material with variations in properties of texture, color, density and strength. It has been used for many purposes because of its excellent characteristics such as a good strength to weight ratio and aesthetic appearance (Ates *et al.,* 2009). It is indubitably one of the best materials for pulp, packing, building construction, furniture, sports goods and innumerable industrial uses. Increased demand for wood has caused a dramatic decease in forest resources. To meet this ever-increasing demand, it is necessary to use appropriate production techniques for best yield.

Over 8 million hectares in the world has been afforested with various eucalyptus species (Turnbull, 1991). Among other species, *Eucalyptus camaldulensis* is fairly rapid growing timber species (Mean Annual Increment-MAI 10-25 m^3 ha^{-1} yr^{-1}) as compared to conventional timbers (*Dalbergia sissoo, Acacia nilotica, Cedrus deodara* 7.5, 4-15, 6-9 m^3 ha^{-1} yr^{-1}, respectively) and can be harvested in a short time as it attains a suitable dbh (diameter at breast height) in a short time. It has been introduced from its specific location Australia to Indo-Pak sub-continent under various social forestry programmes to cope with the increasing demand of wood supply. It is adapted to a variety of ecological conditions and consequently has been planted frequently and is especially favored on farmlands (Siddiqui & Mahmood, 1986, Abbas *et al.,* 2010, Ashraf *et al.,* 2012).

E. camaldulensis wood is extensively used in some industrial processes like pulp, paper, chipboard and plywood manufacturing (Abbas *et al.*, 2010). However, despite abundant supply, its wood has not yet gained any distinct utilization share in view of various questions about its strength properties and problems relating to seasoning. There is a general concept among the people about its so-called “poor" wood quality and strength properties. Therefore, this wood has received little attention as an alternate raw material for domestic sector. People generally prefer conventional timbers (*D. sissoo, A. nilotica, C. deodara*) to *E. camaldulensis* for manufacturing various items like furniture, joinery, construction material, etc. As the supply of timber of these species is limited which can not cope with ever-increasing demands, efforts were made in present study to characterize the farm-grown *E. camaldulensis* and conventional timbers for comparison to get scientific basis for promoting efficient and diversified utilization in domestic sector.

Materials and Methods

In order to collect material to be utilized for present trials as per minimum standard required by ASTM (American Society for Testing Materials) in population characterization, six identical farm-grown trees of each species (*E. camaldulesis, D. sissoo, A. nilotica* with dbh 30 cm) were harvested from the research area of Department of Forestry, Postgraduate Agricultural Research Station *(Lat. 31°30' N, Long. 73°05' E)*, University of Agriculture, Faisalabad, Pakistan and converted into 2 m long logs where as scants of *C. deodara* were purchased from local timber market and converted into planks. To evaluate comparative wood properties of each timber, defect free specimens (n = 20 for each species) of 2×2 cm cross sectional area were sawn starting from the side of plank up to the pith. Dimension of specimens for various physical and mechanical tests is given in Table 1.

Table 1. Dimension of test specimens used for physico-mechanical tests.

Wood quality tests	Dimension (cm)
Wood density	5×2×2
Static bending	30×2×2
Compression strength parallel to grain	5×2×2
Compression strength perpendicular to grain	5×2×2
Maximum tensile strength	7.5×2×2
Impact bending test	30×2×2
Nail holding capacity	10×2×2

Specimens were air dried at 20-25°C for a period of 10 weeks, whereas specimens for wood density were kept in oven at 70°C for such period till each sample got moisture free and gained a constant mass. Strength properties including static bending, compression strength parallel to grain, compression strength perpendicular to grain, tensile strength and impact bending were determined by using ASTM D-143-94 and ASTM D-2395-93 procedures (Anonymous 1996). The data were subjected to analysis of variance to find out statistically significant relationship among various parameters by using MSTATC programme (version 2.10).

Results

Physico-mechanical parameters: The tested timber species viz., *E. camaldulensis*, *A. nilotica*, *D. sissoo* and *C. deodara,* differ a lot in various physical and mechanical strength properties (Table 2). Various wood properties of timber species are investigated in the present study and related parameters are described here under.

Table 2. Physico-mechanical properties (± SD) of *E. camaldulensis* and conventional timbers.

Properties investigated	*E. camal.* (n= 20)	*D. sissoo* (n= 20)	*A. nilotica* (n= 20)	*C. deodara* (n= 20)
Density (g cm^{-3})	0.681^{c} (0.018)	0.738^{b} (0.007)	0.809^{a} (0.013)	0.515^{d} (0.062)
Static bending (Modulus of rupture-MOR kg cm^{-2})	1046^{c} (16.2)	1152^{b} (18.04)	1357^{a} (32.45)	821^{d} (67.92)
Maximum compression parallel to grain (kg cm^{-2})	88^{d} (2.24)	101^{b} (2.61)	132^{a} (3.95)	91^{c} (2.76)
Maximum compression perpendicular to grain (kg cm^{-2})	56^{d} (3.47)	68^{b} (4.09)	80^{a} (4.06)	60^{c} (1.94)
Tensile strength (kg cm^{-2})	610^{c} (67.2)	682^{b} (71.8)	756^{a} (37.4)	503^{d} (13.8)
Impact bending (kg cm^{-1})	578^{d} (62.4)	601^{d} (65.87)	684^{a} (31.8)	661^{b} (15.26)
Nail holding capacity (kg cm^{-1})	129^{d} (3.54)	173^{b} (5.87)	221^{a} (5.87)	142^{c} (4.06)

*Means with different superscript alphabets differ significantly at $p \leq 0.001$

Density (g cm^{-3}): The comparison of individual treatment means for density showed statistically significant differences (F=1067, df=3, $p \leq 0.001$) in the order *A. nilotica* > *D. sissoo* > *E. camaldulensis* > *C. deodara*. As per results, it is obvious that density values of *A. nilotica* and *D. sissoo* with 0.809 and 0.738 respectively, are higher to that of *E. camaldulensis* (0.681) whereas the lowest value for density was recorded for *C. deodara* (0.515).

Static bending (modulus of rupture-MOR kg cm^{-2}): MOR showed statistically significant differences (F=919, df=3, $p \leq 0.001$) as observed in case of *A. nilotica* > *D.sissoo* > *E. camaldulensis* > *C. deodara*. MOR values of 1357 and 1152 were the highest for *A. nilotica* and *D. sissoo* respectively, among the tested wood to that of the lowest value of MOR (821) recorded for *C. deodara*.

Maximum compression strength parallel to grain (kg cm^{-2}): Individual treatment means for maximum compression strength parallel to grain showed significant differences (F=1015, df=3, $p \leq 0.001$) as observed, *A. nilotica* > *D. sissoo* > *C. deodara* > *E. camaldulensis.* The compression strength values of 132, 101 and 91 were recorded in *A. nilotica, D. sissoo* and *C. deodara,* respectively with high values while a value of 88 was the lowest one recoded in wood of *E. camaldulensis*.

Maximum compression strength perpendicular to grain (kg cm^{-2}): Maximum compression strength perpendicular to grain showed statistically significant differences (F=564, df=3, $p \leq 0.001$) recorded as *A. nilotica* > *D. sissoo* > *C. deodara* > *E. camaldulensis.* Therefore, got the values of compression strength in *A. nilotica, D. sissoo* and *C. deodara* (80, 68 and 60, respectively) and the lowest one (56) for *E. camaldulensis*.

Tensile strength (kg cm^{-2}): Tensile strength of the individual treatment means showed statistically significant differences (F=1877, df=3, $p \leq 0.001$) among the trees in sequence of *A. nilotica* > *D.sissoo* > *E. camaldulensis* > *C. deodara* which indicated that tensile strength values for *A. nilotica* and *D. sissoo* (756 and 682 respectively) were higher to that of observed in *E. camaldulensis* (610) whereas, the lowest value (503) was recorded for *C. deodara*.

Impact bending (kg cm^{-1}): Impact bending showed statistically significant differences (F=440, df=3, $p \leq 0.001$) after the comparison of individual treatment means were observed in order of C. *deodara* > *A. nilotica* > *D. sissoo* > *E. camaldulensis*. In case of *C. deodara, A. nilotica* and *D. sissoo* values of 667, 640 and 601, respectively, were recorded while the lowest value (578) was observed in *E. camaldulensis*.

Nail holding capacity (kg cm^{-1}): The comparison of individual treatment means for nail holding capacity showed statistically significant differences (F=594, df=3, p≤0.001) in order *A. nilotica* > *D. sissoo* > *E. camaldulensis* > *C. deodara.* Nail holding capacity values in *A. nilotica, D. sissoo* and E. *camaldulensis* were observed as 221, 173 and 142, respectively while the lowest value (129) was recorded in *C. deodara*.

Discussion

D. sissoo, *A. nilotica* and *C. deodara* are the principal hard/soft wood species that are extensively utilized for a variety of purposes in Pakistan. In present study, physico-mechanical properties of *E. camaldulensis* wood were compared with aforementioned conventionally preferred timbers. Results presented in Table 2, indicate significant differences among these timber species for various wood quality parameters (basic density, static bending MOR, maximum tensile strength, impact bending, and hardness). *E. camaldulesis* exhibited physical and strength properties comparable with *A. nilotica* and *D. sissoo* and even better than *C. deodara* in some properties like density, MOR and tensile strength. These results suggest that Eucalyptus wood can be technically used as a good substitute of these hardwoods due to their short supply.

Our results are in line with research work of other scientists who have compared wood quality of *E. camaldulensis* with other timber species. Kumar *et al.,* (1981) found that physical and mechanical properties of air-dried *E. camaldulensis* were inferior to those of teak and classified it as hard, heavy, moderately strong, not tough, liable to wrap and possibility to crack badly showed results are in the line we have in our study. Our results also coincide with the findings reported by the previous workers as Siddiqui & Mahmood (1986), Sturion *et al.,* (1987), Brouard *et al.,* (1989) and Siddiqui *et al.,* (1989). Similarly Chapola & Ngulube (1990) measured basic density of 5-8 year old tree species (14 Eucalyptus sp., *Albizzia lebbek, Cassia siamea, Gmelina arbobera* and *Melia azedarach*) from nine sites suitable for particular end uses and found that density varied significantly between species ranging 300-700 kg m^{-3}. Arslan *et al.,* (1997) compared physical, mechanical and technological properties of *E. camaldulesis* with other Eucalyptus species on regional base according to mathematical/statistical methods and suggested productive usable areas. Brunetti *et al.,* (2001) conducted studies on some physical and mechanical properties of 30-years-old Atlas cedar (*Cedrus atlantica* Manetti) and characterized it by rather good values highlighting that the wood was very stable and that the structural efficiency of the wood was high compared to that of the most utilized softwood species for structural purposes.

The physical and mechanical properties of wood can vary as a result of environmental conditions, soil type (Gundogan *et al.,* 2005; Abbas *et al.,* 2010), silvicultural factors, tree age, tree anatomy (Bhat & Priya, 2004) and even the position of the test piece within the tree (DePalacios *et al.,* 2008). Souza *et al*., (2009) evaluated 6-8 year old wood of *E. camaldulensis* and *E. urophylla* for various strength properties like cut by a table saw either parallel or perpendicular to the grain; shaping; planning; drilling; routing, etc. to evaluate their possible use by the furniture industry and concluded that wood was quite appropriate for furniture production. Regarding some differences for values in density and strength properties of *E. camaldulensis* in the present study and values determined earlier, the variations might be due to various factors like site location, planting density or genetic make up. Considerable variations in strength properties of *E. camaldulensis* species should be expected when it is grown at different sites. Therefore, it is suggested that additional studies are needed to determine full range of variation in wood quality within a species on regional basis.

Conclusion

On the basis of comparison of the physico-mechanical properties, it may be concluded that farm-grown *E. camaldulensis* wood can be used for all purposes in which highly strong and hard timbers are needed. Thus, its wood seems appropriate as alternate raw material for furniture, housing construction, wooden columns, beams, roof truss members, props, paving blocks, floors, ship decking, load bearing blocks, poles, communication poles, agricultural implements as well as other traditional wood based products. Therefore, there are strong prospects for commercial uses of this wood for technological and economical advantages.

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