Indian Journal of Ecology (2024) 51(2): 272-276
DOI: https://doi.org/10.55362/IJE/2024/4229

Manuscript Number: 4229
NAAS Rating: 5.38

Genetic Variation in Wood Mechanical Properties Among *Eucalyptus* Clones

S.A. Huse, R.P. Gunaga, S.K. Sinha and L.K. Behera
College of Forestry, Navsari Agricultural University, Navsari-396 450, India
E-mail: santoshhuse@nau.in

***Abstract*:** *Eucalyptus* spp. is considered as major commercial fast-growing pulp-wood species of Gujarat. Farmers of this region are keen interested in cultivation of this species. Therefore, study was carried out in the campus of Navsari Agricultural University, Navsari, Gujarat to evaluate eighteen different high yielding clones of *Eucalyptus* for its yield and strength properties. The trial was established in randomized block design with three replications and planted at 2 X 2m spacing. At the age of four years, trees were selected and harvested for recording wood mechanical properties such as compressive strength, tensile strength and static bending (MoE and MoR) to understand the suitability of wood for different end uses including pole. Result shows that the compressive strength, MoE and MoR varied significantly among 18 clones. Further, the basic density of wood had positive correlation with MoE (r=0.561) and MoR (r=0.571). Among 18 *Eucalyptus*clones, EC-12>EC-8>EC-4>EC-5>EC-11 performed superior in terms of mechanical strength, hence, these clones are suggested for pole to be utilized in various structural applications. Among 18 *Eucalyptus* clones, EC-12>EC-8>EC-4>EC-5>EC-11 performed superior in terms of mechanical strength, hence, these clones are suggested for pole to be utilized in various structural applications.

***Keywords*:** Clonal variation, Compressive strength, *Eucalyptus* spp., Static bending, Tensile strength

Eucalyptus spp. is a major exotic tree species grown throughout the country for the production of pulp and paper as well as pole for construction (Luna et al 2009, Huse et al 2018). In Gujarat, forest department and paper & pulp industries are raising *Eucalyptus* plantation commercially across the state for pulp, plywood and as a pole for construction purpose. By looking into the economic benefit and early rotation, several farmers of Gujarat are growing *Eucalyptus* in their farmlands as block plantation and on the farm bunds also (Huse et al 2016). It is important to understand the genetic variation in mechanical properties as well as suitability of *Eucalyptus* clones in the south Gujarat condition so that suitable clones for large scale plantation in this agroclimatic situation can be selected in order to obtain higher productivity as well as profitability (Huse et al 2012). Mechanical properties of wood such as compressive strength parallel to grain, compressive strength perpendicular to grain, shear strength parallel to grain, static bending strength, impact bending strength, tensile strength perpendicular to grain and hardness are the most commonly measured strength parameters to test the suitability of timber for various end uses (Izekor et al 2010, Pima 2015, Saravanan et al 2014). Since *Eucalyptus* is highly used for pole purpose by the construction industries, especially in south Gujarat, so there is a great demand for good genotypes that provide good strength as pole. Hence, the present investigation was undertaken with an objective to identify the superior clones using 18 commercial *Eucalyptus* clones for short rotation forestry that suits for pole requirement by the construction industry well spread along the industrial corridor connecting Mumbai and Ahmadabad.

MATERIAL AND METHODS

Study area: The present investigation was carried out at Navsari Agricultural University, Navsari, Gujarat, India (20.95^0 N latitude, 75.90^0 E longitude and at 12 m MSL) during 2014-15 to 2016-2017. This region belongs to tropical climate characterized by fairly hot summer, moderately cold winter and more humid and warmer monsoon with average annual precipitation of 1355 mm.

Methodology: This paper covers the research findings of the clonal evaluation trial laid out with 18 commercial *Eucalyptus* clones including four from Institute of Forest Genetics and Tree Breeding, Coimbatore, Tamil Nadu. The trial was established for a period of four years following Randomized Block Design (RBD) at Navsari Agricultural University, Navsari. In the present study, total six ramets (trees) per clone were harvested at the age of four and used for assessment of wood mechanical property variation among 18 clones. Wooden samples were collected from all the harvested clones and the mechanical properties such as static bending, compressive strength parallel to grain and tensile strength parallel to grain were estimated following Rajput et al (1996) with Indian Standard Specification IS

1708 (Part 1-18):1986 (ISI 1986). These properties were tested by using Universal Testing Machine (UTM) of 50 kN capacity (Make: Shimadzu Analytical Private Limited).

For determination of compressive strength parallel to grain (MCS), the specimens were prepared as per IS: 1708 (Part 8)-1986. Specimens were having cross-sections 2 x 2 cm and 8 cm in length and the rate of loading was 0.6 mm min^{-1}. The compressive strength parallel to the grain (MCS in kg cm^{-2}) was calculated by the equation:

$$\text{Maximum crushing strength (MCS)} = \frac{Pmax}{A}$$

Where, Pmax = maximum crushing load at break point (Kg) and A = area of cross section of the specimen on which force was applied (cm²).

Tensile strength: The test specimens for tensile strength were prepared are as per IS: 1708 (Part 12)-1986. Specimens used were dumbbell shaped and had cross section of 2 x 2 cm and length of 26.4 cm. The tensile strength parallel to grain (TS at ML in $kgcm^{-2}$) was calculated.

$$\text{Tensile stress at maximum load (TS at ML)} = \frac{Pmax}{A}$$

where, P max = maximum load required for failure perpendicular to grain (Kg) and A = area of the spe cimen on which force was applied (cm²).

Static bending strength: For determination of static bending strength, the specimens were prepared as per IS: 1708 (Part 6)-1986. Specimens used were having a cross-section of 2 x 2 cm, length of 30 cm and with span length of 28 cm. The loading was applied at a constant rate of 1.0 mm/min on the tangential surface of the sample. Static bending strength parameters such as modulus of rupture (MoR in kg cm^{-2}) and modulus of elasticity (MoE in kg cm^{-2}), were worked out.

$$\text{Modulus of rupture (MoR)} = \frac{3 \times Pmax \times 1}{2 \times b \times h^2}$$

$$\text{Modulus of elasticity (MoE)} = \frac{P \times 1^3}{4 \times D \times b \times h^3}$$

Where, P = load at the limit of proportionality (kg); Pmax = maximum load (kg), l = span of the test specimen (cm), b = breadth of the test specimen (cm), h = depth of the test specimen (cm), D = deflection at the limit of proportionality (cm).

Statistical analysis: The experimental data were subjected to statistical analysis using statistical software (Sheoran et al 1998). Pearson's correlations analysis was performed to determine the relationship between wood density and the mechanical properties using the same software.

RESULTS AND DISCUSSION

Clonal variation for mechanical strength: The maximum crushing stress showed non-significant variation among 18 clones, however, the mean values varied from 445.60 to 592.77 kg cm^{-2}. Similar to tensile strength, clones EC-12, EC-10 and EC-11 also showed higher compressive strength than other clones. Similar range of variation for compressive strength was reported by Pima (2015) and ranged from 427.6 to 583.48 kg cm^{-2} among eucalypts clones (Table 1).

The tensile strength varied significantly from 751.46 (clone EC-6) to 1250.20 kg cm^{-2} (clone E-4) with overall mean 966.74 kg cm^{-2}. The clones such as EC-4, EC-12 and EC-11 recorded high tensile strength parallel to grain and may be good for roof trusses.

Static bending : The static bending strength varied significantly among 18 *Eucalyptus* clones. The modulus of elasticity (MoE) ranged from 667.08 $x10^2$ (clone EC- 18) to 1320.81 x 10^2 kg cm^{-2} (clone EC-12) among 18 clones with overall mean 950.25 x 10^2 kg cm^{-2}. Pima (2015) also reported similar observations where MoE estimated for various *Eucalyptus* clones ranged from $869x10^2$ to $1296x10^2$ kg cm^{-2}. This variation among clones is attributed by genetic characters. However, several wood anatomical properties may also affect the MoE of wood (Bhat and Priya 2004). For instance, thicker fiber wall and longer fiber length may affect the MoE (Pima 2015). Moreover, the sapwood and heartwood samples extracted from a same wood log may show variation in mechanical properties. Bal and Bektas (2013) studied the variation in mechanical properties of sapwood and heartwood of *E. grandis* and similar values of MoE reported to be 100.40 and $841.20x10^2$ kg cm^{-2} respectively in sapwood and heartwood for *E. grandis*.

The values of MoR ranged from 782.70 (clone EC-16) to 1527.32 kg cm^{-2} (EC-12) with overall mean 1004.98 kg cm^{-2}. Such observation was also recorded by several scientists in *Eucalyptus* spp. (Olufemi and Malami 2011; Bal and Bektas 2013, Pima 2015) and their range for MoR were in line with our result. Among 18 *Eucalyptus* clones, E-12, E-4 and E-8 clones showed higher MoR and MoE values in static bending.

Comparative profile of mechanical properties of seven *Eucalyptus* species and some other important timber yielding species is overviewed at Table 2. The findings of this experiments on various mechanical properties studied in *Eucalyptus* clones are comparable not only with the standard timber Teak (Shukla et al 2007) but also with *Melia dubia* (Saravanan et al 2014), *Casuarina* spp. (Patel 2023) and with some other lesser-known trees of Mizoram (Hegde 2019) too. This shows the suitability of some superior tested clones of *Eucalyptus* for its use as poles and for other structural applications.

Correlation between mechanical properties with wood density: The relationship between wood mechanical

Table 1. Clonal variation for wood mechanical properties among 18 *Eucalypts* clones at 4 years age

Clone	Compressive strength parallel to grain [MCS (kg cm^{-2})]	Tensile strength parallel to grain [TS at ML (kg cm^{-2})]	Static bending	
			MOE (10^2 kg cm^{-2})	MOR (kg cm^{-2})
EC-1	445.60	960.36	1023.30	857.73
EC-2	546.05	869.38	1086.45	1046.28
EC-3	539.53	871.00	991.51	900.87
EC-4	529.14	1250.20	1025.25	962.51
EC-5	535.81	1001.46	976.95	1107.61
EC-6	546.21	751.46	1135.79	1106.49
EC-7	509.72	1024.08	905.25	963.35
EC-8	582.68	985.83	972.06	1039.92
EC-9	529.01	967.95	935.62	1178.06
EC-10	581.92	1004.46	915.56	951.59
EC-11	549.01	1149.51	911.12	965.24
EC-12	592.77	1184.8	1320.81	1527.32
EC-13	454.56	940.49	908.95	874.88
EC-14	461.66	775.34	786.41	1020.03
EC-15	473.82	911.57	851.52	1016.77
EC-16	495.37	999.47	848.90	782.70
EC-17	532.59	849.57	841.92	973.59
EC-18	472.58	904.33	667.08	814.69
Mean	521.00	966.74	950.25	1004.98
CD (p=0.05)	NS	176.84	136.39	144.23

Table 2. Comparative profile of mechanical properties of *Eucalyptus* spp. and other timber species

Species/ Mechanical properties	Compressive strength parallel to grain [MCS (kg cm^{-2})]	Bending strength [TS at ML (kg cm^{-2})]	MoE (x10^2 kg cm^{-2})	MoR (kg cm^{-2})	References
Eucalyptus clones	490 to 650	-	-	-	Pima et al. (2000)
E. urophylla x E. grandis	742	1410	1734	-	Anon. (2006)
E. grandis	570	1230	1268	-	Anon. (2006)
E. urophylla	620	1730	2547	-	Anon. (2006)
E. tereticornis	770	1460	1739	-	Anon. (2006)
E. camaldulensis	619	-	1532	1333	Olufemi and Malami (2011)
E. saligna	394	-	-	-	Olufemi and Malami (2011)
E. robusta	286	-	-	-	Olufemi and Malami (2011)
E. grandis	458	-	-	-	Olufemi and Malami (2011)
E. butryoides	553	-	-	-	Olufemi and Malami (2011)
E. grandis sapwood	600	-	1007	1000	Bal and Bektas (2013)
E. grandis heartwood	520	-	841	840	Bal and Bektas (2013)
Eucalyptus clones	419 to 572	-	853 to 1271	725 to 1085	Pima (2015)
Casuarina hybrids	364	553	737	800	Patel (2023)
Thespesia populnea	358	-	726	787	Kantariya and Sinha (2023)
Tectona grandis	520	-	1170	941	Shukla et al. (2007)
Melia dubia	-	-	684	852	Saravanan et al. (2014)
Anogeissus acuminata	728	-	806	970	Hegde (2019)
Castanopsis tribuloides	592	-	865	777	Hegde (2019)
Duabanga grandiflora	408	-	751	719	Hegde (2019)
Schima wallichii	618		882	1021	Hegde (2019)

Units for mechanical properties are brought under common unit.

Table 3. Correlation between basic density and mechanical properties in *Eucalyptus* clones using Pearson's Correlation analysis

Physical & mechanical properties	CS	TS	MoE	MoR	BS
1. CS (Compressive strength parallel to grain)	1.000				
2. TS (Bending strength)	0.337^{NS}	1.000			
3. Modulus of Elasticity (MoE)	0.561^{*}	0.312^{NS}	1.000		
4. Modulus of Rupture (MoR)	0.571^{*}	0.237^{NS}	0.709^{**}	1.000	
5. Basic density (BS)	0.363^{NS}	0.247^{NS}	0.650^{**}	0.867^{**}	1.000

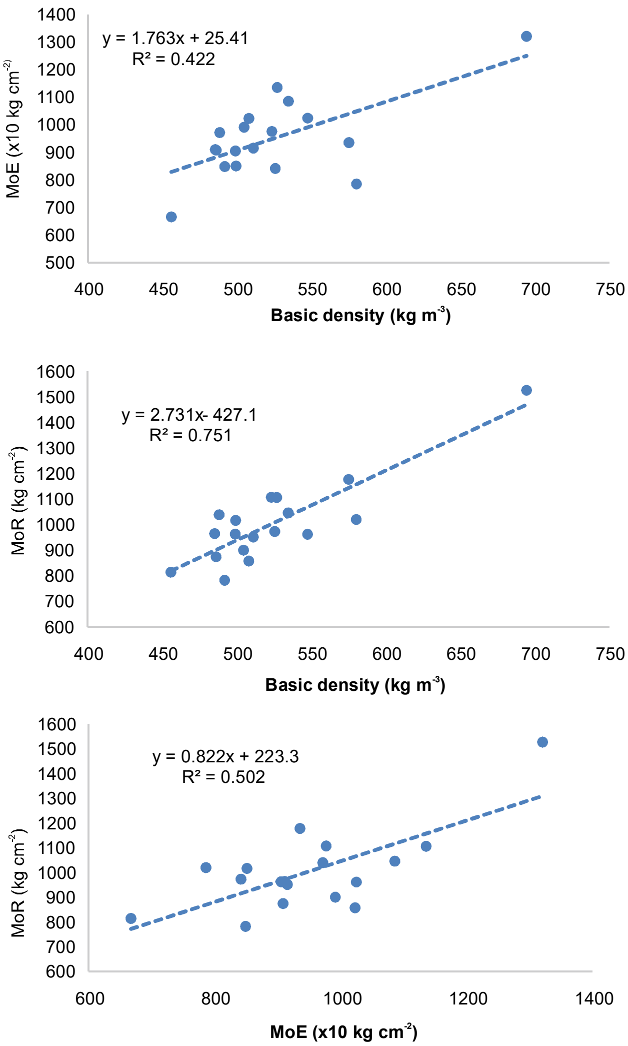

Fig. 1. Association between basic density of wood with MoE and MoR among 18 *Eucalyptus* clones

properties with basic density among 18 *Eucalyptus* clones was assessed. There was a significant correlation between compressive strength (parallel to grain) with MoE (r=0.561) and MoR (r=0.571); however, it was non-significant between compressive strength (parallel to grain) and tensile strength (parallel to grain). Furthermore, MoE was also positively correlated with MoR (Table 3). Basic density is one of the important physical parameters used in the assessment of wood quality, hence, basic density of wood was correlated with all the four wood mechanical properties. The basic density of wood showed positive correlation with MoE and MoR. Figure 1 shows the influence of basic density of wood on MoE and MoR and between MoE and MoR. Similarly, Edward and Matsumura (2016) also found a strong positive significant linear relationship between MoE and MoR in *Pinus kesiya.* Sharma et al (2005) also worked out correlation between wood density with mechanical properties and observed positive relationship in *Eucalyptus tereticornis*. This indicated that wood density can potentially be used as an indicative trait for predicting mechanical properties of wood in *Eucalyptus* spp.

CONCLUSION

Among 18 *Eucalyptus* clones studied for variation in wood mechanical properties, EC-12>EC-8>EC-4>EC-5>EC-11 clones showed superior wood quality in terms of mechanical properties. Therefore, these clones can be used as pole for various structural applications. Moreover, these selected clones may be used for commercial plantations and also for further breeding programme to obtain higher productive potential.

AUTHORS CONTRIBUTION

Dr. R. P. Gunaga helped in technical aspects, Dr. S.K. Sinha helped in wood analysis and Dr. L.K. Behera helped in field data collection.

REFERENCES

Anonymous 2006. *Guide on utilization of Eucalyptus and Acacia plantations in China for solid wood products*. Technical Report of ITTO Project PD 69/01 Rev.2 (I). Research Institute of Wood Industry, Chinese Academy of Forestry, Beijing. 183p.

Bal BC and Bektas I 2013. The effects of heat treatment on some mechanical properties of juvenile wood and mature wood of *Eucalyptus grandis. Drying Technology* **31**(4): 479-485.

Bhat KM and Priya PB 2004. Influence of provenance variation on wood properties of Teak from the Western Ghat region in India. *IAWA Journal* **25**(3): 273-282.

Desch HE and Dinwoodie JM 1981. *Timber: its structure, properties and utilization.* 6th Edition, Macmillan London, 410p.

Edward Missanjo and Junji Matsumura 2016. Wood density and mechanical properties of *Pinus kesiya* Royle ex Gordon in Malawi. *Forests* **7**: 135..

Hegde N 2019. *Physical and mechanical properties of lesser known timber species of Mizoram*. Ph.D. thesis submitted to Mizoram University, Aizawl, Mizoram. 112p.

Herajarvi H 2004. Static bending properties of Finnish birch wood. *Wood Science and Technology* **37**: 523-530.

Huse SA, Gunaga RP and Sinha SK 2018. Genetic Estimates of Growth and Wood Anatomical Properties in Eucalypts Clones. *International Journal of Genetics* **10**(9): 495-497.

Huse SA, Gunaga RP and Sivakumar V 2016. Overview of *Eucalyptus* improvement in India. In*: Compendium of abstract: National Seminar on Agroforestry* held at College of Forestry, ACHF, Navsari Agricultural University, Navsari-396450.

Huse SA, Jadeja DB, Rajpoot RS and Kumar V 2012. Growth performance of twelve *Eucalyptus* clones in South Gujarat. In: *Proceedings of National seminar on Agroforestry*. Navsari Agricultural University, Navsari, pp. 304-301.

ISI (Indian Standards Institution) 1986. *Indian standards method of testing small clear specimens of timber. IS:1708 (Parts 1-18)*, Bureau of Indian Standards (BIS), New Delhi, pp. 6-62.

Izekor DN, Fuwape JA and Oluyege AO 2010. Effects of density on variations in the mechanical properties of plantation grown *Tectona grandis* wood. *Applied Science Research* **2**(6): 113-120.

Kantariya NM and Sinha SK 2023. Wood properties and utilization of pollard shoots of Indian tulip tree (*Thespesia populnea* (L.) Sol. ex Correa). *Indian Journal of Ecology* **50**(4): 980-983.

Kollmann FF and Côté Jr W A 1968. Principles of wood science and technology. *Solid Wood*-I, 592p.

Luna RK, Thakur NS and Kumar V. 2009. Performance of clonal Eucalyptus in different agro-climatic zones in Punjab, India. *Indian Forester* **135**(11): 1455-1464.

Received 11 September, 2023; Accepted 22 February, 2024

Olufemi B and Malami A 2011. Density and bending strength characteristics of North Western Nigerian grown *Eucalyptus camaldulensis* in relation to utilization as timber. *Research Journal of Forestry* **5**(2): 107-114.

Patel MU 2023. *Study of clonal variation for growth, wood physical, anatomical and mechanical properties among Casuarina clones.* B.Sc. dissertation submitted to Navsari Agricultural University, Navsari, India.

Pima NE 2015. *Growth performance, water use and wood properties of eucalypt clones in Tanzania*. Ph.D. thesis submitted to Sokoine University of Agriculture, Morogoro, Tanzania.

Rajput SS, Shukla NK, Gupta VK and Jain JD 1996. *Timber mechanics: Strength, classification and grading of timber.* Indian Council of Forestry Research and Education, Dehradun, pp. 4-32.

Saravanan V, Parthiban KT, Thirunirai R, Kumar P, Vennila S and Kanna SU 2014. Comparative study of wood physical and mechanical properties of *Melia dubia. Research Journal of Recent Sciences* **3**(ISC-2013): 256-263.

Sharma SK, Rao RV, Shukla SR, Kumar P, Sudheendra R, Sujatha M, Dubey YM 2005. Wood quality of coppiced *Eucalyptus tereticornis* for value addition. *IAWA Journal* **26**: 137-147.

Sheoran OP, Tonk DS, Kaushik LS, Hasija RC and Pannu RS 1998. Statistical Software Package for Agricultural Research Workers. In: *Recent Advances in information theory, Statistics & Computer Applications* (DS Hooda and RC Hasija), Department of Mathematics Statistics, CCS HAU, Hisar, 139-143.

Shukla SR, Rao RV, Sharma SK, Kumar P, Sudheendra R and Shashikala S 2007. Physical and mechanical properties of plantation-grown of three different ages. *Acacia auriculiformis*. *Australian Forestry* **70**(2): 86-92.

Taylor SE and Bender DA 1991. Stochastic model for localized tensile strength and modulus elasticity in lumber. *Wood and Fiber Science* **23**(4): 501-519.