

Physical and Mechanical Properties of *Pinus Radiata* from Jebel Marra Western Sudan

Osman Taha Elzaki ^{*1} and Tarig Osman Khider ²

^{(1)*}Institute of Technological Research, NCR, Khartoum, Sudan

P.O. Box: 2404 Khartoum, Sudan

E-mail : osmantaha2007@yahoo.com

⁽²⁾University of Bahri-College of Applied and Industrial Sciences, Khartoum, Sudan

E-mail : tarigosmankhider@gmail.com

(Received March 24, 2013; Accepted April 28, 2013)

Abstract— The wood of 25-year-old *Pinus radiata* D. Don. from Jebel Marra area Western Sudan was studied as a potential exotic timber tree. The physical and mechanical properties were determined including wood density, static bending, modulus of rupture (MOR), modulus of elasticity (MOE), Impact bending, compression strength parallel to grain, and shear stress. The obtained results were compared with the values for the same *Pinus* species from Southern Sudan and California state. The results have shown that the average value for the oven-dry wood density (529.0 kg m^{-3}) for the Western Sudanese pine was lower than that for the Southern Sudan pine (600 kg m^{-3}). And nearer to the California pine (515 kg m^{-3}). The Sudanese radiata pine has shown lower shrinkage ratio (1.55). The average value for the modulus of rupture (MOR) for the Western Sudan pine ($807.0 \text{ kPa cm}^{-2}$) was higher than for the Southern Sudan pine ($775.7 \text{ kPa cm}^{-2}$) and a bit lower than the California pine (814 kPa cm^{-2}). The modulus of elasticity (MOE) was higher average value for the Southern Sudan pine ($12.72 \text{ GPa cm}^{-2}$) which resembles that of the California pine ($12.70 \text{ GPa cm}^{-2}$) while it was lower for the Western Sudan pine ($11.63 \text{ GPa cm}^{-2}$). The compressive strength was higher than both Southern Sudan and the California pines while the shear stress was lower than that of the American pine.

Index Terms— *Pinus radiata*, Static bending, Modulus of elasticity, Compressive Strength, Mechanical properties.

I. INTRODUCTION

Pinus radiata D. Don. Or Monterey pine (Sunober in Arabic) is an evergreen coniferous tree. It belongs to the pinaceae family [1, 2 and 3]. It is indigenous to Southern and Central California in the United States of America where the climate is of a Mediterranean type [4] [5]. Mature trees ranges from 21 to 30m in height and 40 to 50cm in diameter [5]. *P. radiata* has been first introduced in Sudan in 1918 from South Africa [6]. In 1950 seeds were brought from New Zealand, and South Africa and were used to establish plantations at Gilo (Southern Sudan). In 1960 plantations were established at Beldong and Toron Tonga in Jebel Marra

area with other pines including *P. patula*, *P. kesiy*, and *P. merkusii* [5] [6]. The wood of *P. radiata*. is white when first cut but changes on exposure to light brown with usually very little difference in color between heartwood and sapwood. Logs are straight and of good form. Those properties made it suitable for general construction and furniture [5] [7] [8] Wood varies widely in its composition, structure, and properties. Each wood species with possible commercial importance, therefore, must be carefully studied and analyzed to know its physical, chemical, anatomical, and mechanical properties in relation to the uses intended for. This will give good indication about the basic modes of distortion for structural timber [9]. Wood density and shrinkage should be studied to know its durability and stability.

The main objective of this study was to show the importance of *Pinus radiata* as a potential exotic fast-growing timber tree for Sudan. The specific objectives lie on the maximization of the economic utilization of plantation forests of Jebel Marra and how could *Pinus radiata* contribute to wood integrated industry and to the national economy of the Sudan.

II. MATERIALS AND METHODS

The raw material used in this study was wood of 25-year-old *Pinus radiata* (sunober) or radiata pine grown in Jebel Marra Western Sudan. The height of trees ranged between 23 and 27 meters with an average of 26 meters. Five representative trees were randomly selected taking into consideration the straightness of the stem and normality of growth. The trees were felled, delimbed, and cross-cut at breast height into logs of 100cm length [10]. The logs were further reduced to different specimens in accordance with the B.S.373; 1957 Standard [11]. Physical properties including wood density, radial and tangential shrinkage were determined. For determination of both the average oven-dry density and basic density, standard blocks of 2cmx2cmx2cm (according to the B.S.373; 1957) were used. Wood basic density was carried out by displacement method. The wood mechanical properties determinations were carried out in accordance with the British Standard methods for testing small clear specimens of timber (B.S. 373; 1957).

Compression strength parallel to the grain was carried out using specimens of 2cmx2cmx6cm. The test was carried on a Losenhausenwerk universal testing machine. The maximum crushing strength (p_{max}) was calculated by dividing the load to failure by the cross-sectional area of the specimen.

For both static bending and impact bending determination the size of the test specimen was 2x2x30cm. For testing the static bending the test specimens were supported over a span of 28cm. on the roller bearings. The load was applied to the center of the beam and the loading head was descending at a constant speed of 0.01mm/second. The Modulus of rupture (MOR) and the modulus of elasticity (MOE) were calculated. The machine used for static bending test was the Hounsfield tensometer while for impact bending a small Hutt-Turner machine was used. The shear stress parallel to the grain test was carried on 2-cm cubes using the Hounsfield tensometer, maintained at a constant rate of crosshead movement of 0.01mm/second. The radial and tangential apparent average shearing stresses were calculated. All test pieces were completely free from defects including knots, splits, wane, resin pockets, bark or cross grain. Any samples showing defects were rejected from the test. All test specimens were conditioned at 12% moisture content for all mechanical tests.

III. RESULTS AND DISCUSSION

Table 1 indicated the data for physical properties of *P. radiata* from Western Sudan compared with the same wood species

from Southern Sudan and California. The obtained results have shown that the average values for the oven-dry wood density for the Western Sudan pine (529.0 kg m⁻³) was lower than that of Southern Sudan pine (600.0 kg m⁻³). But it was a bit higher than or nearer to that of the California pine (515.0 kg m⁻³). This may be due to the effect of different sites and climatic conditions especially for the Southern Sudan pine which grows in dark clay soils compared to the Western Sudan which grows in light volcanic soils of Jebel Marra. Basic density (460.0 kg m⁻³) for the Western Sudanese pine was also higher than the California pine (401 kg m⁻³) but it was in the normal range for tropical softwoods according to Mirov [3]. Since the wood density is a characteristic of wood that affects the properties of the products manufactured from it, this pine wood could be classified as a medium density pulpwood and structural timber. The greater differences between radial and tangential shrinkage values have shown that the tangential shrinkage was almost more than double the radial. this proved by Panshin [15]. The Sudanese *radiata* pine has shown lower radial and tangential shrinkage values (3.1 and 4.8% respectively) than that of California pine (3.4 and 6.7%) giving an indication of good stability and lower volumetric shrinkage during its utilization. According to the above results for physical properties the Sudanese pine wood could be classified as general purpose wood with moderate strength. The above properties also indicate that the Western Sudan pine wood could be suitable for boat building and plywood production. The impact bending of Western Sudan pine was 70 (**Table 2**).

Table 1
Physical Properties of *Pinus radiata* wood from Western Sudan, Southern Sudan, and California.

Origin	Western Sudan	Southern Sudan Nasroun 1979 [12]	California 1997[13]	Alden
Properties				
Density oven-dry base kg m ⁻³	529.00	600.0	515.0	
Basic density kg / m ⁻³	460.00	-	401.0	
Radial shrinkage %	3.1	-	3.4	
Tangential shrinkage %	4.8	-	6.7	
Ratio of shrinkage (T/R)	1.55	-	1.97	

Table 2
Impact Bending for *P. radiata* Wood from Western Sudan

Origin	Western Sudan	Southern Sudan [12]	California[13]
Impact Bending			
Maximum height of drop, cm	70.0	-	-

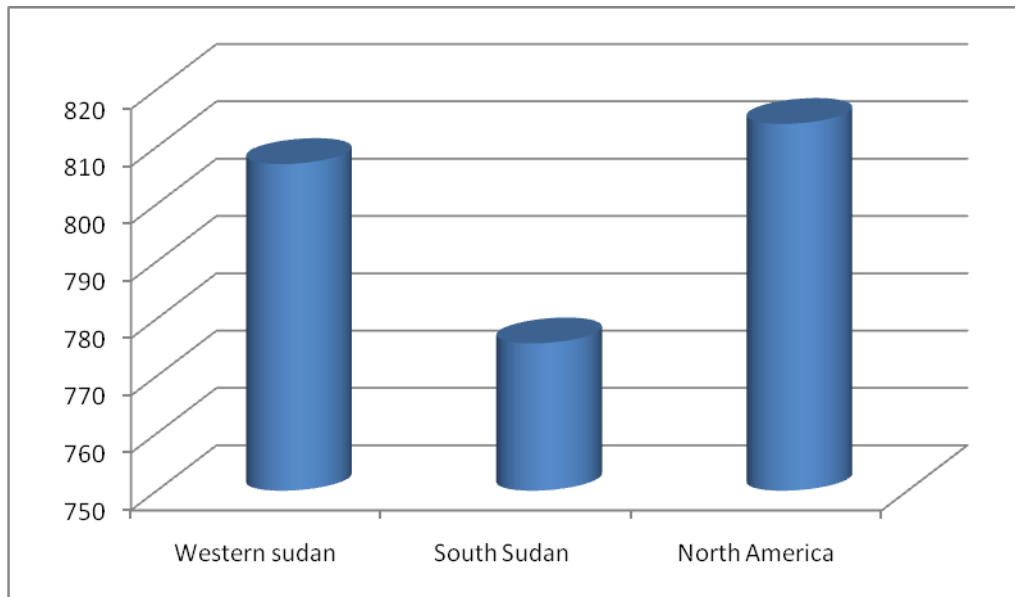


Figure 1. Modulus of rupture (kPa cm⁻²) for *Pinus radiata* wood from Western Sudan, Southern Sudan and California.

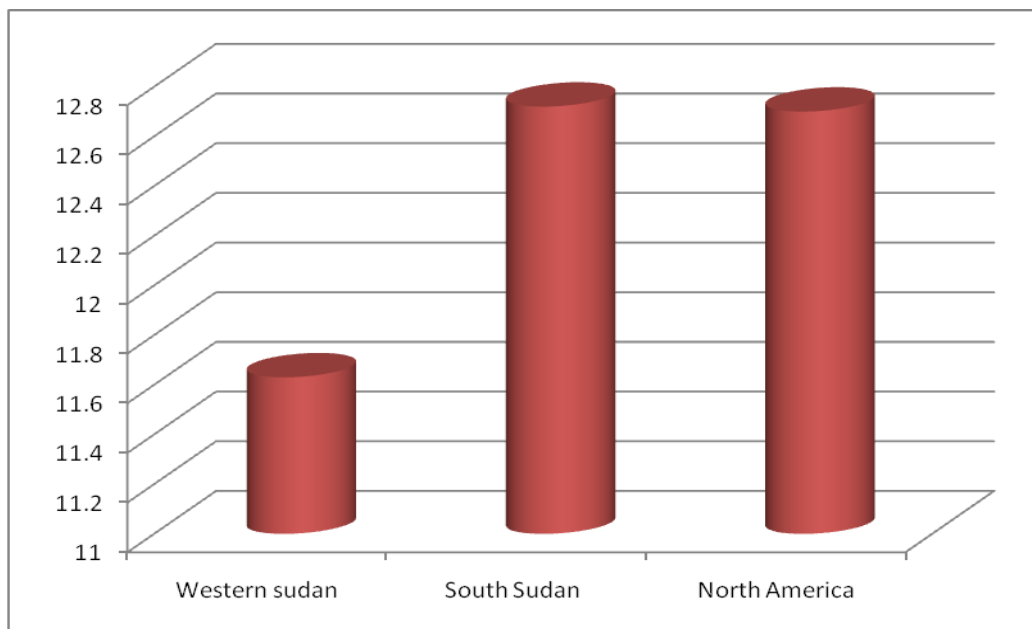


Figure 2. Modulus of Elasticity (GPa cm⁻²) for *Pinus radiata* wood from Western Sudan, Southern Sudan and California.

The average values obtained for the modulus of rupture (MOR) as shown in Figure (1) have shown that the average values for modulus of rupture for the Western Sudan *radiata* pine (807.0 kPa cm⁻²) was higher than the Southern Sudan pine (775.7 kPa cm⁻²) and a bit lower than the California pine or almost nearer to it. (814 kPa cm⁻²) The modulus of rupture is an indication of the bending strength of a board or a structural element. Due to this fact, the Western Sudan pine could be good for use as structural timber the same as the California pine. The modulus of elasticity

(MOE) which is an indication of stiffness (Figure 2) has shown a higher average value for the Southern Sudan pine (12.72 GPa cm⁻²) which resembles or almost the same as that for the California pine (12.70 GPa cm⁻²) while it was lower for the Western Sudan pine (11.63 GPa cm⁻²) but was in the normal range for pine wood species. Both MOR and MOE are very important for the determination of the suitability of wood for structural purposes [16].

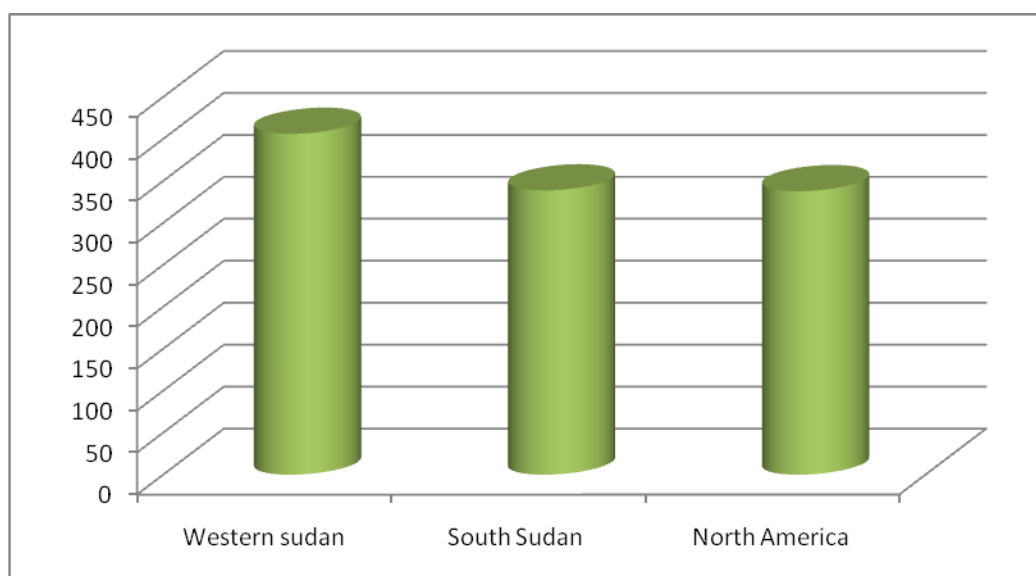


Figure 3. Compression strength parallel to the grain (kPa cm⁻²) for *Pinus radiata* wood from Western Sudan, Southern Sudan and California.

Table 3
Shear Stress for *P. radiata* Wood from Western Sudan compared to pine f
South Sudan and California

Origin	Western Sudan	California Alden 1997[13]
Stress Direction		
Radial, kpa cm⁻²	101.9	113.0
Tangential, kpa cm⁻²	116.9	-

The average values for compression strength parallel to the grain for Western Sudan pine and Southern Sudan pine as well as for the North American pine expressed as maximum crushing stress were shown in Figure 3. Compression strength parallel to the grain was higher for the Western Sudan pine (451.6 kPa m⁻²) followed by the Southern Sudan pine (420.0 kPa m⁻²) and was lower for the North American pine (338.0 kPa m⁻²). This is governed by the average angle of the helical layers in the secondary all of pine tracheids and the longitudinal orientation of microfibrils as well as the effect of site and environmental conditions on the anatomical structure and strength properties of wood. However the shear stress of western Sudan pine was less compared to that of California pine (Table 3).

IV. CONCLUSION

Although different growing and climatic conditions as well as age of individual trees would be reflected on the physical and mechanical properties of Pine. The overall conclusion, Due to the obtained results the wood of *P. radiata* studied could be considered as a medium density and good structural and general purpose wood with better strength properties compared with the same species from other localities. Wise utilization of pine from western Sudan was more or less similar to that of California. Thus the pine of Western Sudan (Jabel Marra) could be utilized for the same purposes of those in North America (California). In multi construction uses and furniture industry.

REFERENCES

- [1] Millar, C.I. 1986 The California closed-cone pines; a taxonomic history and review. *Taxon*. 35: 657 – 670.
- [2] Bailey, L. H., Bailey, E. Z. 1976. *Hortus third: A concise dictionary of plants cultivated in the United States and Canada*. Macmillan, New York.
- [3] Mirov, .T. 1967. *The Genus Pinus*. Ronald Press, New York.
- [4] Jackson, J. K. 1960. The Introduction of Exotic Trees into Sudan. *Sudan Silva* Volume 10 : 14 – 30.
- [5] FAO, 1981. *Forest Resources for Tropical Africa*. Tropical Forest Resources Assessment. FAO, Rome.
- [6] Elzaki, O. T. 1990. *Utilization Potentialities of Some Exotic Fast -growing Wood Species Grown in Western Sudan*. Sudan. Ph.D. thesis. University of Kartoum.
- [7] Keatig, W. G. and Bolza, E. 1982. *Characteristics, properties, and uses of timbers :Southeast Asia, Northern America, and the Pacific*. Inkata Press, Melbourne.
- [8] Khristova, P. Gabir, S. Taha, O. 1989 *Physical, Morphological and Chemical Properties of Some Exotic Fast-growing Wood Species in Sudan*. *Cellulose Chemistry and Technology*. Vol. 32 No.2 : 121 – 129.
- [9] Lindstrom, H. , Harris, P., Nakada, R. 2002. Methods for measuring stiffness of young trees. *Eropean Journal of Wood and Wood Products*. Volume 60 No. 3, pp. 165-174.
- [10] Elzaki, O. T. Otuk, S. and Khider, T. 2012 Sulfur-free pulping of *Crateva adansnii* from Sudan. *Journal of Forest Products & Industries*, vol.1 (1): 23 – 26.

- [11] B. S. 373 1957. The British Standard Methods of Testing Small clear Specimens of Timber. British Standards Institute, London.
- [12] Nasroun, T.H. 1979. Home-grown timber properties that are required for engineering Purposes. Proc. Int. Symp. Use of Home-grown Timber in Building: 113-121.
- [13] Alden, Harry A. 1997. Softwoods of North America. Gen. Tec. Rep. FPL. GTR 120. Madison WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 151 p.
- [14] Bolza, E, and Keating, W. V. 1972. African Timbers, the properties, uses, and characteristics of 700 species. Industrial Research Organization . Building Research, Commonwealth Scientific and Industrial Research Organization, Melbourne.
- [15] Panshin, A. J. and C. de Zeeuw, 1980. Textbook of Wood Technology 4th ed. McGraw-Hill. New York. 722 pp
- [16] Karlsen G. and Slitskohov, Y. 1989 Wooden and Plastic Structures. Mir Publishers, Moscow.