

# Effects of height on physical properties of wood of jhau (*Casuarina equisetifolia*)

Md Qumruzzaman Chowdhury<sup>1</sup>, A.Z.M. Manzoor Rashid<sup>1,2</sup>, Md Shah Newaz<sup>3</sup> and Mabubul Alam<sup>1</sup>

<sup>1</sup>Department of Forestry, Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh

<sup>2</sup>Email: pollen-for@sust.edu, pollen\_for@hotmail.com

<sup>3</sup>Institute of Forestry and Environmental Sciences, Chittagong University, Chittagong, Bangladesh

Revised manuscript received 20 July 2006

## Summary

Moisture content, and tangential, radial and longitudinal shrinkage, and basic density were assessed in samples of wood from near the centre of the cross-section at three different heights in 25-y-old jhau (*Casuarina equisetifolia*). The mean initial moisture content was 41% in the butt log, 40% in the centre log and 48% in the crown log. Mean tangential shrinkage was 10% in the butt, 9% in the centre and 11% in the crown. The corresponding measurements for radial shrinkage were 6%, 5% and 5%, and for longitudinal shrinkage 0.4%, 0.3% and 0.5%. There were no statistically significant differences in either moisture content or radial and longitudinal shrinkage with increasing height above ground, but differences in tangential shrinkage were significant at  $P < 0.05$ . The overall mean basic density was about 800 kg m<sup>-3</sup>, and this property varied a little with height in the tree.

**Keywords:** wood properties; moisture content; shrinkage; density; height; *Casuarina equisetifolia*

## Introduction

*Casuarina equisetifolia* L., named jhau in Bangladesh, is one of four species of the Casuarinaceae (a phylogenetically isolated family and the sole representative of the order Casuarinales) which naturally occur on subtropical and tropical coastlines in northern Australia, and throughout northern Malaysia, Melanesia, Polynesia and Vanuatu (Pinyopusarerk and House 1993). The species has been introduced to many countries outside its natural range and used for soil stabilisation, reclamation work and coastal protection, as well as rehabilitation of degraded land (Midgley *et al.* 1983; El-Lakany *et al.* 1990). In Bangladesh this species has been planted for decades in coastal areas and near beaches for sand dune stabilisation (Gafur *et al.* 1979).

The tree has light red to dark reddish-brown heartwood, sometimes darker in older trees, and usually-distinct, thick, buff-coloured sapwood with a fine to moderately-fine texture. The grain is typically straight or shallowly interlocked. The wide medullary rays result in an attractive prominent figure on radial surfaces when logs are quartersawn. The wood is generally hard and dense, and tends to split when sawn (Burgess 1966).

Jhau is popular for use as underground piles for construction work, as well as for fish-trap stakes and tool handles. Hardboard, particleboard and woodchips for pulping are also produced from

this species (Guha *et al.* 1970). The tree is used extensively for firewood (Burgess 1966).

Research interest has moved from taxonomy, species trials in different sites, and growth rates to suitability for shelterbelts, tolerance to harsh environmental conditions, and yield studies. However, wood properties have received little attention, in spite of increasing industrial use of the wood (Dudley and Fownes 1992; El-Osta *et al.* 1992; Constantinides and Fownes 1994; Puri *et al.* 1994).

In Bangladesh, trees in jhau plantations are approaching their economic maturity in size and vigour, and must be used to the greatest economic advantage. As information regarding wood properties is required for best utilisation, this study was intended to evaluate the physical properties of this species.

## Methods

### Study area

Samples were collected from a plantation on the Chittagong University campus, with coordinates of 91°50'E and 22°30'N. The altitude is about 87 m above sea level, and the hills of this area are part of the South Fatikchari Range with mostly sandy soils (Baten 1969). Annual rainfall is about 3000 mm, mostly falling between June and September. With minor variations, humidity remains high at 70–85% throughout the year (Gafur *et al.* 1979).

### Selection of sample trees

Four plots, 10 m × 10 m (0.01 ha), were laid down at least two rows from the stand edge so as to exclude edge effects. The diameter at breast height over bark (dbhob) of all trees in each plot was measured, and five trees randomly selected from each plot to give a total of 20 trees for testing.

### Specimen preparation

After felling, trees were docked to commercial-sized logs 5 m long. From each of the butt logs, a section 1 m long was cut with breast height as close to the log's mid-point as possible. A 1-m length was cut from the lower end of the centre and crown logs. A section about 500 mm long was cut from the largest internal area clear of knots and other defects or injury in each of the 1-m

logs. These samples were wrapped in polythene film for transport to the laboratory, where they were processed a week after felling. Typically a single specimen of 25 mm × 25 mm (in the stem cross-section) × 100 mm (in the stem longitudinal direction) was taken from the near the middle of a diametrical strip cut from each section, a few millimeters from the pith and excluding reaction wood. In the largest discs, more than one specimen was taken. If the specimen developed collapse during oven drying, it was replaced with a new sample from the same section.

### Determination of physical properties

Moisture content was measured using the oven-dry method, and shrinkage in the three linear directions was evaluated as dimensional change from the green to oven-dry condition expressed as a fraction. Oven-dry measurements were taken after the specimens were dried to constant weight in an oven at  $103 \pm 2^\circ\text{C}$ . The dimensions were measured in both green and dry conditions by a slide caliper, and mass measured on an electric balance to an accuracy of 0.01 g. Basic density was determined from green volume (using the water displacement method) and oven-dry mass.

### Statistical analysis

An ANOVA test was done to determine the significance of variation of physical properties (moisture content, density and shrinkage) at the three different heights (butt, centre and crown), followed by a post-hoc (Tukey–HSD) test if the ANOVA showed significant differences. Relationships between moisture content and shrinkage in different directions were evaluated by using a general linear model (GLM).

### Results and discussion

The mean diameter over bark at breast height of the trees in the sample plots was 200 mm.

Heartwood of the 25-y-old trees was light red to reddish-brown.

Moisture content is an important physical property of wood because it affects other physical and mechanical properties, and consequently utilisation. In this trial, the mean moisture content of jhau was 41% in the butt log, 40% in the centre and 48% in the crown (Fig. 1). In comparison, Burgess (1966) found average moisture content to be 36.5% in Sabah-grown wood. The greater moisture content in the crown samples is presumably due to the greater proportion of juvenile wood in the upper bole, but the differences between heights were not significant.

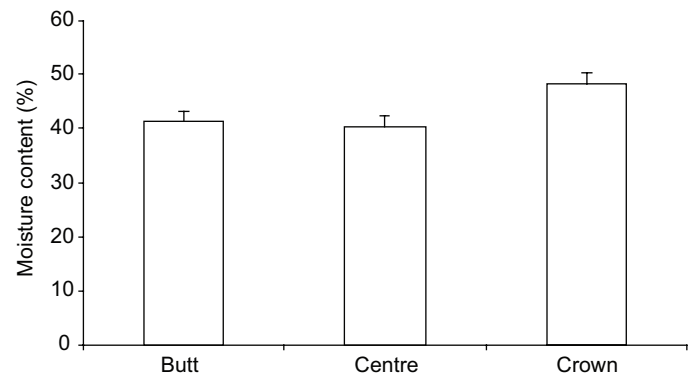
The mean tangential shrinkage was 10% in the butt log, 9% in the centre and 11% in the crown section (Fig. 2). The corresponding radial shrinkages were 6%, 5% and 5%, and longitudinal shrinkages 0.4%, 0.3% and 0.5% respectively (Fig. 2). As regularly discussed in the literature (e.g. Panshin and de Zeeuw 1980), tangential shrinkage is regularly about twice that of radial shrinkage. Variation of shrinkage in different directions is due to the cellular structure and physical organisation of cellulose chain molecules within the cell walls (Schniewind 1989); the microfibril angle of the  $S_2$  layer is an important factor (Koponen *et al.* 1989). Yamamoto *et al.* (1992) reported that the presence of a gelatinous

layer in fibres results in large shrinkage in the longitudinal direction.

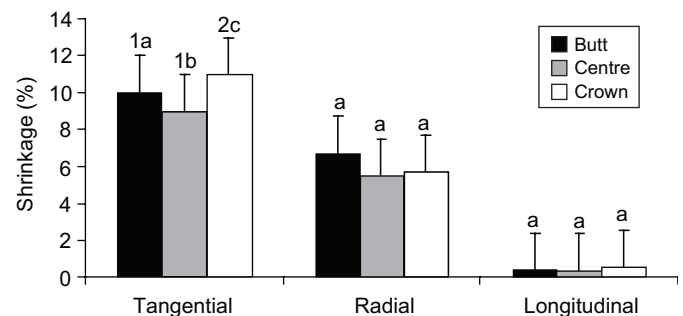
The magnitude of shrinkage and swelling is affected by the amount of moisture gained or lost by wood when the moisture content fluctuates between zero and fibre saturation point (Tsoumis 1991). Kollman and Cote (1968) explained that shrinkage differs in the three different directions due to the influence of wood rays and different arrangements of fibrils in the cell walls. In our study, radial and longitudinal shrinkages did not vary significantly with increasing height in the tree. However, tangential shrinkage did vary significantly with increasing height (Fig. 2), and the Tukey–HSD test showed that the crown wood had significantly greater shrinkage than wood from the two lower logs. This greater value could be due to the presence of more unrecognized tension wood in the crown samples than in those from lower positions.

The effects of moisture content on different shrinkages (tangential, radial and longitudinal) were assessed by linear regression (Figs 3, 4 and 5).

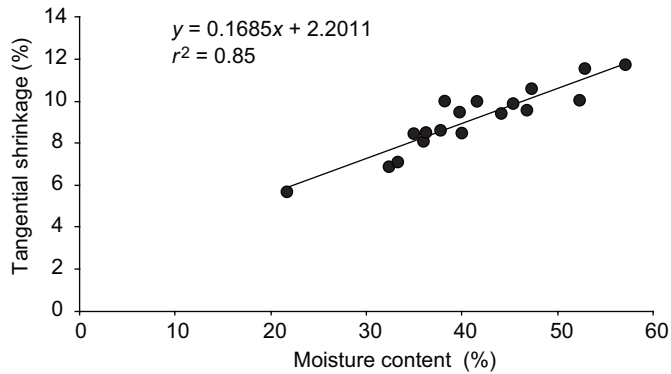
The coefficients of determination ( $r^2$ ) are 0.85, 0.80 and 0.86 respectively for the three relationships between shrinkage and moisture content. The regression models showed a linear relationship, and the models are significant at  $P < 0.05$ .



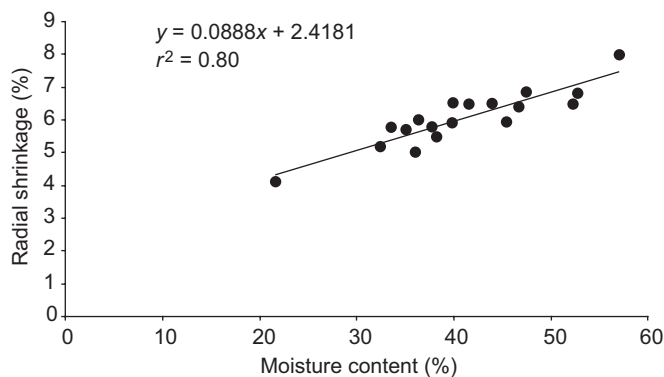
**Figure 1.** Average moisture content of jhau wood at different heights. The whiskers indicate the standard error of the means.



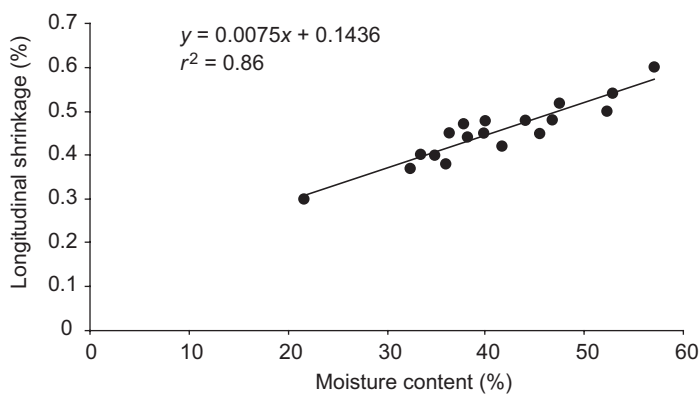
**Figure 2.** Average shrinkage of jhau wood at different heights. Within categories, different letters denote significant variation (ANOVA) at  $P < 0.05$ ; in the tangential case different numbers denote significant variation (Tukey–HSD test) at  $P < 0.05$ . The whiskers indicate the standard error of the mean.



**Figure 3.** Relationship between moisture content and tangential shrinkage



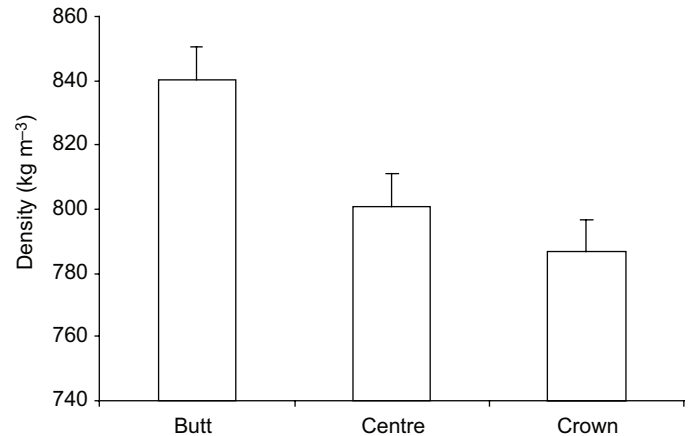
**Figure 4.** Relationship between moisture content and radial shrinkage



**Figure 5.** Relationship between moisture content and longitudinal shrinkage

The mean basic density of jhau at different heights in the stem (Fig. 6) was about  $800 \text{ kg m}^{-3}$ , with no significant differences between heights. The density decreased by a small amount from butt to crown, possibly the result of a higher proportion of juvenile wood in the crown region (Zobel and Jett 1995).

Our result that jhau is a high-density wood is supported by findings of other authors (e.g. Burgess 1966; Sosa-Suarez *et al.* 1990). Sosa-Suarez *et al.* (1990) measured basic density of the



**Figure 6.** Average basic density of jhau wood at different heights. The whiskers indicate the standard error of the means.

species in Cuba as  $840 \text{ kg m}^{-3}$ , while Jain and Lala (1966) reported Indian-grown wood as  $740 \text{ kg m}^{-3}$ . As strength is directly related to wood density (Shrivastava 1997), jhau will have satisfactory strength properties.

Finally, a comparison was made with teak (*Tectona grandis*). Teak is regarded in Bangladesh as a standard with which other locally-grown or imported timbers may be compared, e.g. the strength properties of 40-y-old Chittagong-grown teak were used by Yakub *et al.* (1978) to assess the relative suitability of other species for various purposes. The moisture content and shrinkage of jhau wood were similar to those of teak, but the density was generally higher than that of teak.

## Conclusion

Initial (green) moisture content of jhau varied little with increasing height in the tree. Radial and longitudinal shrinkages did not vary with increasing height, but tangential shrinkage did vary significantly. Good correlations were found between the different shrinkages and initial (green) moisture content. Basic density, which is considered an important indicator of strength, was marginally higher in the butt log (about  $800 \text{ kg m}^{-3}$ ), but there was no significant variation with increasing height in the tree.

## Acknowledgements

We thank the Institute of Forestry and Environmental Sciences, Chittagong University (IFESCU), for supplying the wood samples, and the reviewers and editors of this journal for assistance in revising the manuscript.

## References

- Baten, S.A. (1969) Revised working plan for the forest of Chittagong Division for the period of 1968–69 to 1977–78; Working Plans Division-1, Dhaka (unpublished).
- Burgess, P.F. (1966) Timbers of Sabah. *Sabah Forest Records* **6**, 70–73.
- Constantinides, M. and Fownes, J.H. (1994) Nitrogen mineralization from leaves and litter of tropical plants: relationship to nitrogen, lignin and soluble phenol concentrations. *Soil Biology and Biochemistry* **26**, 49–55.

- Dudley, N.D. and Fownes, J.H. (1992) Preliminary biomass equations for eight species of fast-growing tropical trees. *Journal of Tropical Forest Science* **5**, 68–73.
- El-Osta, M.L., Megahed, M.M., El-Lakany, M.H. and Hegazy, S.S. (1992) Estimates of above-ground biomass and its distribution for *Casuarina* windbreak trees in the northwestern region of Egypt. *Alexandria Journal of Agricultural Research* **37**, 57–83.
- El-Lakany, M.H., Turnbull, J.W. and Brewbaker, J.L. (1990) *Advances in Casuarina Research and Utilization*. Proceedings of the 2nd International *Casuarina* Workshop, 15–20 January 1990, Desert Development Center, AUC, Cairo, Egypt, 241 pp.
- Gafur, M.A., Karim, A. and Khan, M.A. (1979) Phytosociological studies of hills of Chittagong University Campus. *Chittagong University Studies*, Part 2, Science **3**, 11–28.
- Guha, S.R.D., Sharma, Y.K., Pant, R. and Dhandiyal, S.N. (1970) Chemical, semi-chemical and mechanical pulps from *Casuarina equisetifolia*. *Indian Forester* **96**, 830–840.
- Jain, N.C. and Lala, M.K. (1966) Compressed wood from Indian timbers. *Indian Forester* **92**, 730–738.
- Kollman, F.F. and Cote, W.A. (1968) *Principles of Wood Science and Technology*. Vol. 1. Springer-Verlag, Berlin, 592 pp.
- Koponen, S., Toratti, T. and Kanerva, P. (1989) Modelling longitudinal and elastic properties of wood. *Wood Science and Technology* **23**, 55–63.
- Midgley, S.J., Turnbull, J.W. and Johnston, R.D. (1983) *Casuarina: Ecology, Management and Utilization*. Proceedings of an international workshop, Canberra, Australia, 17–21 August 1981. CSIRO Division of Forest Research, Canberra, 286 pp.
- Panshin, A.J. and de Zeeuw, C. (1980) *Textbook of Wood Technology*. 4th edn, McGraw-Hill, New York, 722 pp.
- Pinyopusarek, K. and House, A.P.N. (1993) *Casuarina: An Annotated Bibliography of C. equisetifolia, C. junghuhniana and C. oligodon*. International Centre for Research in Agroforestry, Nairobi, Kenya, 298 pp.
- Puri, S., Sdigh, S. and Bhushan, B. (1994) Evaluation of fuelwood quality of indigenous and exotic tree species of India's semi-arid region. *Agroforestry Systems* **26**, 123–133.
- Sosa-Suarez, C., Ibanez, A. and Hesse, R. (1990) Physical and strength properties of *Casuarina equisetifolia* Forst. Part 1. Physical properties. *Holztechnologie* **30**, 129–131.
- Shrivastava, M. B. (1997) *Wood Technology*. Vikas Publishing House Pvt Ltd, Jangpura, New Delhi, India.
- Schniewind, A.P. (1989) *Concise Encyclopedia of Wood and Wood-Based Materials*. Pergamon Press, 248 pp.
- Tsoumis, G. (1991) *Science and Technology of Wood*. Chapman and Hall, New York, 491 pp.
- Yakub, M., Ali, M.O. and Bhattacharjee, D.K. (1978) *Strength Properties of Chittagong Teak (Tectona grandis) Representing Different Age Groups*. Bulletin 4. Timber Physics Series, BFRI, Chittagong, 12 pp.
- Yamamoto, H., Okuyama, T., Sugiyama, K. and Yoshida, M. (1992) Generation process of growth in stresses in cell walls IV. Action of the cellulose microfibril upon the generation of the tensile stresses. *Mokuzai Gakkaishi* **38**, 107–113.
- Zobel, B.J. and Jett, J.B. (1995) *Genetics of Wood Production*. Springer-Verlag, Berlin, 337 pp.