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Axial Variation of Wood Density in *Pinus merkusii* Jungh. & de Vriese

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ABSTRACT

Pinus merkusii Jungh. & de Vriese is one of the fast growing tropical pines in the world. It has an important role in daily needs of tribes of Anjaw district of Arunachal Pradesh. The present study on axial variation in wood density was conducted on straight trees of *P. merkusii* collected from Anjaw district of Arunachal Pradesh. The cross-sectional discs were taken at breast-height and at regular intervals of 3m from breast-height to top of trees. The main aim of present investigation was to determine wood density variations from base to the top of trees and to see the relationship between height and wood density. A gradual decrease in wood density variation was observed from bottom to top in both vertical and oblique sequences in all selected trees. In vertical sequence, relationship between wood density and height was significantly negative and weak while it was too weak to be significant in oblique sequence. There was a significant and positive relationship between breast-height and total tree wood density. It can be concluded that breast-height is the most suitable and good indicator of total tree value of wood density for tree to tree comparison.

Key Words:

Breast height, Wood density, Axial variation, Vertical sequence, Oblique sequence, *Pinus merkusii*.

INTRODUCTION

Pinus merkusii is a fast growing species and one of the few truly tropical pines in the world. It occurs naturally in South-East Asia in Burma, Thailand, Laos, Cambodia, Vietnam, Indonesia, Philippines (Srivastava and Bahar 2007). In India, it occurs in huge tracks in Walong near Kibithoo in Anjaw district of Arunachal Pradesh neighbouring to China and Myanmar in Indo-Myanmar Pine Forest Eco-region. It has a wide altitudinal range from 90 m to over 1800m. It occurs in pure stands and also in open scattered groves along the higher ridges and slopes (Cooling 1968; Srivastava and Bahar 2007). The tree has extreme potential in oleo-resin production. It fulfills the daily needs of tribes of Anjaw district. The dried young shoots are used as a substitute of green tea by locals. The shoots and oleo-resin are also used in ritual purposes.

Wood density is the most important wood characteristics, which represents total amount of wood substances present in it. It is an important component of above biomass and carbon stock estimation (Wiemann and Williamson 2013; Zhang et al. 2012).It has significant role in predicting strength, stiffness, hardness, pulp yields and physical properties of paper products (Molteberg and HØibØ 2007; Saava et al.2010), analyses of tree growth and prediction of future tree productivity due to climatic change(Bouriaud et al. 2004) A perusal of literature shows that wood density is highly variable and varies from tree to tree circumferentially, radially, axially and even within an annual ring (Sharma et al. 2012). Though there are reports of wood density variation from base to top of trees in other *Pinus* species (Mutz et al. 2004; Antony et al. 2010; Auty et al. 2014; Deng et al. 2014; de Melo 2015), but there is no report of such study in this endemic pine species of Arunachal Pradesh. Therefore, the aim of the present study is to see the patterns of wood density variation from base to top of trees in vertical and oblique sequences and to see the relationship between height and wood density.

MATERIAL AND METHODS

Six trees of *Pinus merkusii* with straight bole, uniform crown and without any visible defects were selected for present investigation from pure pine forest of Dong village under Walong administrative circles of Anjaw district of Arunachal Pradesh at the time of road construction by Border Road Organization (BRO) under Border Area Development Programme. The average height and diameter of the trees were 23.14± 8.89m and 54.88± 19.23 cm. The geographical coordinates of the selected sites taken with GPS were 28±10'16.10"N latitude and 97±02'32.88"E longitude. The cross-sectional discs of about 10 cm thickness were taken at breast height and at regular intervals of 3 meter above breast-height (Figs. 1 and 2). The north direction was marked with nail in each cross-sectional disc. The discs were packed in poly bags and brought to laboratory for further processing.

All cross- sectional discs were smoothened to end grain with the help of an electric planer and sand paper to obtain clear annual rings on the surface and were photographed. Radial wedges from two opposite directions namely North-South was sawn out from bark to pith from each disc (Lego et al. 2017). Annual rings from both juvenile wood and mature wood were selected randomly from each tree. Thus, 7 rings from tree no. 1, 2, 3, 4 and 12 rings from tree no. 5 and 6 were selected. Wood density of selected annual rings was determined by water displacement method (Smith 1955). SPSS software package was used for statistical analysis and graphs were plotted by Microsoft excel

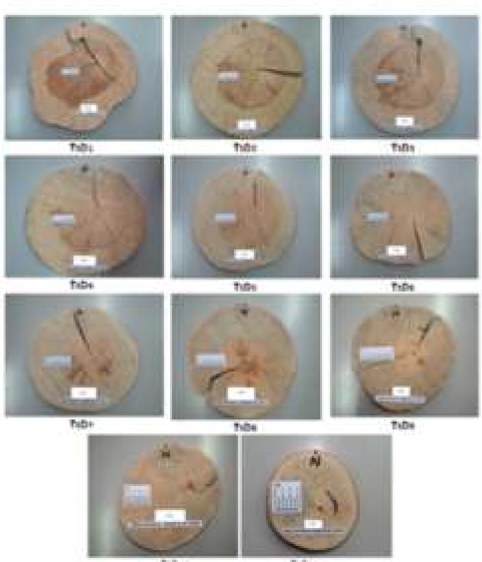

Fig. 1. Cross-sectional discs of *Pinus merkusii*

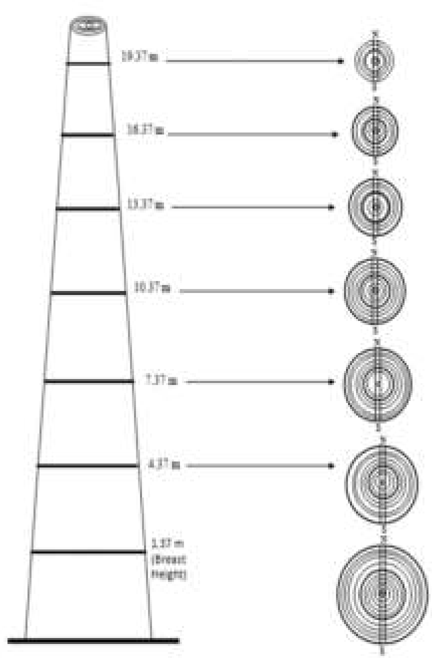

Fig.2. Sampling protocol for wood density variation

RESULTS AND DISCUSSION

In the present investigation, axial variation in wood density was studied in selected rings of both juvenile wood and mature wood. In addition, these were also studied at both (a) constant age i.e. rings count from pith to bark showing that selected ring from the pith has the same cambial age but they are formed during different years at various heights in the stem (vertical sequence) and (b) rings count from bark to pith indicating the selected ring from bark is formed in the same calendar year at various heights (oblique sequence) as recommended by Jyske et al. (2008).A perusal of literature reveals that hard pines usually have decrease in wood density with increasing height of the trees (Brown, 1971; Pronin, 1971). *Pinus merkusii* is also a hard pine and the selected rings in vertical and oblique sequences showed decreasing trend of wood density variation from base to top of tree (Figs. 3-10). The present findings are in accordance with the studies on other pine species like *Pinus sylvestris* (Auty et al., 2014); *Pinus massoniana* (Deng et al.,2014) *Pinus taeda* (de Melo, 2015). Decrease in ring width with more percentage of early wood cells than latewood cells in the top rings as observed anatomically is attributable to decreasing trend of wood density variation from base to top in *Pinus merkusii* trees. There was similar pattern of density variation in both juvenile and mature wood. The present results are contrary to the findings of Park et al. (2009) and Rodrigo et al. (2013). In some of selected juvenile rings, the wood density at different heights i.e. 4.37m, 7.37m and 10.37m was higher than that of breast-height. Similar patterns of density variation as in vertical sequence were present in oblique sequence. Since, eccentric discs with compression wood and false rings are present at different heights in *Pinus merkusii*, which may be the possible reason for significant increase in density at various heights.

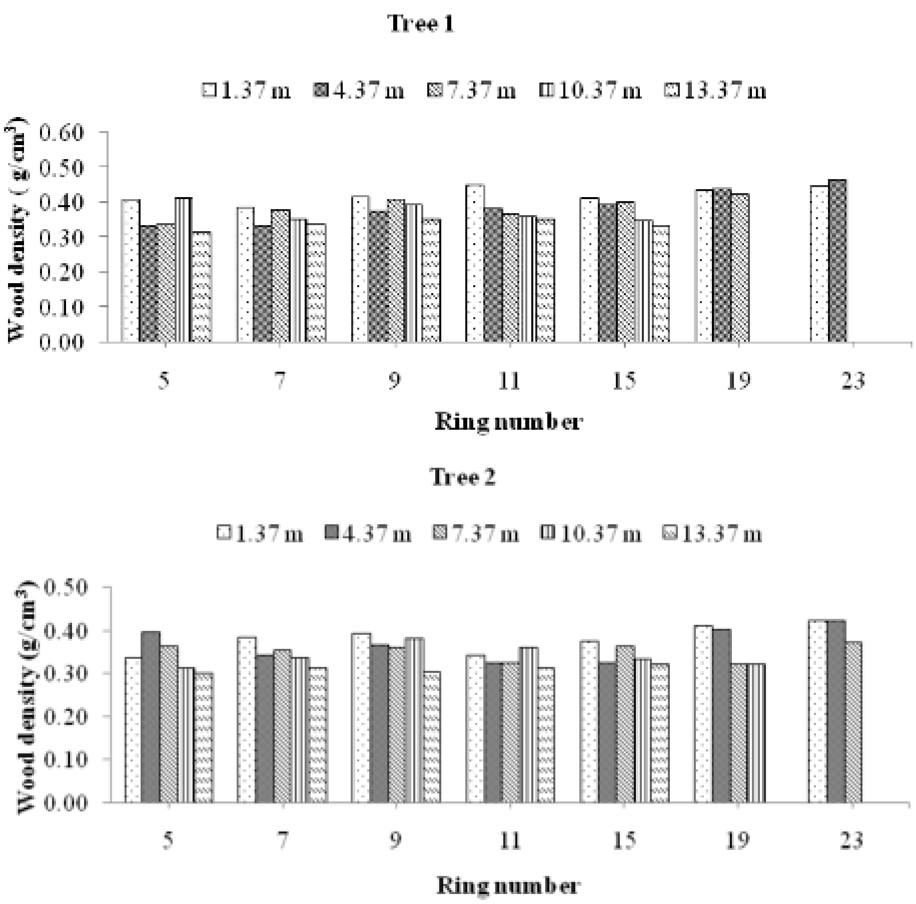

Fig. 3. Axial variation of wood density (vertical sequence) in Tree 1 and 2

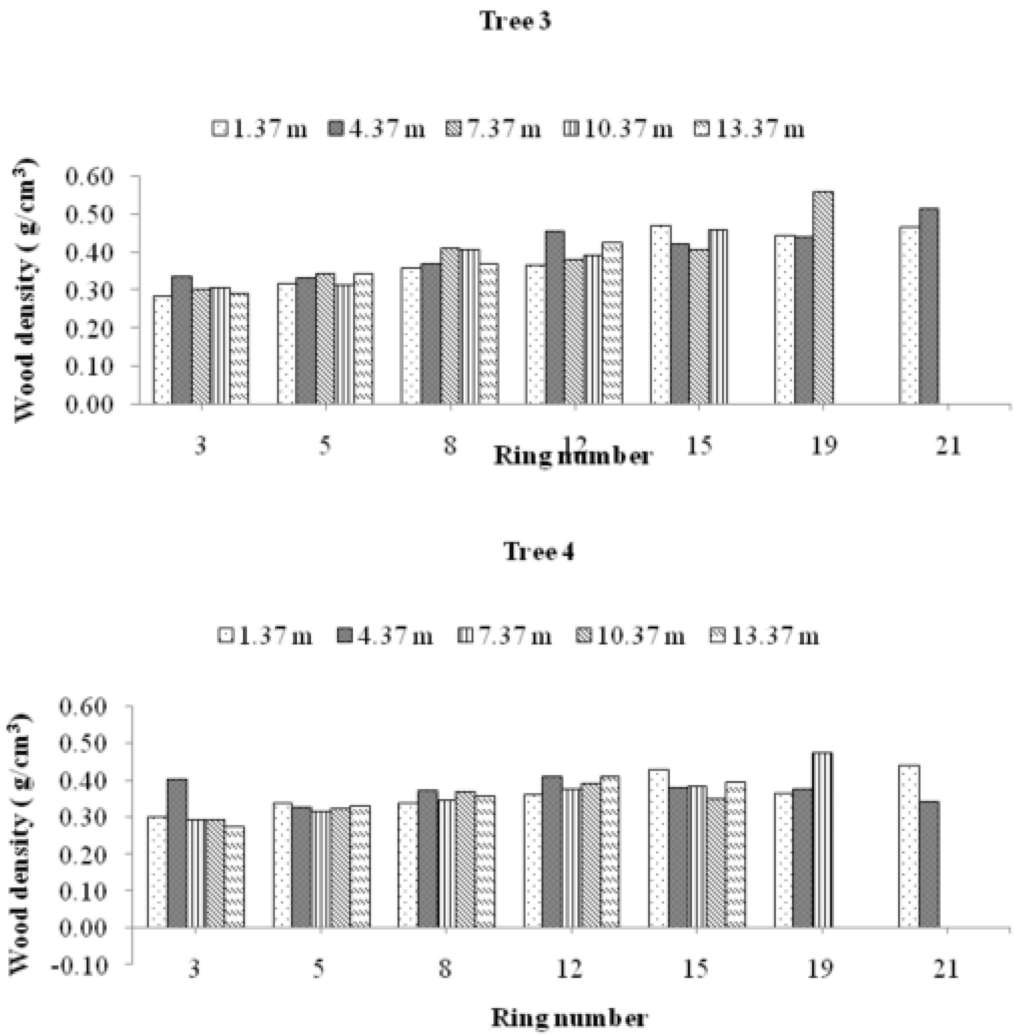

Fig. 4. Axial variation of wood density (vertical sequence) in Tree 3 and 4

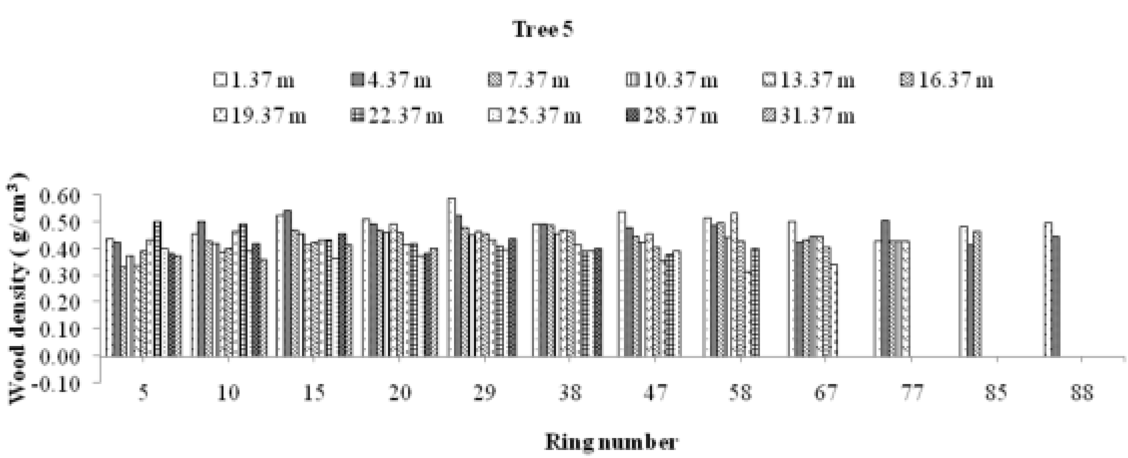

Fig. 5. Axial variation of wood density (vertical sequence) in Tree 5

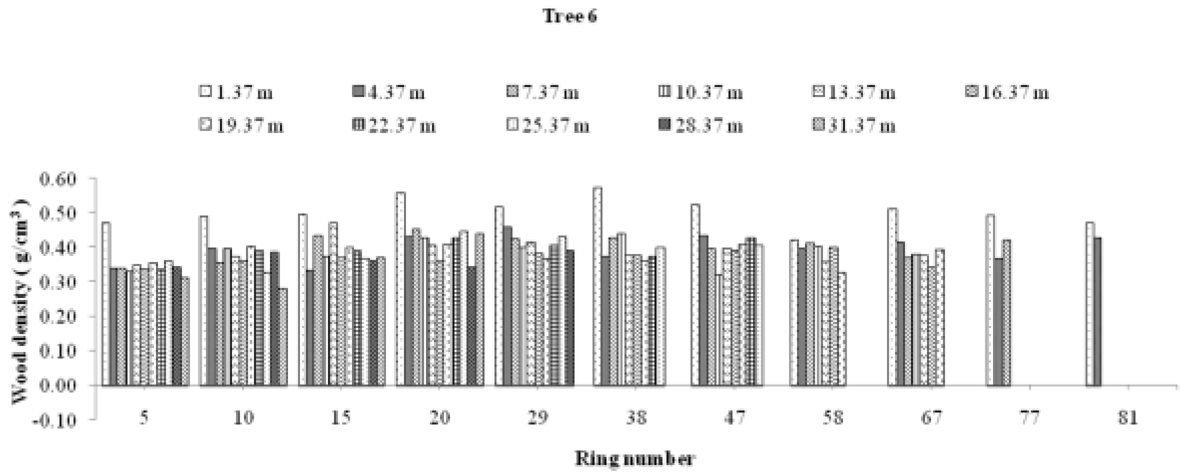

Fig. 6. Axial variation of wood density (vertical sequence) in Tree 6

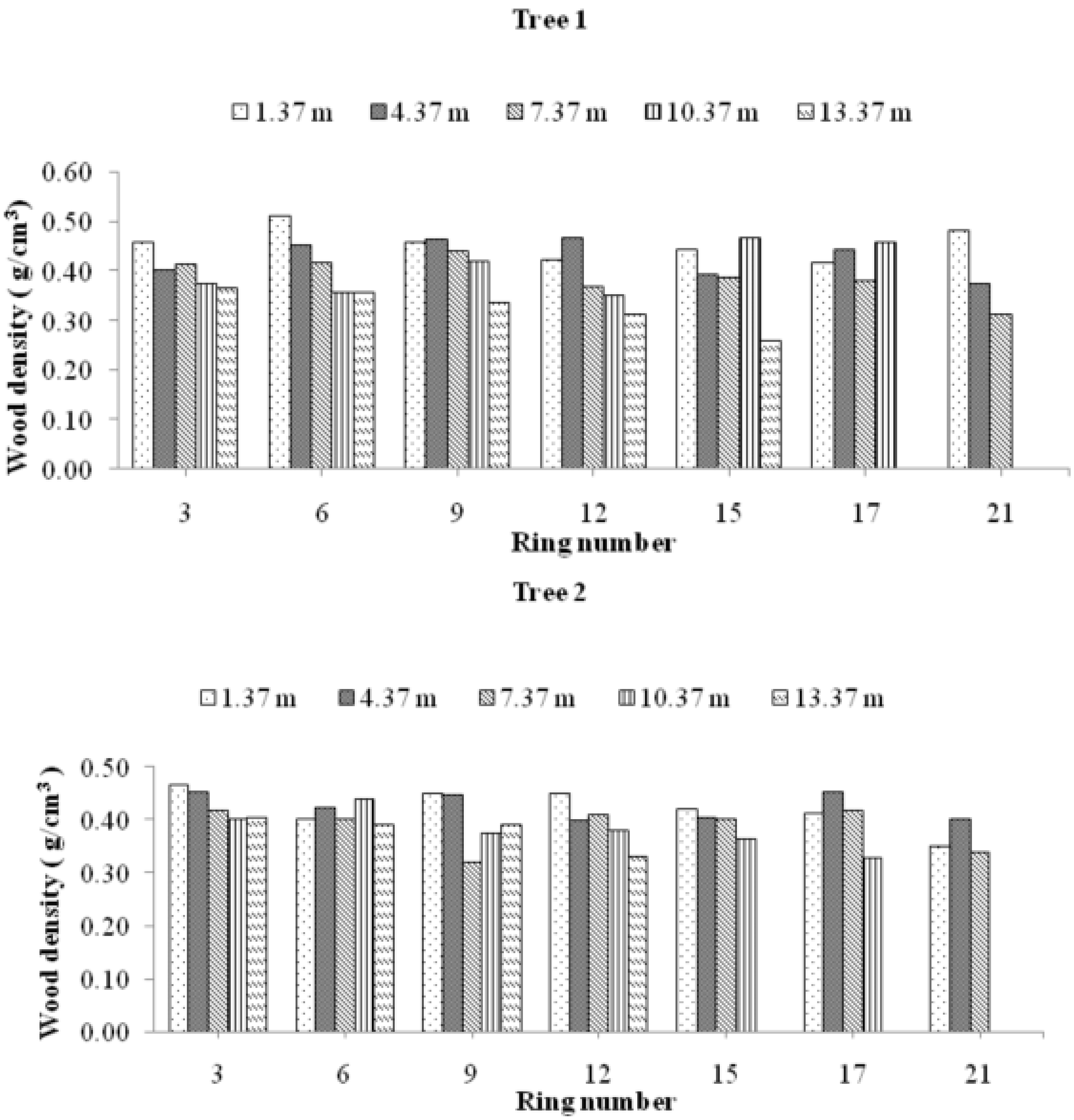

Fig. 7. Axial variation of wood density (oblique sequence) in Tree 1 and 2

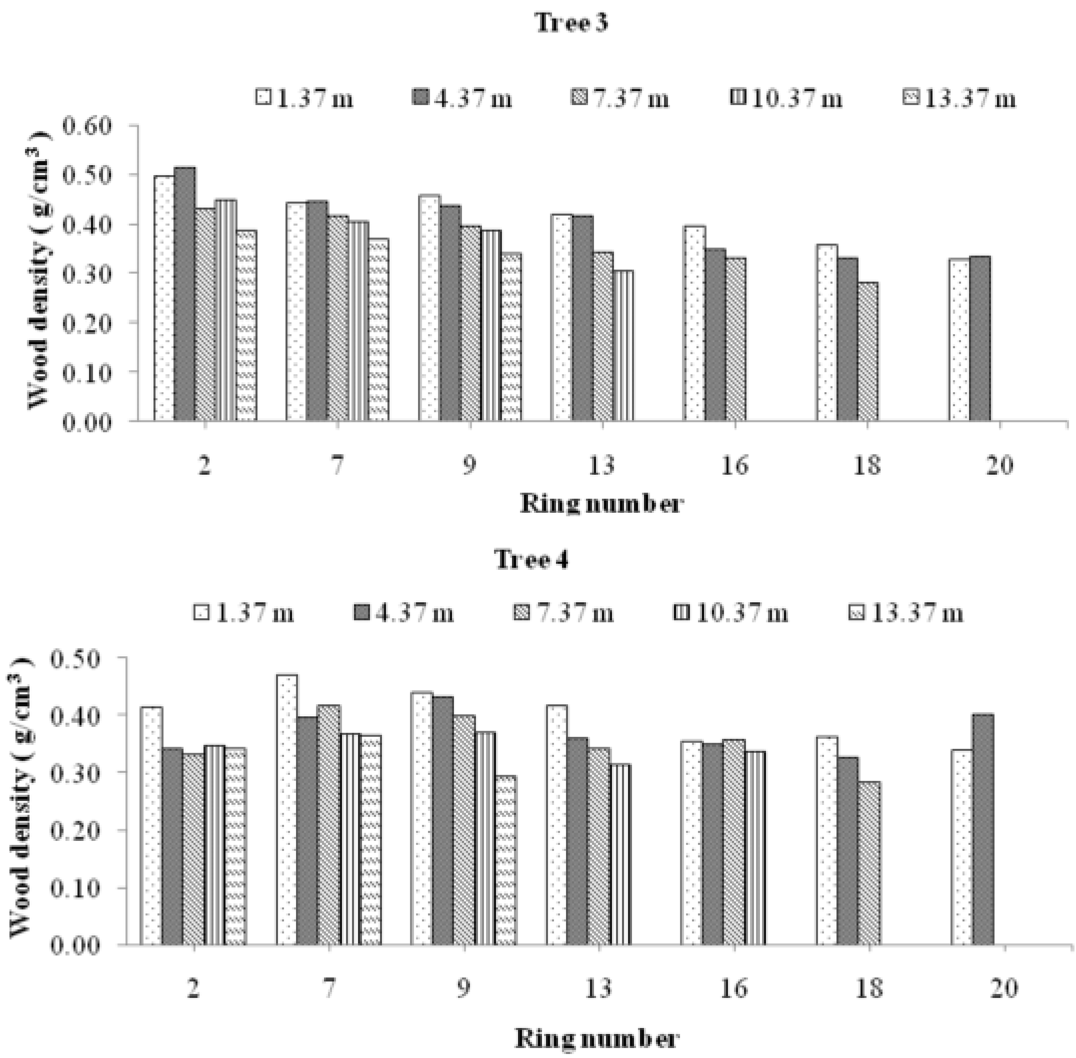

Fig.8. Axial variation of wood density (oblique sequence) in Tree 3 and 4

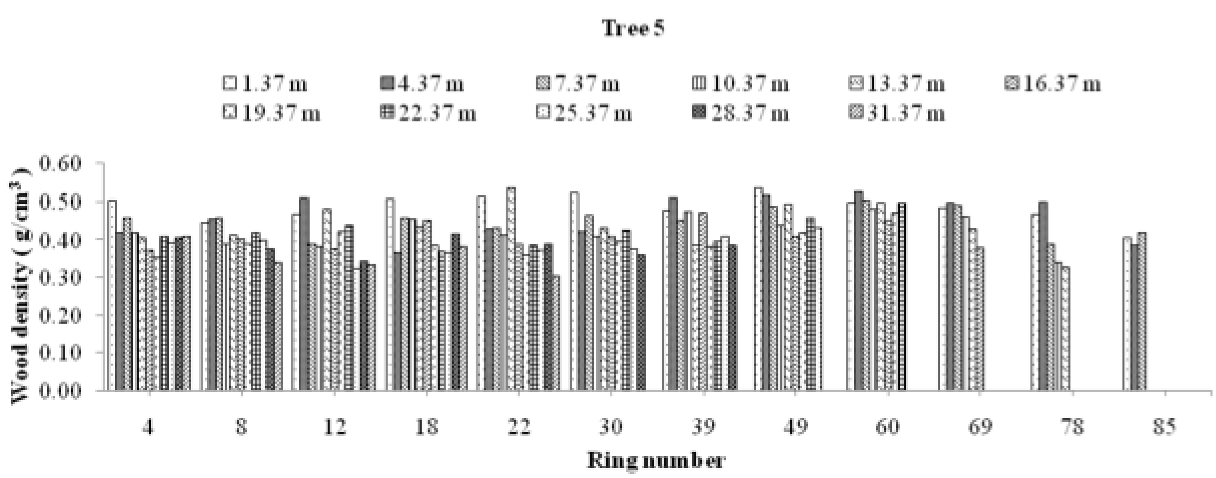

Fig. 9. Axial variation of wood density (oblique sequence) in Tree 5

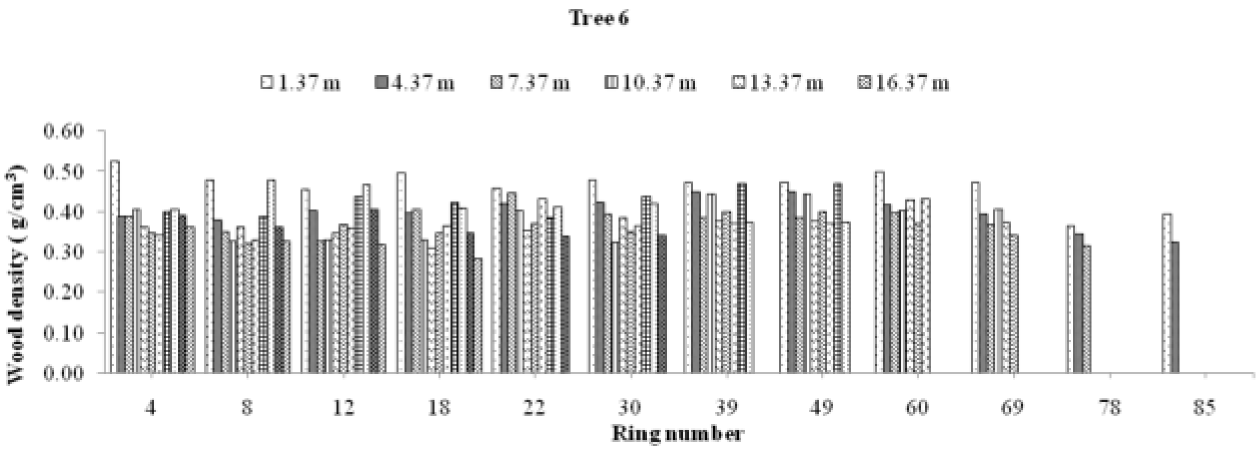

Fig. 10. Axial variation of wood density (oblique sequence) in Tree 6

Simple correlation and regression analyses were carried out to see the effect of height on average wood density of discs in both vertical and oblique sequences. The following regression equations were obtained:

1. $Y = 0.436 + (-0.003) X$
   $r = -0.312^{*} \quad r^2 = 0.097$
2. $Y = 0.399 + 0.001X$
   $r = 0.129^{ns} \quad r^2 = 0.016$

Where, Y = Average wood density of discs.
X = Height
r = correlation coefficient at 0.05 level
r^2 = coefficient of determination.

These equation revealed that in vertical sequence, the relationship between height and density was though statistically significant and negative but it was poor (Table 1). The relationship between wood density and height in oblique sequence was too weak to be significant (Table 2). Similar results were obtained by Jyske et al. (2008) and Saranpää (2003). In *Pinus merkusii*, the average density of discs is higher at base than the top of trees. It may be because of decrease in volume of mature wood with increasing height. Also, most of the cross-sectional discs at the height of 1.37m, 4.37m and 7.37 m have compression wood. The result given in (Figs. 11 and 12) showed a positive and highly significant relationship between breast-height and whole tree wood density in vertical and oblique sequences. The present investigation is in agreement with the findings of other species like *Pinus wallichiana* (Seth et al. 1989), *Pinus elloittii* (Melo et al. 2013) and *Pinus taeda* (de Melo 2015). Therefore, breast-height sampling may be suggested for comparison of wood density among trees of merkus pine.

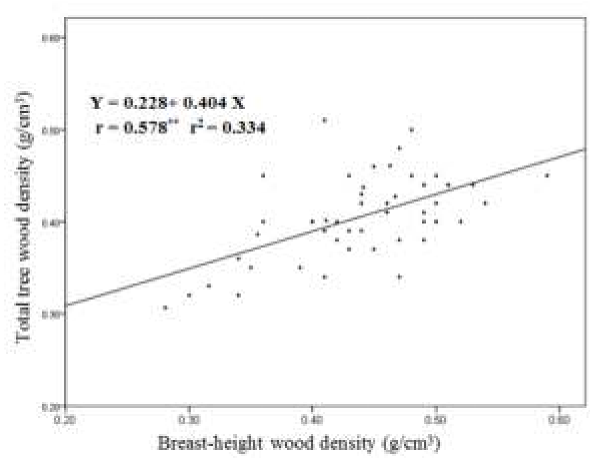

Fig.11. Relationship between breast-height and total tree wood density (vertical sequence) in *Pinus merkusii*

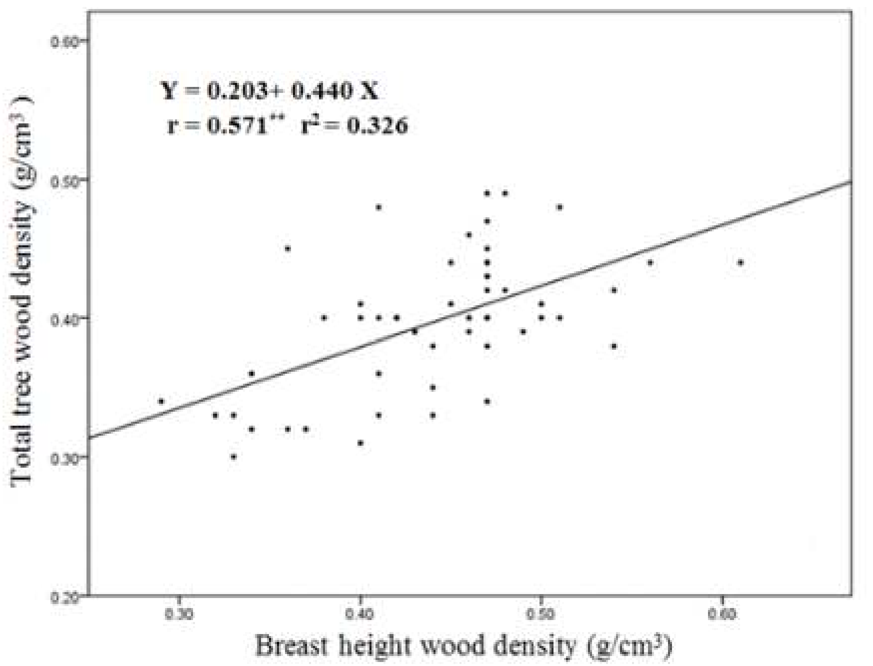

Fig. 12. Relationship between breast-height and total tree wood density (oblique sequence) in *Pinus merkusii*

Table 1. The relationship of height and wood density in vertical sequence in *Pinus merkusii.*

Tree No.	Correlation coefficient (r)	Coefficient of determination (r^2)	Regression constant (B_o)	Regression coefficient (B_1)	Standard error (Sb_1)
Tree-1	- 0.855**	0.730	0.482	- 0.015**	0.004
Tree-2	- 0.616ns	0.379	0.520	- 0.014ns	0.007
Tree-3	- 0.772*	0.586	0.496	- 0.018*	0.005
Tree-4	- 0.822*	0.676	0.469	- 0.016*	0.004
Tree-5	- 0.657*	0.431	0.486	- 0.005*	0.002
Tree-6	- 0.788**	0.621	0.465	- 0.004**	0.001
Pooled	- 0.312*	0.097	0.436	- 0.003*	0.001

The levels of significance used are: ns= non-significant; * = Significant at 0.05 level.
** =Significant at 0.01 level i.e. highly significant

Table 2. The relationship of height and wood density in oblique sequence in Pinus merkusii.

Tree No.	Correlation coefficient (r)	Coefficient of determination (r^2)	Regression constant (B_o)	Regression coefficient (B_1)	Standard error (Sb_1)
Tree-1	- 0.624^{ns}	0.390	0.548	- 0.009^{ns}	0.004
Tree-2	0.896**	0.803	0.178	0.041**	0.009
Tree-3	0.822*	0.676	0.267	0.018*	0.005
Tree-4	- 0.898**	0.807	0.515	- 0.023**	0.005
Tree-5	0.113^{ns}	0.013	0.425	0.001^{ns}	0.002
Tree-6	- 0.752**	0.566	0.467	- 0.005**	0.001
Pooled	0.129^{ns}	0.016	0.399	0.001^{ns}	0.001

The levels of significance used are : ns= non-significant; * = Significant at 0.05 level.
** =Significant at 0.01 level i.e. highly significant

CONCLUSIONS

Juvenile wood and mature wood rings show similar pattern of axial variation in wood density. There is decreasing trend of wood density variation from bottom to top of trees axially in both vertical and oblique sequences. There exists a positive and highly significant relationship between wood density of breast-height and total tree value.

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