Wood Anatomical Features and Physical Properties of Fast Growing Red Meranti from Line Planting at Natural Forest of Central Kalimantan

Joko Sulistyo, Harry Praptoyo, Ganis Lukmandaru, Ragil Widyorini, Widyatno, Oka Karyanto, Futoshi Ishiguri, and Sri Nugroho Marsoem

Abstract

High productivity fast growing species plantation establishment such as the line planting of red meranti (i.e *Shorea leprosula* and *Shorea parvifolia*) with intensive silviculture is one potential solution to improve wood supply for industries in Indonesia. However, the information of anatomical properties and wood properties of these two species related to the influence of the line planting system and tree growth rate is limited. This paper studies the anatomical features, wood cell proportions, fiber dimensions and physical properties of wood in radial variation in relation to the line planting effect and tree growth rate. Wood of the trees grown in the line planting system showed higher proportion of vessel element compared to those of wood from natural forest. The vessel diameter of wood from the line planting was also larger than that of in wood from natural forest. The specific gravity of wood from *Shorea parvifolia* grown on the line planting was higher than that of wood grown in natural forest. The variation of specific gravity on wood portion near to the pith of *Shorea leprosula* and *Shorea parvifolia* trees grown on the line planting was related to the variation of the cell wall thickness. The bigger diameter of trees grown or the faster growth rate in the line of planting at the same age shows the greater vessel diameter in wood of *Shorea leprosula* and *Shorea parvifolia* and greater specific gravity of *Shorea parvifolia* wood.

Keywords: Fast growing red meranti, wood cells proportion, fiber dimension, physical properties.

Introduction

In the last decade, there was a gap of wood material supply and the capacity of wood industries in Indonesia. The wood material supply from forest is unable to meet the industries' demand. For example in 2010, the production capacity of sawmill and plywood/LVL was 13-2.7 million and 20.8-3.6 million m^3/year, respectively. On the other hand, the raw material supply for these two industries were only 5.5 and 6 million m^3 (Ministry of Forestry 2010). These conditions also deteriorate the sustainability of forest in Indonesia. Establishment of fast growing species plantations with high productivity such as the line planting of red meranti including *Shorea leprosula* and *Shorea parvifolia* with intensive silviculture in tropical rain forest are potential solutions of these problems (Na'iem and Widiyatno 2012). The line planting of red meranti trees species is expected to improve the productivity in tropical forest from 3 m^3/ha/year to 300 m^3/ha/year. The establishment of the line planting in tropical rain forest also shows another advantage i.e. to keep the high biodiversity in the area between the lines planting. Fig. 1 shows a schematic design of the line planting in tropical rain forest.

During the initial 5 years-old tree planted on the lines in tropical rain forest, there are clearing treatments for 5 times in the lines in order to open the space to make the trees planted have open space to receive enough sunlight (Na'iem and Widiyatno 2012). The availability of sunlight might be desirable for tree growth and tends to maximize the density and strength of the trees (Shmulsky and Jones 2011). The field observations are found the good performances of red meranti trees including *Shorea leprosula* and *S. parvifolia* i.e. fast growing, straight and cylindrical stems, tall free branches stems, etc. However, there is less information of the anatomical properties and wood properties of these two species related to the influence of the line planting system and tree growth rate. This paper study the anatomical features, wood cell proportions, fiber dimensions and physical properties of wood in radial variation related to the line planting effect and tree growth rate. This study observed 10 years-old two red meranti species i.e. *S. leprosula* and *S. parvifolia* grown on the line planting with diameter variation from 7, 15 and 20 cm. These two tree species from natural forest with diameter of 20 cm was also observed.

Materials and Methods

Wood disc samples of *S. leprosula* and *S. parvifolia* were obtained from the bottom part of about 1.3 m above ground of 10 years-old trees grown on the line planting in natural forest concession managed by PT. Sari Bumi Kusuma, Central Kalimantan. Each tree species were selected from sound trees showing cylindrical and straight stem characteristics with variation on diameters i.e. 7, 15 and 20 cm. Trees of these two species grown naturally on natural forest with diameter of 20 cm were also cut for this study (Table 1). The wood disc was then cut into a strip with a thickness of 5 cm. The wood strip was cut for every 1 cm in the radial position for the observation of anatomical features, proportion of wood cells, fiber dimensions and physical properties.

Fiber dimensions were analyzed from square wood samples with the size of 1 x 1 x 20 mm (tangential, radial and longitudinal) which was taken from every 1 cm on the radial position from pith to the area close to the bark of tree. The wood samples were macerated with the mixed solution of glacial acetic acid and hydrogen peroxide (1:20) and heated at 100°C for more than 4 hours. Stained wood fibers were then placed on deck-glass. The wood fibers of each species were photographed by an optical light microscope (OLM, Olympus BX 51 DP 72, Japan). The dimension including fiber length, cell diameter, cell wall thickness and lumen diameter, as well as proportion of dimension of wood fibers were examined and recorded. Preparation and measuring of the physical properties of wood including green moisture content and green specific gravity were carried out based on *British Standard* no 373, 1957. The wood samples of physical properties were taken from every 1 cm on the radial position from pith to the area close to the bark of tree.

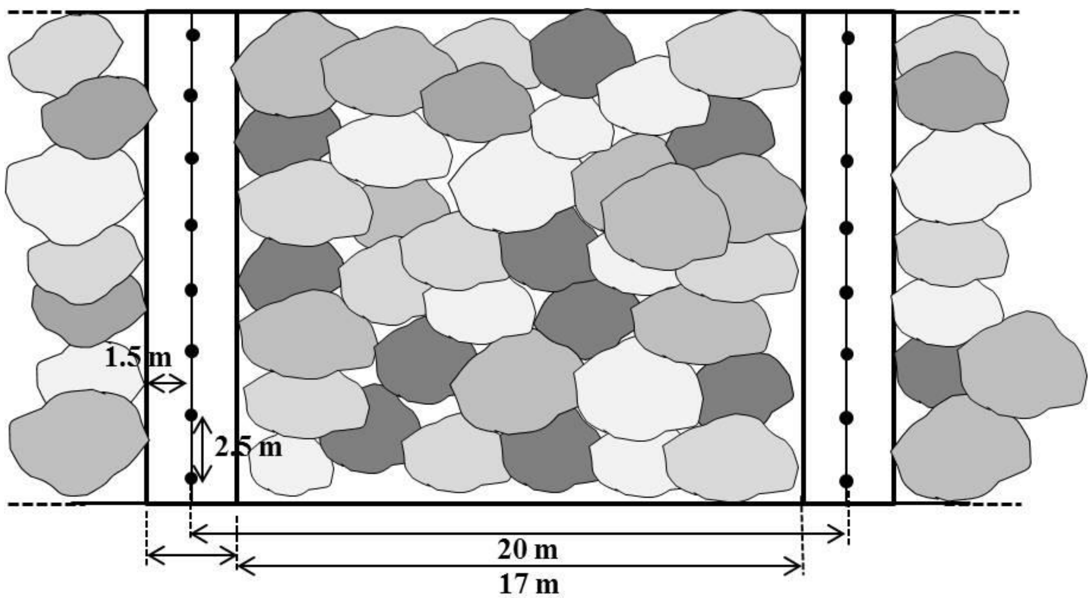

Figure 1. Schematic design of the line planting with intensive silviculture in tropical rain forest

Table 1. Two species of meranti trees were cut from the line planting and natural forest sites

Species	Age (year)	Ø (cm)	Site
Shorea leprosula	10	7	Line planting
	10	15	Line planting
	10	20	Line planting
	-	20	Natural forest
Shorea parvifolia	10	7	Line planting
	10	15	Line planting
	10	20	Line planting
	-	20	Natural forest

Results and Discussion

Fig. 2 shows the anatomical features on the cross section, radial and tangential surfaces of *S. leprosula* and *S. parvifolia* wood. Both *S. leprosula* and *S. parvifolia* wood possessed solitary and two radial multiples pores or vessel (Martawijaya *et al*. 1989).

Fiber showed the largest proportion on both wood species of *S. leprosula* and *S. parvolia* with the proportion in the range of 39.1-56.3% and 48.8-61.2%, respectively. The least cell proportion was found on resin canal and ray cells.

Meanwhile the proportion of vessel on *S. leprosula* and *S. parvolia* was in the range of 8.5-11.3%, 8.14-11.7%, respectively. The line planting system increased the proportion of vessel and parenchyma, on the other hand influenced the decreasing the proportion of wood fiber, as shown in Table 2. Moreover, the line planting which increases the tree growth rate influenced on the increase of vessel diameter as shown in Fig. 2. The relationship between tree growth rate and vessel diameter was similar to previous study (Sisi *et al*. 2010).

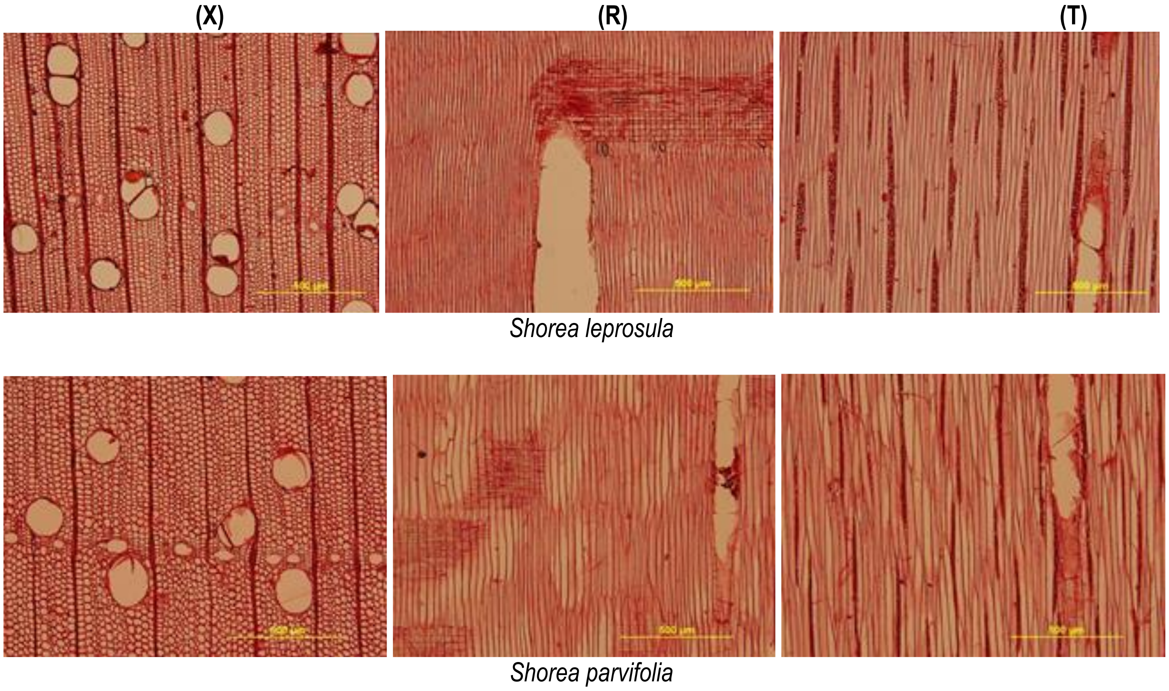

Figure 2. Anatomical features of *S. leprosula* (above) and *S. parvifolia* (below) on the cross section (X), radial (R) and tangential (T) surfaces.

Table 2. Proportion of wood cells of *S. leprosula* and *S. parvifolia* grown on the line planting and natural forest sites

Species	Site	Vessel (%)	Parenchyma (%)	Rays (%)	Fiber (%)	Resin Canal (%)
Shorea leprosula	Line planting	8.34	14.70	7.49	56.36	1.05
	Natural forest	7.85	13.09	8.36	56.90	1.04
Shorea parvifolia	Line planting	11.75	13.75	10.42	48.94	1.34
	Natural forest	8.01	11.70	8.51	59.49	1.30

Table 3 shows the fiber dimensions of *S. leprosula* and *S. parvifolia* grown both on the line planting and natural forest. The fiber length, fiber diameter and cell wall thickness of wood from *S. leprosula* grown on natural forest was higher than those of wood from the trees grown on the line planting. On the contrary, *S. parvifolia* grown in the line planting possessed the increase of fiber length compare to the fiber length from the tree grown on natural forest. The increase of fiber length on *S. parvifolia* grown on the line planting probably determined on the higher specific gravity of wood as shown in Table 4. The higher specific gravity of wood of *S. leprosula* was found from the tree grown on natural forest due to the effect of fiber length, lumen diameter and cell wall thickness. Panshin and DeZeeuw (1980) pointed out that, in general terms, the density of wood depends on (1) the size of cells, (2) the thickness of the cell walls, and (3) the inter-relationship between those two.

Fig. 3 shows that the specific gravity of wood from *S. leprosula* and *S. parvifolia* trees grown on natural forest rapidly increased from pith to bark. The specific gravity increases from the pith to the bark has been reported by others (Huang *et al*. 2003; Jordan *et al*. 2008). The pattern of green moisture content variation on the radial position of *S. parvifolia* grown on natural forest was on the contrary with the pattern of the specific gravity variation as reported previously (Chu and Lin 2007). However, the pattern of green moisture content variation on the radial positions of *S.*

leprosula was similar to the pattern of specific gravity variation. The amount of water in cell wall or lumen of wood cell near the pith may decrease as result of deposition of extractive (Shmulsky and Jones 2011). *Shorea leprosula* and *S. parvifolia* trees grown on the line planting showed a different pattern of specific gravity of the radial positions. The specific gravity of wood near the pith of tree grown on the line planting tended to be higher than that of tree grown on the natural forest. The increase of specific gravity on part near the pith of tree grown on the line planting was probably due to the response of the clearing for 5 times in the initial 5 year to make the trees planted had open space to receive enough sunlight. The availability of sunlight might be desirable for tree growth and tends to maximize the density these trees (Shmulsky and Jones 2011).

The fiber proportion of *S. leprosula* and *S. parvifolia* showed no consistent pattern on the effect of tree growth rate or tree diameter, as shown in Table 5. The vessel proportion of *S. leprosula* and *S. parvifolia* was recognized a contrast pattern related to tree growth rate. The vessel proportion of *S. leprosula* decreased with the increase of tree diameter or growth rate, which was similar to that *Populus nigra* (Sisi *et al*. 2010; Phelps *et al*. 1982) and *Shorea acuminatissima* (Ishiguri *et al*. 2012). In contrast, the increase of vessel proportion was found with the increase of *S. parvifolia* tree diameter or growth rate (Ishiguri *et al*. 2012).

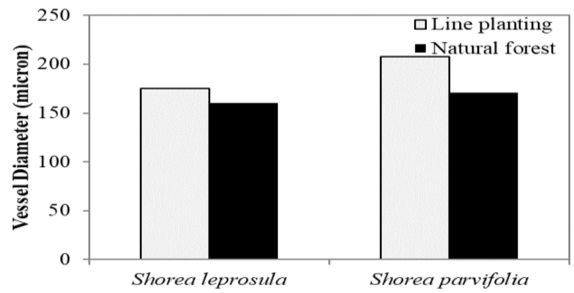

Figure 3. Vessel diameter of *S. leprosula* and *S. parvifolia* grown on the line planting and natural forest sites.

Table 3. Fiber dimensions of *S. leprosula* and *S. parvifolia* grown on the line planting and natural forest sites.

Species	Sites	Fiber Length (mm)	Fiber Diameter (micron)	Lumen Diameter (micron)	Cell wall Thickness (micron)
Shorea leprosula	Line Planting	1.042	22.68	19.04	1.820
	Natural Forest	1.081	22.88	18.84	2.020
Shorea parvifolia	Line Planting	1.095	21.65	17.94	1.851
	Natural Forest	0.955	27.16	23.15	2.005

Table 4. Green specific gravity (SG) and green moisture content (MC) of wood of *S. leprosula* and *S. parvifolia* grown on the line planting and natural forest sites

Species	Sites	Green SG	Green MC (%)
Shorea leprosula	Line Planting	0.255	101.6
	Natural Forest	0.277	78.1
Shorea parvifolia	Line Planting	0.320	118.5
	Natural Forest	0.260	97.6

Table 5. Proportion of wood cells of *S. leprosula* and *S. parvifolia* grown with different rates on the line planting

Species	Diameter (cm)	Vessel (%)	Parenchyma (%)	Rays (%)	Fiber (%)	Resin Canal (%)
Shorea leprosula	7	11.30	12.64	10.54	51.41	
	15	10.47	13.57	14.68	39.17	0.95
	20	8.34	14.70	7.49	56.36	1.05
Shorea parvifolia	7	8.14	14.74	8.89	48.79	0.88
	15	9.46	12.18	11.39	52.46	1.54
	20	11.75	13.75	10.42	48.94	1.34

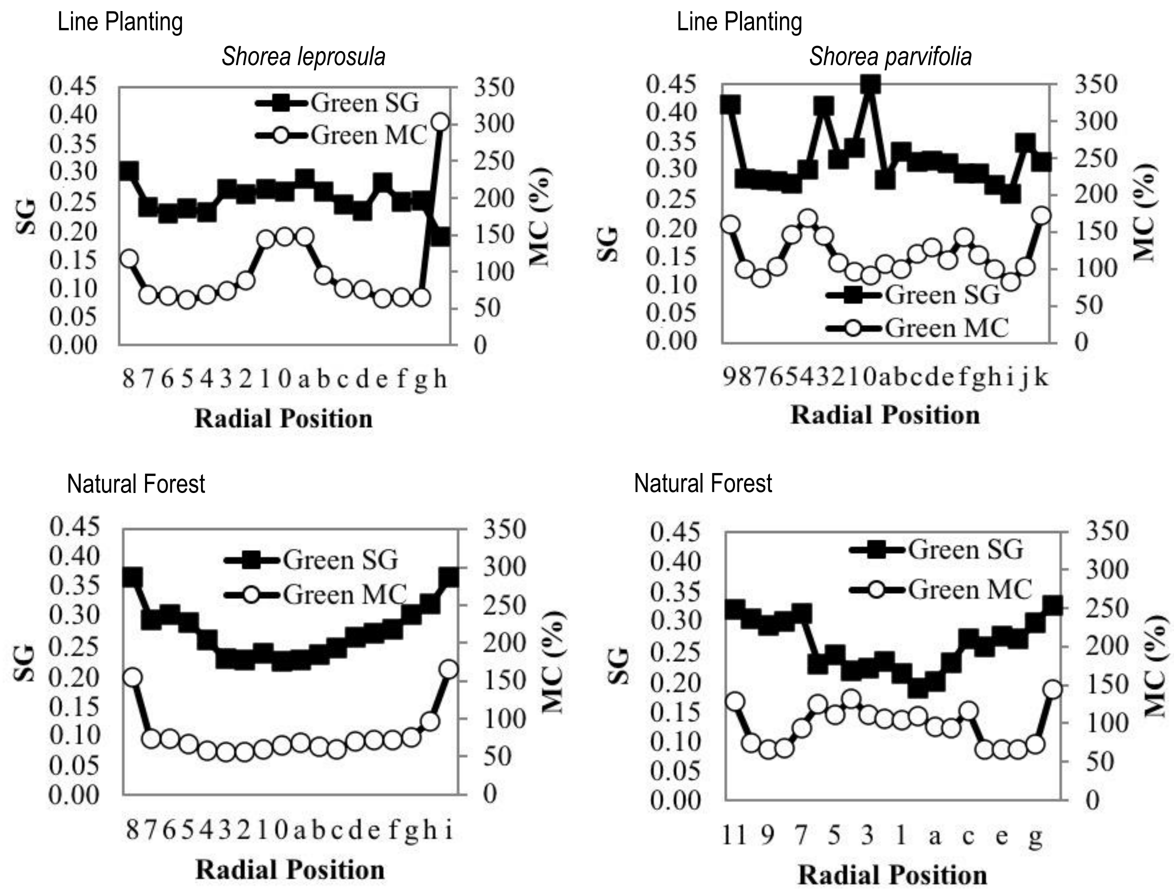

Figure 4. Variation of green SG and green MC in radial positions of wood of *S. leprosula* (left) and *S. parvifolia* (right) grown on the line planting (upper) and natural forest (below) sites.

Table 6. Green specific gravity (SG) and fiber dimensions of wood of *S. leprosula* and *S. parvifolia* grown with different rates on the line planting

Species	Tree Diameter (cm)	Green SG	Fiber Length (mikron)	Fiber Diameter (mikron)	Lumen Diameter (mikron)	Cell wall Thickness (mikron)
Shorea leprosula	7	0.40	1.023	22.28	17.79	2.251
	15	0.41	1.062	20.08	15.63	2.226
	20	0.26	1.042	22.68	19.04	1.820
Shorea parvifolia	7	0.26	0.941	23.40	19.58	1.908
	15	0.28	0.999	23.41	19.66	1.875
	20	0.31	1.095	21.65	17.94	1.851

Fig. 4 shows that the vessel diameter increased with the increase of both *S. leprosula* and *S. parvifolia* tree diameter or growth rate. These results are comparable to that found by other research on that *Populus nigra* (Sisi *et al*. 2010) and *Shorea acuminatissima* (Ishiguri *et al*. 2012).

Table 6 shows the proportion of wood cells of 10 year-old *S. leprosula* and *S. parvifolia* grown on the line planting with different rates. The fiber length tended to increase with the increase of tree diameter from 7 to 15 cm, on the other hand the cell wall thickness decreased. The further increase of tree diameter tended to decrease the fiber length and cell wall thickness. The interesting finding was shown by the fiber dimensions of *S. parvifolia* related the tree growth. The fiber length increase, on the contrary the fiber diameter and cell wall thickness decreased with the increase of tree diameter of *S. parvifolia*. Therefore the increase of tree growth rate on *S. parvifolia* trees and the increase up to a certain tree diameter of *S. leprosula* increased the fiber length but decreased the fiber diameter and cell wall thickness which was determined by the increase of the specific gravity of wood (Panshin and De Zeeuw 1980). The similar result that showed the increase of basic density of wood with the increase of growth rate of *Shorea acuminatissima* trees reported previously (Ishiguri *et al*. 2012).

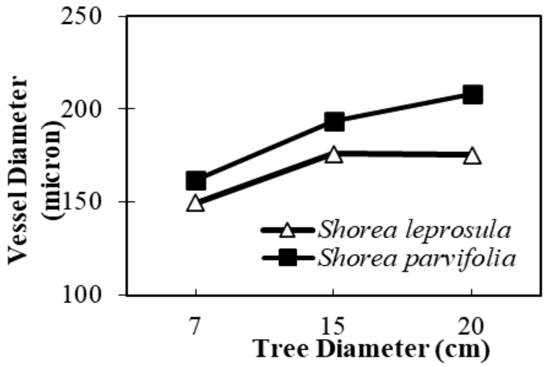

Figure 5. Vessel diameter in wood of 10 year old *S. leprosula* and *S. parvifolia* trees grown with different rates on the line planting.

Fig. 5 shows the different radial variation found for green moisture content, which was high near the pith and then decrease toward to the bark of *S. leprosula* trees. On the other hand, the green moisture content was low near the pith and then increased toward the bark of *S. parvifolia* trees. The variation of green moisture content was reported previously (Chu and Lin 2007). Tree diameter of both tree species influenced the green moisture content in the radial position. The green moisture content of tree with diameter of 7 cm possessed the thickest cell wall which was lower than those of tree with bigger diameter.

Fig. 6 shows the variation of specific gravity, fiber length and cell wall thickness on the radial positions of 10 year-old *S. leprosula* and *S. parvifolia* trees grown on the line planting with different rates. The variation of specific gravity on the radial positions of both tree species was discussed on the previous part. The effect of tree diameter on the variation of specific gravity was strongly related to the fiber dimensions as discussed on the previous part. The specific gravity variation on the radial positions near to the pith was obviously determined by the variation of cell wall thickness due to the response of the clearing for 5 times in the initial 5 year to make the trees planted had open space to receive enough sunlight. The availability of sunlight might tend to maximize the cell wall thickness which was determined by specific gravity.

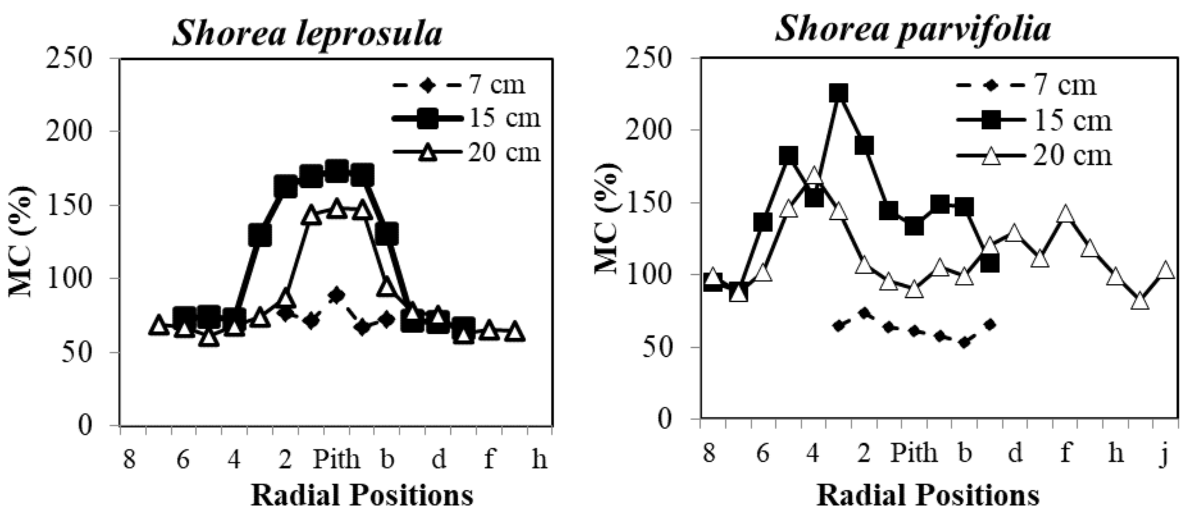

Figure 6. Variation of green moisture content (MC) in the radial positions of wood of *S. leprosula* (left) and *S. parvifolia* (right) trees grown with different rates on the line planting.

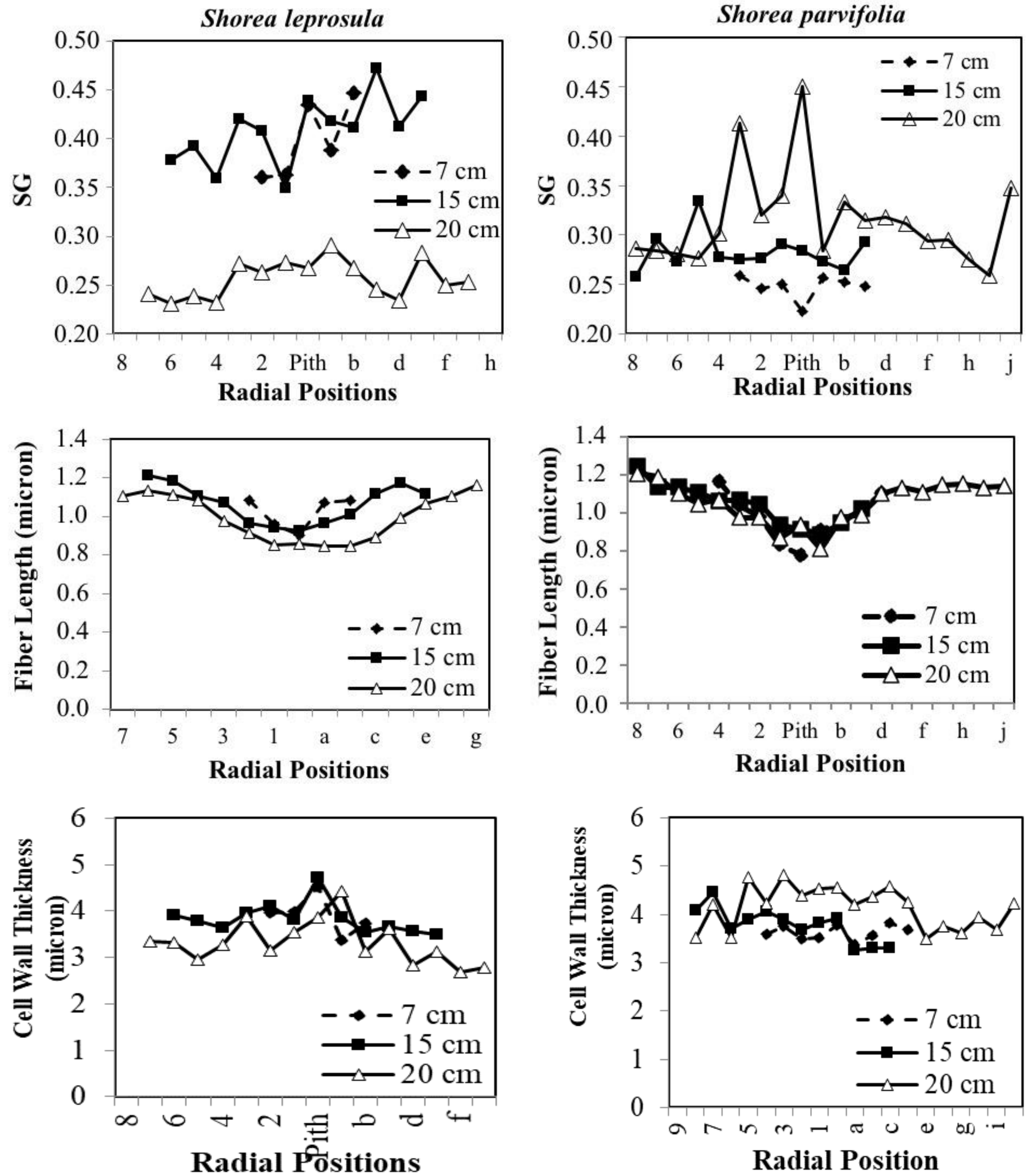

Figure 7. Variation of green specific gravity (SG), fiber length and cell wall thickness in the radial positions of wood of *S. leprosula* (left) and *S. parvifolia* (right) trees grown with different rates on the line planting.

Conclusions

The line planting system influenced on the higher proportion of vessel element in wood compare to those of wood collected from natural forest. The vessel diameter of wood from the line planting was greater than that of wood from natural forest. The specific gravity of wood from *Shorea parvifolia* grown on the line planting was greater than that of trees grown in the natural forest. The variation of specific gravity of wood in the radial positions grown on the line planting was different to that of trees grown in the natural forest. The variation of specific gravity on part near to the pith of *Shorea leprosula* and *Shorea parvifolia* trees grown on the line planting related to the variation of the cell wall thickness. The bigger diameter of trees grown or the faster growth rate in the line planting at the same age shows the greater vessel diameter in wood of *Shorea leprosula* and *Shorea parvifolia* and the higher specific gravity of wood of *Shorea parvifolia.*

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