VARIATIONS IN VOLUME AND DIMENSIONS OF RAYS AND THEIR EFFECT ON WOOD PROPERTIES OF TEAK

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ABSTRACT

Six teak (*Tectona grandis* L.) trees were sampled from two districts in Bangladesh. Ray proportion and dimensions of rays (ray area, ray height, and ray width) on tangential sections were measured, and the influence of ray volume on longitudinal and radial compression strength was investigated. Ray proportion remained more or less constant from pith to bark. Number of rays/mm^2 and dimensions of rays became constant at about ring 10 from the pith. Ray proportion and dimensions showed characteristic values from tree to tree and were not affected by growth rate. The trees that had the highest ray volume showed higher specific gravity and higher radial compression strength. It can be considered as the influence of the rays. Hence it may be advisable to breed teak with a high ray proportion.

Keywords: *Tectona grandis* L., ray volume, ray dimensions, compression strength, Bangladesh.

INTRODUCTION

In a previous report (Rahman et al. 2004), we investigated the relationship between tissue proportions and wood density of teak grown in Bangladesh and found that ray proportion had an important effect on wood density together with vessel proportion. Teak wood is composed of four major kinds of cells: fibers, vessel elements, longitudinal parenchyma, and ray parenchyma. As in softwoods and some species of hardwoods, ray proportion in teak is not very high compared to fiber or vessel proportion. Thus, rays are often ignored by wood technologists or forest geneticists. Ray tissue constitutes on an average about 17% of the hardwood xylem; sometimes it may reach to more than 30% (Haygreen and Bowyer 1982). In teak, Bhat et al. (2001) reported that ray percentages were 20.3% in fast-grown trees and 18.7% in slow-grown trees. In our research, ray tissue occupied 10.6~14.0% of the wood volume. In addition to identifying tree species, rays have an important effect on wood properties for determining wood quality. Relationships between ray proportion and strength properties (Schniewind 1959; Kennedy 1968; Beery et al. 1993; Mattheck and Kubler 1997) and shrinkage values (Schniewind 1959; Kawamura 1979, 1984) have been reported. Taylor (1969a,b) and Boyce et al. (1970) also indicated that ray proportion was positively correlated with specific gravity in hardwoods.

Thus, variation in ray volume, especially in hardwoods, is quite an important factor in determining wood quality parameters such as density, strength properties, and shrinkage. But reports on teak have apparently not been published, despite its being a useful wood species. In this research we investigated the relationship between ray dimensions (ray area, ray height and ray width) and ray proportion, and the influence of ray proportion on compression strength (longitudinal and radial).

MATERIALS AND METHODS

Sample trees

Teak (*Tectona grandis* L.) wood samples were taken from forests under Forest Department of Bangladesh in two districts—the Sylhet district (ST teak), situated in the northeast region, and the Rangamati district (RT teak), situated in the southeast region of Bangladesh, the two main teak-growing areas of the country. Three sample trees were taken from each district. Bangladeshi teaks are mainly of Myanmar origin, but the original provenances of the trees studied are unknown. Ring numbers were 32–38 for ST teak and 37–45 for RT teak.

Measurement of ray dimensions

For the measurement of dimensions of rays, a disc from each sample tree was taken at breast height, and tangential sections were cut from pith to bark. Rays were observed on tangential sections with electron microscopy and five photographs (one cross-section was 1 mm × 1 mm) were taken from each ring. Ray proportion, ray dimensions (ray height, ray width, and ray area), and number of rays were measured from the photographs by an image analysis system.

Compression test

Specimens, 10 mm × 10 mm in cross-section and 20 mm in length, were subjected to two

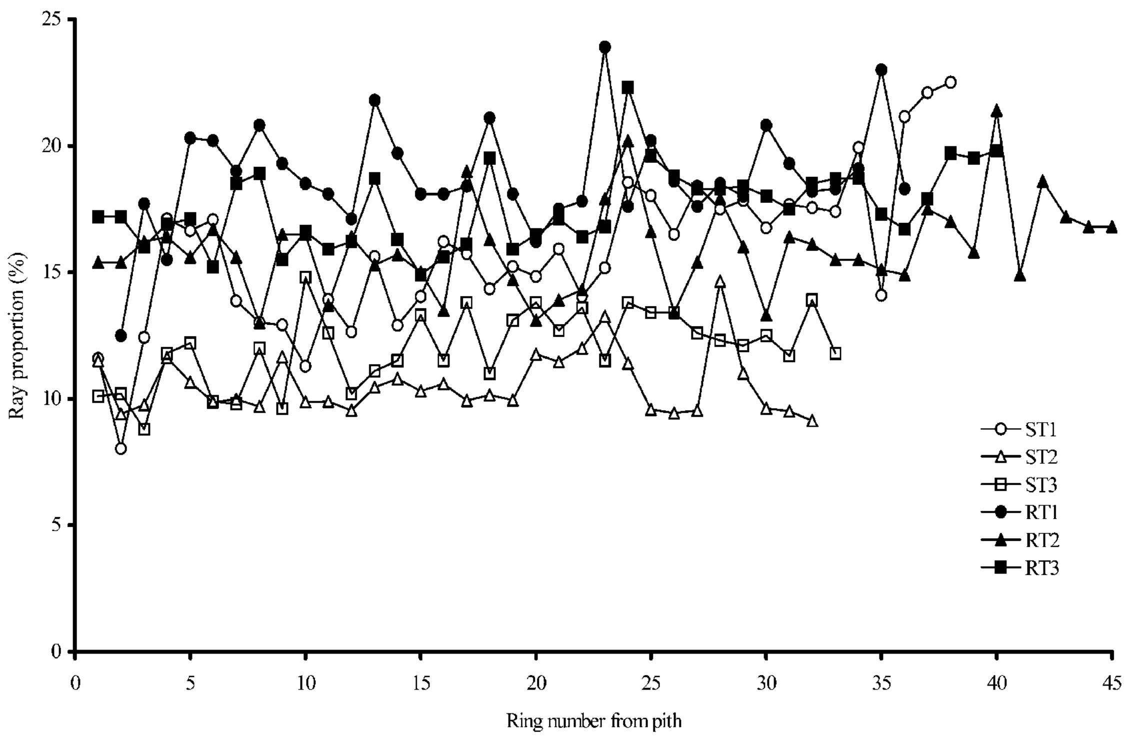

FIG. 1. Variation of ray proportion.

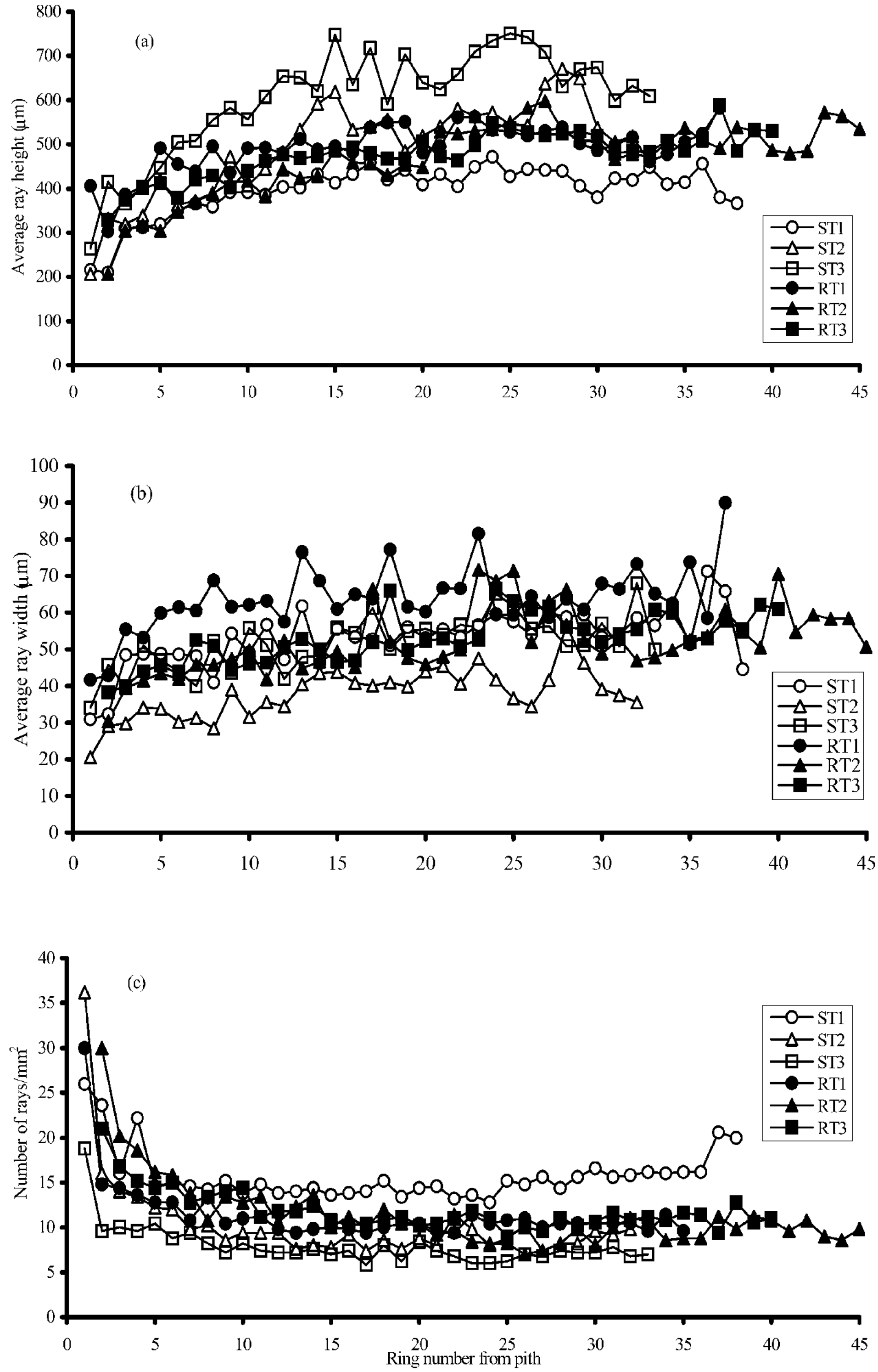

FIG. 2(a)-(c). Variation of ray height (a), ray width (b), and number of rays/mm^2 (c).

tests: compression parallel to the grain (longitudinal compression), and compression perpendicular to the grain (radial compression). The load was applied on tangential and cross-sectional surfaces at the rate of 0.3 mm/min.

RESULTS AND DISCUSSION

Variation of ray proportion and ray dimensions

Figure 1 shows the variation of ray proportion with ring number from the pith. Ray proportion remained more or less constant within individual trees though showing variation between rings. There was variation in ray proportions among the trees. The same radial variation of ray proportion was reported by Taylor (1971) in sugarberry, a ring-porous hardwood and Gartner et al. (1997) in red alder. But different results were also reported. Ohbayashi and Shiokura (1990) reported that proportion of rays (%) was smallest near the pith and increased towards the bark up to a certain distance and then remained more or less constant in some tropical trees. These results have shown that variation of ray proportion from pith to bark depends on the species. The radial variations of ray dimensions, ray height, ray width, and number of ray/mm^2 are shown in Fig. 2a-c. It was found that these variables increased or decreased from the pith to about 10 rings and thereafter remained more or less constant. The averages of ray proportion, ray area, ray height, and ray width in mature wood (above 10th ring from pith) by district are shown in Table 1. Sample trees from Rangamati district (RT teak) had a higher ray proportion. There is no significant relationship between ring width and ray proportion in mature wood. It is clear that ray proportion is not affected by the growth rate. Taylor (1971) reported a similar result in sugarberry. In other studies with *Anthocephalus chinensis* (Lam.) Rich ex Walp, *Gmelina arborea* Roxb, and *Eucalyptus saligna* Sm., it was found that proportion of rays (%) was higher in large diameter trees in comparison to that in small diameter trees (Ohbayashi and Shiokura1990). There was also no effect of ring width on ray dimensions (ray height, ray width, and number of rays/mm^2). Similarly, in our study, average ray area and ring width showed no significant relationship. White and Robards (1966) reported that in ash, sweet chestnut, and sassafras wider rays were found in wood with wider growth rings than in the slower grown wood. It is apparent from our results and reports about other hardwoods that the ray proportions and dimensions of rays are not significantly affected by growth rate (growth ring width) but are peculiar to individual trees. Ray proportion is determined by number of ray/mm^2 and average ray area. It is clear from Table 1 that RT teak had higher ray proportion than ST teak. The most important variable that is closely connected with ray proportion is ray width, that is, trees with wider rays have a tendency to increase ray proportion. It became clear that the anatomical structure of the rays is an individual characteristic that is not affected by growth rate. Therefore, we investigated the distribution patterns of ray dimensions on tangential sections. Figure 3

TABLE 1. *Ray proportion and dimensions of rays in tangential section.*

District	Sample tree	Average ray proportion (%)	Average ray area (μm^2)	Ray height (μm)	Ray width (μm)
Sylhet	ST1	16.7	18,886	422	56
	ST2	10.6	17,814	553	41
	ST3	12.5	29,442	666	55
Average	(ST)	13.3	22,047	547	51
Rangamati	RT1	19.0	27,409	514	67
	RT2	16.0	22,558	499	55
	RT3	17.8	22,634	500	55
Average	(RT)	17.6	24,200	504	59

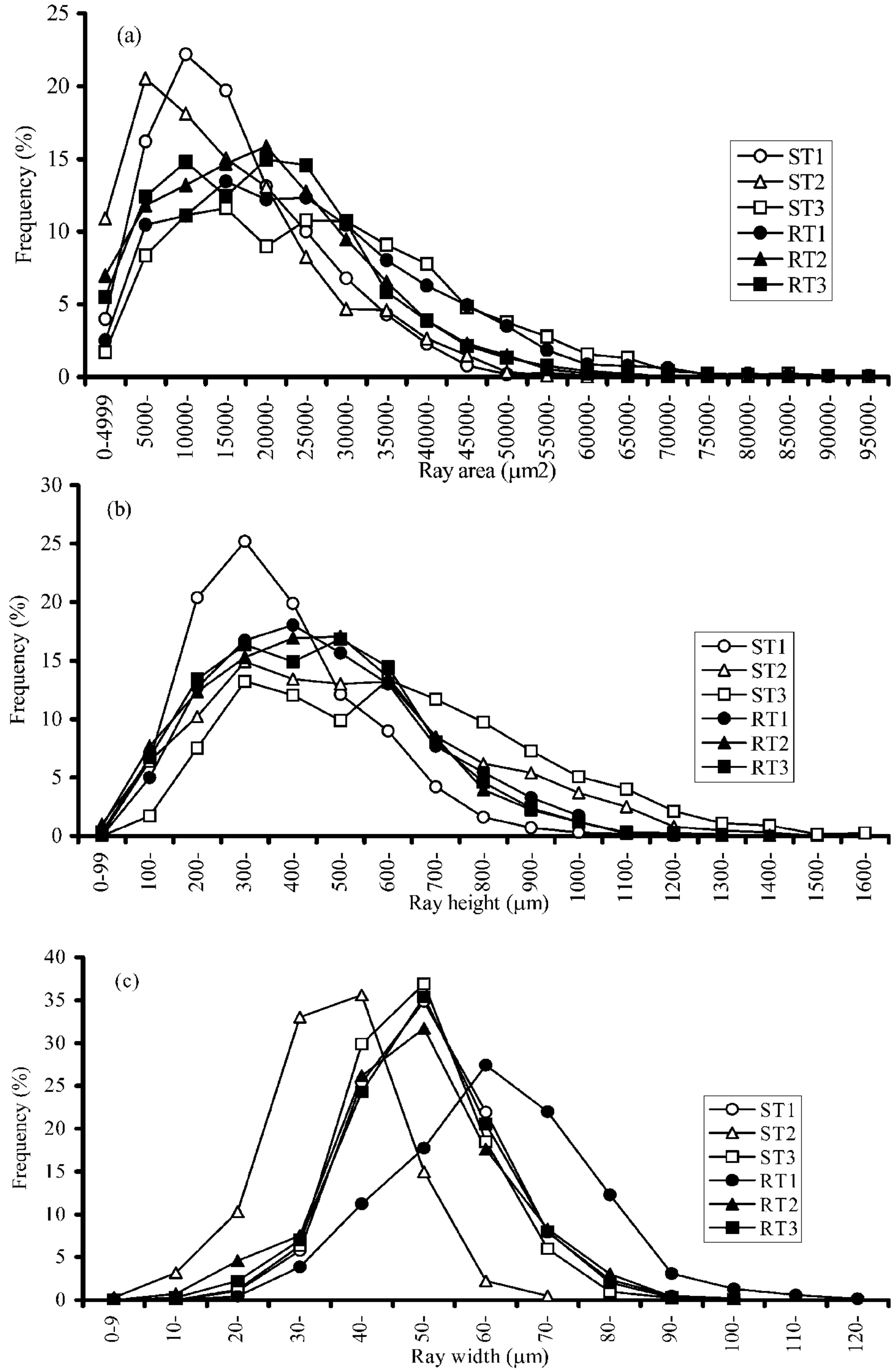

FIG. 3(a)-(c). Distribution of average ray area (a), ray height (b), and ray width (c).

a-c shows the distribution pattern of the dimensions of rays on tangential sections. Two different patterns were found in ray area distribution. ST1 and ST2 had many smaller rays and had a ray area peak within the range from 5000 μm^2 to 15000 μm^2 (Fig. 3a). The rest showed more or less the same pattern. In the distribution pattern of ray height, ST1 had a peak on ray height at 300–399 μm, but the rest showed more or less the same pattern (Fig. 3b). In case of ray width distribution (Fig. 3c), three different patterns were observed. The inherent distribution pattern of ray height was confirmed in teak, a hardwood. It is considered that the differences of ray proportion between the trees of the two districts are due to the difference of distribution patterns of ray dimensions.

Compression strength

To investigate the influence of ray proportion on strength properties of teak, compression strength was examined. Figures 4 and 5 show the relationship between specific gravity and longitudinal compression strength and radial compression strength, respectively. It is clear from Fig. 4 that longitudinal compression strength was closely connected with specific gravity. The differences in compression strength among samples are largely attributable to difference in the specific gravity. In radial compression strength (Fig. 5), each sample tree was positively correlated with specific gravity, but RT1 showed higher strength values for its specific gravity. It suggests another influencing factor besides specific gravity on radial compression strength. In relation to the difference between the tangential and radial compression strength among hardwood species, Kennedy (1968), Bodig (1965), and Beery et al. (1983) stated that ray volume accounted for the larger part of the between-species differences of lateral compression strength. Also, as to the difference of lateral compression strength within the stem, Schnie-

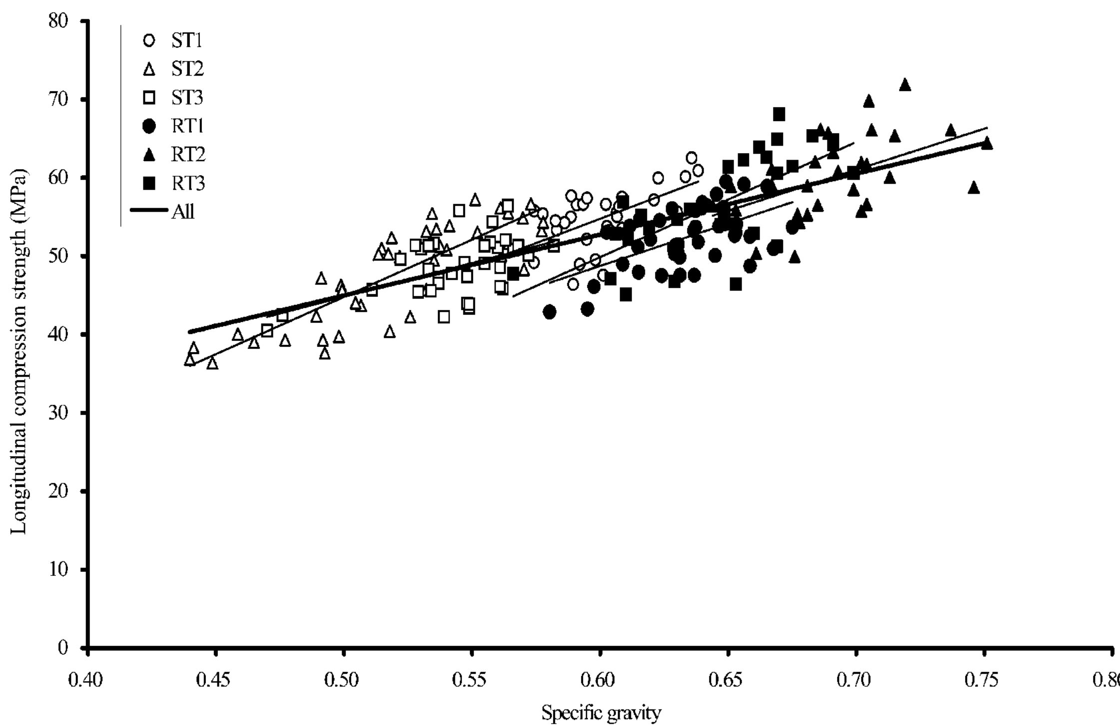

FIG. 4 Relationship between specific gravity and longitudinal compression strength.

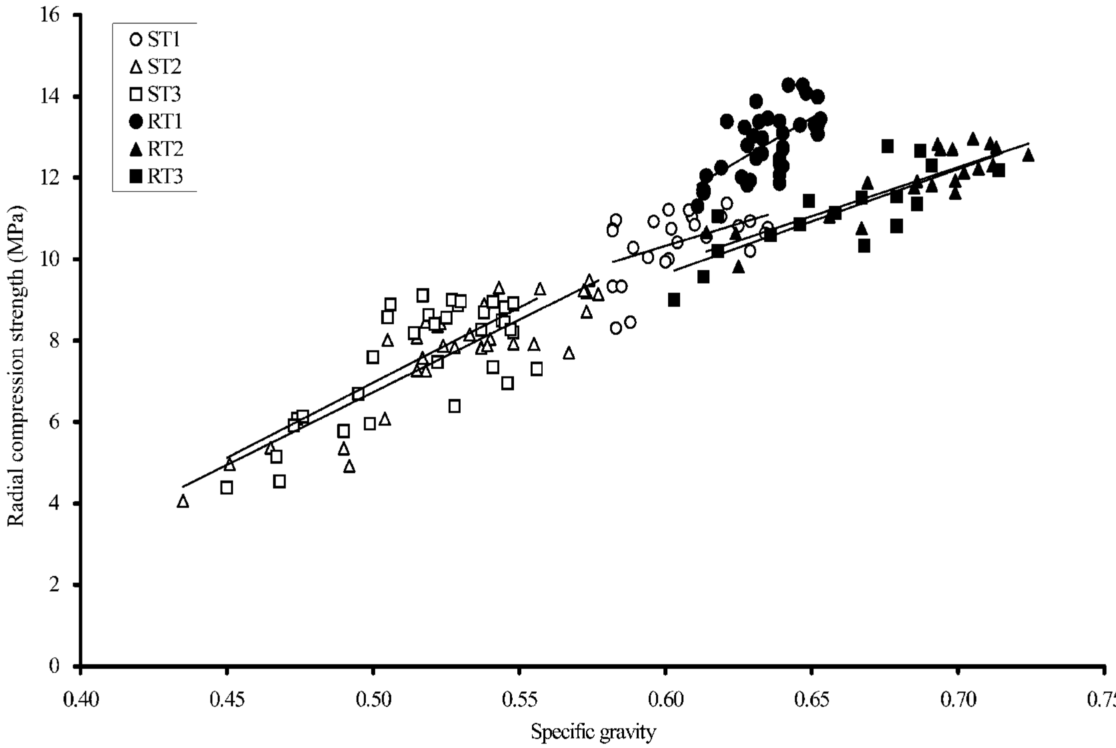

FIG. 5. Relationship between specific gravity and radial compression strength.

wind (1959) and Burgert and Ekstein (2001) reported that the difference between radial and tangential strength was attributed to the higher radial strength of the rays in black oak and in beech, respectively. Table 2 shows the average of specific gravity and compression strength properties. From Table 1 and Table 2, the specific gravity were inclined to increase with ray proportion, and the specific radial compression strength (which is strength divided by specific gravity and a useful index to determine whether the strength differences are due to factors other than the specific gravity) showed the tendency to increase with the ray proportion. In longitudinal compression strength, such a tendency was not found. Our experimental results about the difference of radial compression strength among sample trees of teak can be explained by the difference in ray proportion. Research on the relationship between ray volume and strength properties of teak has not been reported in spite of large differences of ray volume among trees. Rays proportion can be considered one of the important factors in selection of trees for wood properties.

TABLE 2. *Average compression strength properties.*

Sample tree	Longitudinal compression			Radial compression		
	SG	LC	SLC	SG	RC	SRC
ST1	0.600	54.8	91.2	0.604	10.4	17.2
ST2	0.520	47.7	91.7	0.528	7.7	14.6
ST3	0.544	48.6	89.4	0.517	7.6	14.6
RT1	0.634	52.4	82.7	0.635	12.8	20.2
RT2	0.692	60.2	87.0	0.686	11.9	17.4
RT3	0.646	56.7	87.6	0.658	11.1	16.9

SG = Specific gravity.
LC = Longitudinal compression strength (MPa).
SLC = Specific longitudinal compression strength (MPa) (LCS/SG).
RC = Radial compression strength (MPa).
SRC = Specific radial compression strength (MPa) (RCS/SG).

CONCLUSIONS

From the results, it can be shown that ray proportion and dimensions of rays appear to be under genetic control. Growth rate (ring width) has no important effect on ray proportions and ray dimensions. Distribution of ray dimensions on tangential section had characteristic patterns. Ray proportion is considered to be an important influencing factor on wood density and radial compression strength. Rangamati teak had many wider rays and a higher ray proportion and consequently showed higher specific gravity and higher radial compression strength. It can be concluded that in teak, selection for a high ray proportion may result in selection for high quality wood with a higher wood density.

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