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Effect of growth on wood properties for Japanese larch (*Larix kaempferi*): Differences of annual ring structure between corewood and outerwood

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Abstract To investigate the relations between growth and the wood properties of Japanese larch (*Larix kaempferi*), six sample trees of varied ages and radial growth were felled and the ring width, ring density, percentage of latewood, and some other factors were determined. There were significant differences in ring density and percentage of latewood between sample trees with vigorous growth and those with poor growth. In corewood the ring density decreased with increasing ring width for all sample trees, whereas in outerwood this trend did not appear. Moreover, the latewood width increased with the increment of ring width only in outerwood, whereas there was almost no change in the corewood. The variation in patterns of ring width, ring density, and percentage of latewood in the radial direction and the relation with height was also studied.

Key words Japanese larch · annual ring structure · corewood · outerwood

Introduction

It is well known that Japanese larch (*Larix kaempferi*) is one of the most important timber species in the sub-Alpine region and northern area of Japan.[1] Consequently, a lot of investigations have been conducted to assess its wood properties.[1–5] Shigematsu[2,3] studied the variation of wood properties and pointed out that there were great differences between juvenile wood and mature wood in terms of tracheid length, spiral grain, strength, and so on. Takata et al.[4] addressed the variations of radial growth and wood quality among provenances in Japanese larch and reported that in both corewood and outerwood the average ring width had the same negative correlation with basic density. Nobori et al.[6] studied the variation of Japanese larch clones for ring width, average density, and other properties using an X-ray densitometric system. More recent research by Koga et al.[5] investigated the effects of thinning on basic density and tracheid length of Japanese larch; they pointed out that a percentage of latewood was not affected significantly by any of the thinning treatments because of the relative increase in latewood width with the increase in ring width after thinning treatments.

Although great achievements have been made in the research of wood properties for Japanese larch and the fact that differences existed between corewood and outerwood have been found, a detailed report on the annual ring structure of corewood and outerwood has not yet been published. The objectives of this study were to deal with the variation of annual ring structure within corewood and outerwood and the effect of growth on some wood properties. Specifically, the objectives of this study were to: (1) determine the effect of varying growth situation on the ring density and percentage of latewood; (2) evaluate the relations between ring width and ring density, ring width and percentage of latewood in corewood and outerwood; and (3) determine the effect of different heights on wood properties.

Materials and methods

In the experimental plantation located in Shinshu University Forest in Terasawa Yama, the south of Nagano Prefecture, the 70-years-old stand is at an elevation of 1250m; it has a northwest exposure and a slope of 15–20 degrees. It was planted in 1928 with an initial stock of 3000 stems/ha and was thinned in 1964 to a stock of 800 stems/ha. The 45-year-old stand is at an elevation of 1020m; it has a south-

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Part of this report was presented at the 47th annual meeting of the Japan Wood Research Society, Kochi, April 1997 west exposure and a slope of 8–12 degrees. It was planted in 1953 with an initial stock of 3000 stems/ha and was thinned in 1976 to a stock of 250 stems/ha.

Based on the tree age, growth situation, and thinning intensity, six representative trees were harvested. A summary of basic information on the sample trees is presented in Table 1. The trees can be described as follows: Trees 1 and 2 were harvested at age 70 with a significant difference in diameter growth. Trees 3, 4, 5, and 6 were 45 years old at harvest; trees 3 and 4 had more diameter growth than trees 5 and 6. Therefore, trees 1, 3, and 4 were considered sample trees with vigorous growth; conversely, trees 2, 5, and 6 had poor growth.

Disks approximately 10 cm thick were cut from breast height to the inside of the crown with an interval of 3 m from each tree. There were five disks for sample trees 1 and 2; six for trees 3, 4, 5; and eight for tree 6. These disks were transported to the Forestry and Forest Products Research Institute, Wood Quality Laboratory, to determine the ring structure of the wood. Test pieces, 5 mm in longitudinal thickness, were cut from each disk; and the ring width, earlywood width, latewood width, ring density, maximum density, minimum density, earlywood density, latewood density, percentage of latewood, and some other factors were measured using X-ray densitometry.[7] Here, the earlywood and latewood were distinguished by a ring density of 550 kg/m^3.

The statistical analysis was conducted using the data from the whole disks for each sample tree and the two directions (mountain side and valley side) for each disc.

Results and discussion

Variation in patterns of ring width, ring density, and percentage of latewood in the radial direction

The variations in ring width, ring density, and percentage of latewood in the radial direction for six sample trees were examined, and all sample trees were found to heve a similar pattern. The variations for sample tree 1 at different heights are presented in Figs. 1 and 2. The annual rings near the pith were relatively wide and decreased rapidly in width during the early years of growth; they then leveled off to a constant width after about 15 years of growth. In contrast, the ring density and percentage of latewood were lower near the pith, increased abruptly before about 15 years, and after that reached a constant level; in sapwood, however, there was a clear decrease for unknown reasons. All of the trees varied greatly during early growth and gradually became stable after about 15 years. A similar tendency was revealed for ring width, ring density, and percentage of latewood at all heights.

Table 1. Basic information for the six sample trees

Sample tree no.	Tree age (years)	Height (m)	DBH (cm)	Clear length (m)
1	70	24.8	43	14.0
2	70	24.8	24	13.9
3	45	32.8	40	12.7
4	45	29.0	40	13.9
5	45	29.0	28	19.6
6	45	29.4	24	24.1

DBH, diameter at breast height

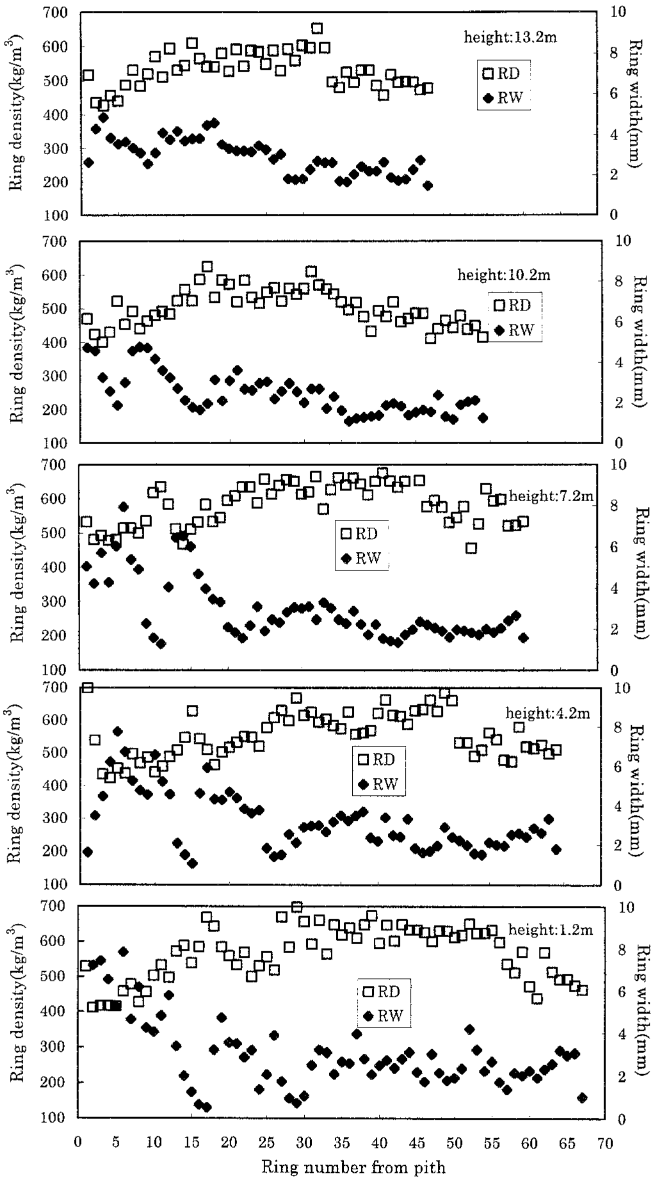

Fig. 1. Variation pattern of ring width and ring density (sample tree 1). *RD*, ring density, *RW*, ring width

It should be noted that whether it was ring width, ring density, or percentage of latewood, the 15th annual ring seemed to be an important changing point during the growth process of Japanese larch. Therefore, it seems reasonable to consider the 15th annual ring as the boundary of corewood (mostly juvenile wood) and outerwood (mostly mature wood) at all heights. Thus before the 15th annual ring (including the 15th annual ring) it is considered corewood, and after that it is considered outerwood.[8]

Effect of growth on wood properties

Although genetic and environmental factors are viewed as sources of wood variation affecting conifer wood formation,[9] this study was concerned only with the influence of radial growth on wood properties of Japanese larch.

A statistical *t*-test was conducted to compare the differences of ring density and percentage of latewood between sample trees (Table 2). As expected, it showed that between sample trees with vigorous growth and poor growth there were significant differences in ring density and percentage of latewood. The sample trees with vigorous growth showed lower ring density and percentage of latewood than sample trees with poor growth, which is in accordance with the research by Kano.[9] These differences between sample trees with vigorous growth and poor growth may be attributed largely to the constitution of annual rings affected by radial growth.[10] An exception was sample tree 6, which did not display the difference in ring density versus trees 3 and 4. The ring width of tree 6 was extremely narrow for some of the annual rings: Especially after age 25 years, the width of most of the annual rings was less than 1.0mm. Moreover, little latewood had formed and as a result the density was lower than usual.

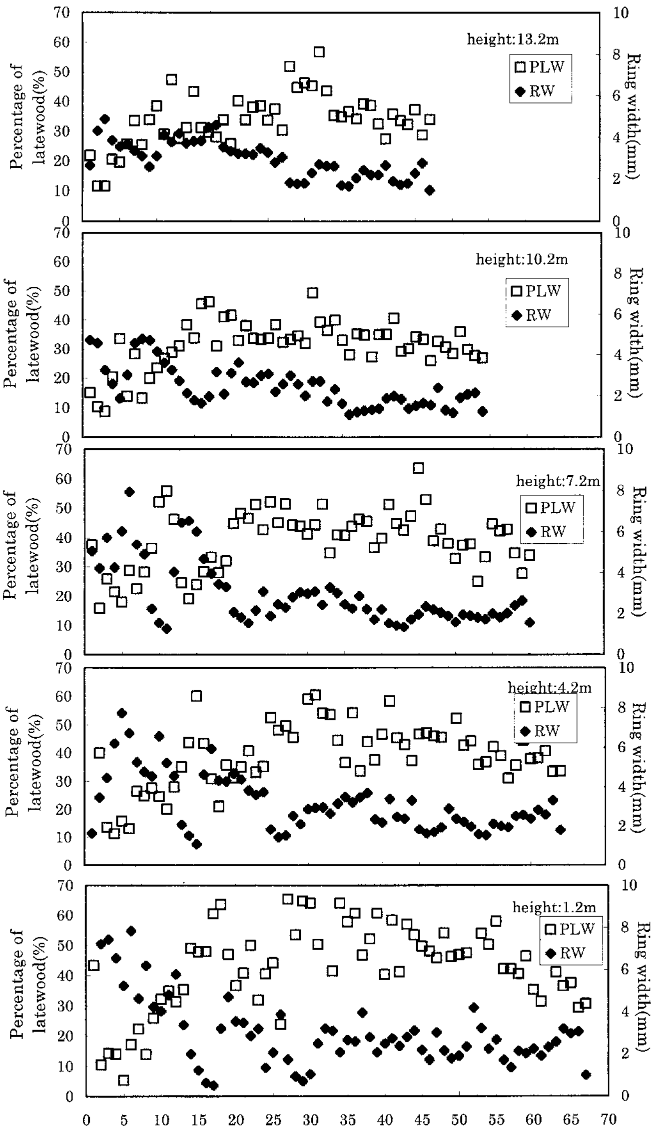

Fig. 2. Variation pattern of ring width and percentage of latewood (sample tree 1). *PLW*, percentage of latewood; *RW*, ring width

Variation of wood properties within corewood and outerwood

In this study the interest was mainly restricted to the differences in the relations between ring width and ring density, and the ring width and percentage of latewood within corewood and outerwood. The correlations between wood properties in the corewood and outerwood of six sample trees are presented in Table 3. It was found that in corewood the ring width was negatively correlated with ring density, whereas in outerwood this close correlation did not appear. For example, Figs. 3 and 4 show the relations between ring width and density in corewood and outerwood for sample trees 1 and 2. The reason for this pattern may be that the ring density in outerwood remained relatively constant whereas that of corewood changed greatly with vigorous growth.

The relations between ring width and earlywood width as well as latewood width are presented in Table 3 and are illustrated in Figs. 5 and 6. It was found that ring width in corewood was significantly correlated with earlywood width but weakly correlated with latewood width. In contrast, in outerwood the correlations were significant for both earlywood and latewood. This means that with the increase of ring width there was an increase only in earlywood width in corewood, whereas earlywood and latewood width were increased in outerwood. The reason for this tendency is not evident, although it may be due to the variations in the radial growth rate.[11]

It is clear from these results that there is a tendency for the percentage of latewood to vary with the ring width (Table 3, Fig. 7), which is in general agreement with the relation between ring width and density.

Table 2. Results of statistical *t*-test between sample trees for different factors

Factor	1 vs. 2	3 vs. 4	3 vs. 5	3 vs. 6	4 vs. 5	4 vs. 6	5 vs. 6
RD	−2.650**	1.42	−2.831**	−0.190	−3.808**	−1.514	2.481*
PLW	−2.363*	1.168	−2.975**	−2.065*	−3.513**	−2.674**	0.032

RD, ring density; PLW, percentage of latewood.
*Significant at 5% level; **Significant at 1% level

Table 3. Correlations between wood properties in corewood and outerwood of six sample trees

Relations	Corewood, trees 1–6						Outerwood, trees 1–6					
	1	2	3	4	5	6	1	2	3	4	5	6
RW vs. RD	−0.57	−0.57	−0.41	−0.40	−0.51	−0.38	NS	0.14	NS	NS	−0.20	0.18
RW vs. EW	0.97	0.94	0.91	0.93	0.90	0.96	0.94	0.89	0.96	0.95	0.92	0.93
RW vs. LW	0.46	0.46	0.29	0.31	0.39	0.74	0.85	0.85	0.91	0.80	0.76	0.91
RW vs. PLW	−0.67	−0.62	−0.56	−0.64	−0.71	−0.48	NS	NS	NS	NS	NS	NS

Results are the correlation coefficients ($P < 0.01$).
RW, ring width; RD, ring density; EW, earlywood width; LW, latewood width; PLW, percentage of late wood; NS, not significant at the 1% level of probability

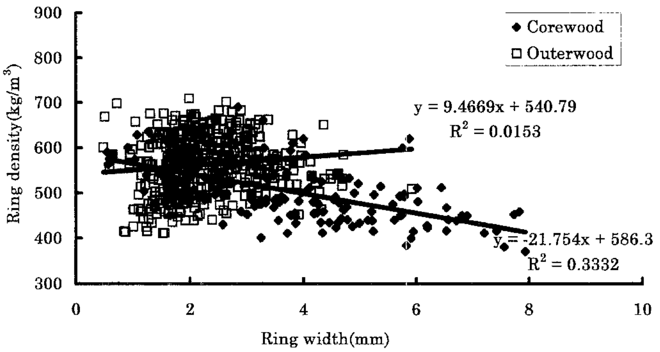

Fig. 3. Relation between ring width and ring density for corewood and outerwood of sample tree 1

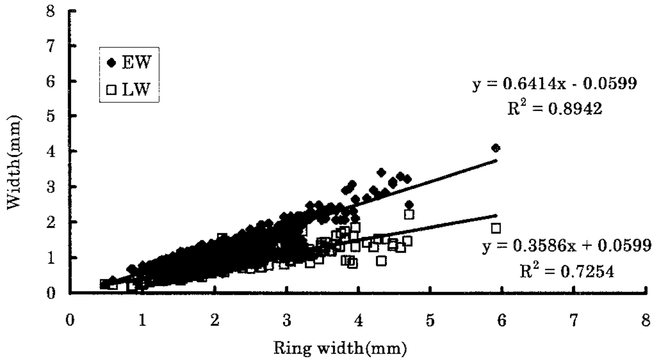

Fig. 6. Relation between ring width and earlywood width as well as latewood width for outerwood (sample tree 1)

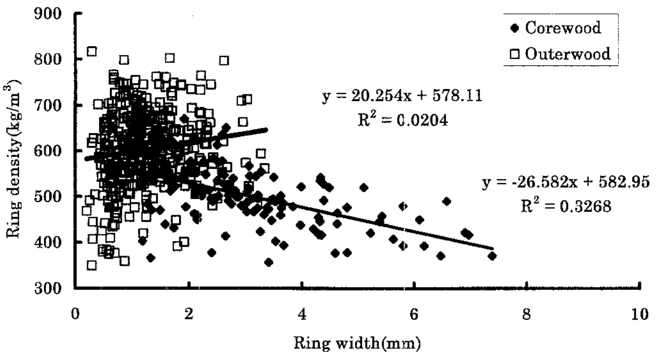

Fig. 4. Relation between ring width and ring density for corewood and outerwood of sample tree 2

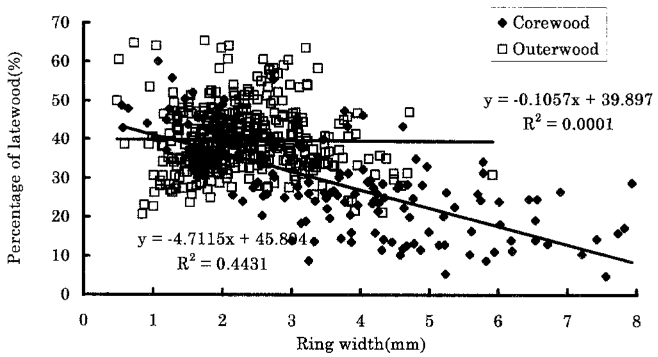

Fig. 7. Relation between ring width and percentage of latewood for corewood and outerwood (sample tree 1)

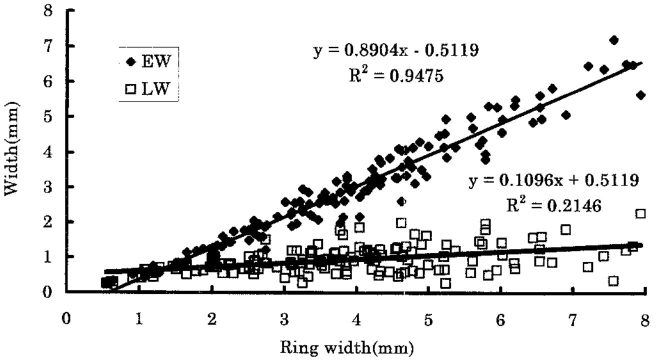

Fig. 5. Relation between ring width and earlywood width as well as latewood width for corewood (sample tree 1) *EW*, earlywood width; *LW*, latewood width

Variation of ring width at different heights

It has been reported that for Japanese larch there is a great variation of wood properties at different heights with individual trees or tree ages. Generally, wood density declines with increasing height.[1] The relations between tree height and ring width, ring density, and percentage of latewood were investigated in this study. The results showed that the ring width tends to decrease with the height in the tree, but the ring density and percentage of latewood did not vary much with height.

The distinction of corewood from outerwood was further analyzed (Figs. 8,9). As stated above, the ring width decreased with increasing height, and from Figs. 8 and 9 it can be seen that this decrease was mainly accounted for in the

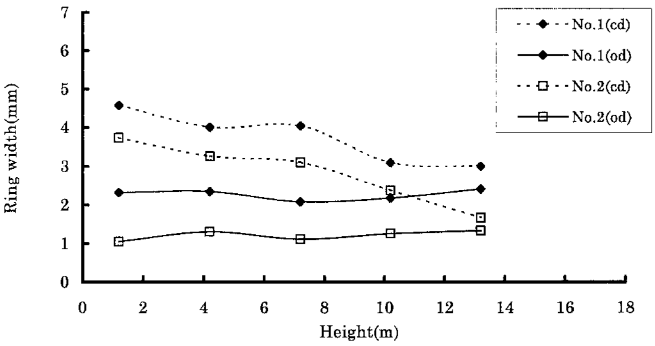

Fig. 8. Relation between height and ring width for corewood and outerwood of trees 1 and 2. *cd*, corewood; *od*, outerwood

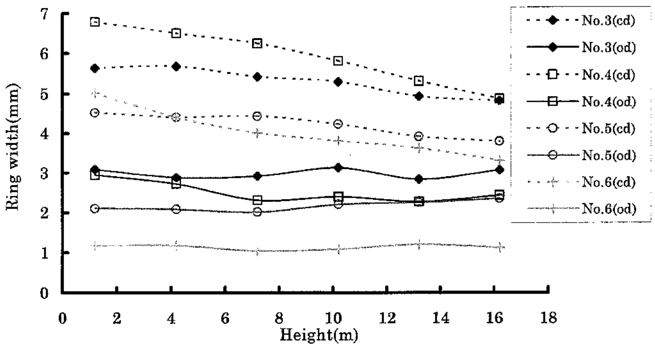

Fig. 9. Relation between height and ring width for corewood and outerwood of trees 3, 4, 5, and 6

corewood; the ring width of outerwood seemed to vary little with height. It is clear from these results that the properties of outerwood are relatively stable compared to those of corewood.

Conclusions

The following conclusions can be drawn from this study.

1. At different tree heights the variations of ring width, ring density, and percentage of latewood in the radial direction displayed a similar pattern; that is, near the pith all of them varied greatly, and after the 15th annual ring they became stable.

2. Between sample trees with vigorous growth and poor growth, significant differences were seen in ring density and percentage of latewood. The sample trees with vigorous growth showed less ring density and percentage of latewood than sample trees with poor growth.

3. In corewood the ring width was negatively correlated with ring density, but in outerwood there was no overall trend for correlations between ring width and ring density.

4. With an increase in ring width, only earlywood width had an apparently increase in corewood, whereas both earlywood width and latewood width were obviously increased in outerwood. This resulted in a negative correlation between ring width and percentage of latewood in corewood and no correlation in outerwood.

5. The ring width tended to decline with increasing tree height, and much of this reduction was attributable to the reduced ring width of corewood. The ring density and percentage of latewood varied little with height.

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