Ray Parenchyma and Ray Tracheid Structure of Four Korean Pine Wood Species

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Ray Parenchyma and Ray Tracheid Structure of Four Korean Pine Wood Species[*1]

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ABSTRACT

To know the structural difference between the ray parenchyma and ray tracheid among Pinus densiflora, Pinus rigida, Pinus koraiensis and Larix kaempferi, an observation was carried out under the FE-SEM. The longest ray parenchyma and ray tracheid were found in Pinus koraiensis species while the shortest ray tracheid and ray parenchyma were found in Pinus densiflora and Larix kaempferi. Larix kaempferi had more than one endwall pit in its ray parenchyma. Pinus densiflora was found highest in the pit aperture diameter in ray tracheid and aperture diameter in the cross-field pit. The pit border width in ray tracheid and lumen diameter of ray parenchyma were found highest in Pinus rigida. The cell wall thickness of ray parenchyma and pit aperture diameter in endwall pit of ray tracheid were found highest in Pinus koraiensis compared to other species.

***Keywords:** Ray tracheid, ray parenchyma, endwall pit, cross-field pit.*

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1. Introduction

Wood is an important material for its wider range of application. Unfortunately it degrades biologically if certain conditions like the supply of water, oxygen and nourishment and a suitable temperature range remain unavailable (Richardson 1993). When impregnation in wood occurs, it is related to the porosity and internal cavities which communicate with each other at the microscopic level communicate. Capillary structures are very important to determine this liquid penetration. Main capillary structures consist of tracheids in softwood. Also, the ray cell, resin canal and pit membrane play an important role in liquid penetration of wood (Kim and Park,1991). A typical softwood species contains about 90 to 94% longitudinal tracheids, 5 to 10% rays and 0.1 to 1% longitudinal resin canals (Wang and De Groot 1996). Those cells play an important role in flow of liquid in wood. The average diameter of pit pores is much smaller than that of tracheid lumens. Some studies have suggested that ray act as important flow paths for liquid during impregnation (Wardrop and Davis 1961). The ray tracheids are usually situated at the outer most tunnels in a ray and are often found to serve as important liquid transport paths during impregnation (Liese and Bauch 1967 Erickson and Balatinecz 1964). In softwood trees, the water in sapwood is known to move longitudinally through the tracheid lumina, passing from one tracheid to the next through bordered pits (Usta 2005). The same pathway will be followed by preservative liquids when penetrating on the transverse surface. Both longitudinal and tangential flow paths are predominant by way of bordered pits, while the horizontal aligned ray cells constitute the principal pathway for radial flow (Comstock 1970). This experiment was, therefore, undertaken to investigate the different anatomical features of ray structures in Korean pine wood by electron microscopy. These features are directly or indirectly related to the variation of treatability among the Korean pine. The anatomical features of ray cells were analyzed which help us attain a better understanding of liquid flow pattern in four Korean pine species in the future.

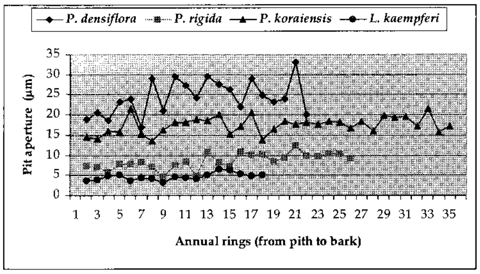
2. Materials and Methods

2-1 Wood species used

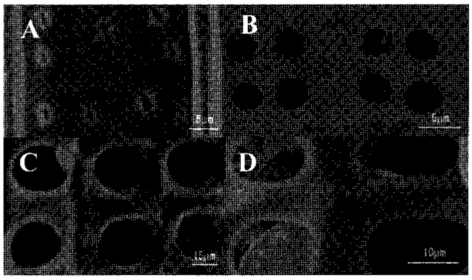
Four kinds of wood species were taken under consideration from ① *Pinus koraiensis* Sieb. et Zucc. ② *Pinus densiflora* Sieb. et Zucc. ③ *Pinus rigida* Mill. and ④ *Larix kaempferi* Carr. Wood samples were collected from the Kangwon National University reserve forest at breast height. Immediately after the collection, discs were made and kept in an air tight cellophane bag to protect against moisture loss. The numbers of annual rings were 27, 26, 35 and 18; the ranges of juvenile wood were 1-17, 1-14, 1-19 and 1-14; the ranges of matured wood were 18-17, 15-16, 20-35 and 15-18; the ranges of heartwood were 1-6, 1-6, 1-22 and 1-13; the ranges of sapwood 7-27, 7-26, 23-35 and 14-18 were found in *P. densiflora, P. rigida, P. koraiensis* and *L. kaempferi*, respectively. Their radial and tangential surfaces were finished with a microtome and the clean-cut surface was (3mm x 2mm) cut with 1mm thickness. They were mounted on FE-SEM specimen stubs using an electrically conducting paste. Samples were dried under vacuum condition and coated with platinum and palladium by using an ion sputter apparatus. At different resolutions and magnifications, samples were examined at 15kV in the Field Emission Scanning Electron Microscope (FE-SEM). Microscopic slides and macerations were made according to standard techniques (Baas and Zhang 1986). Structural differences among the species were tested by using a one-way ANOVA. Where significant differences occurred ($p < 0.05$), the ANOVA procedure was followed by a Duncan significant difference post hoc test to the separate species effects (SPSS, Version 11.5.0, 2002).

3. Result and Discussion

The Field Emission Scanning Electron Microscope was used to find out the different anatomical features of the four wood species shown in Table 1. Six features related to ray structures were taken under consideration for explaining the structural difference of among the four wood species which are related to lateral conduction of liquid. Ray parenchyma and ray tracheid endwall pitting and cross-field pit aperture are also important factors for lateral conduction. As for example, tangential flow is controlled by the bordered pits situated on the radial walls of tracheids (Banks 1970),while the flow in radial direction is controlled by ray cells (Stamn 1953). *P. koraiensis* has the longest average ray parenchyma and ray tracheid compared to other species (Table 3). But, it was found shortest in *L. kaempferi* for ray parenchyma and *P. densiflora* for ray tracheid. Besides, the endwall pitting ray parenchyma and ray tracheid also can regulate the amount of liquid penetration in radial direction.



〈Fig. 1〉 Cross-field pit aperture diameter of ray parenchyma in different wood species.



〈Fig. 2〉 Cross field pit or ray parenchyma in A. *L. kaempferi* B. *P. rigida* C. *P koraiensis* and D. *P. densiflora*.

〈Table 1〉 Different features of four wood species observed under FE-SEM.

Features	Species			
	P. densiflora	*P. rigida*	*P. koraiensis*	*L. kaempferi*
Pit aperture diameter in ray tracheids (㎛)	2.70 a	2.37 b	2.67 b	2.60 b
Pit border width in ray tracheids (㎛)	3.24 b	3.64 a	2.95 c	2.61 d
2wall thickness of ray parenchyma (㎛)	1.07 c	0.63 d	1.65 a	1.47 b
Pit aperture diameter in end wall of ray tracheid(㎛)	2.05 d	2.38 c	3.87 a	2.58 b
Lumen diameter of ray parenchyma (㎛)	8.71 c	11.41 a	8.09 d	9.26 b
Aperture diameter in cross-field pit (㎛)	24.41 a	8.51 c	17.44 b	4.61 d

Mean with the same letter are not significantly different at p=0.05

〈Table 2〉 Average length of ray tracheid and ray parenchyma.

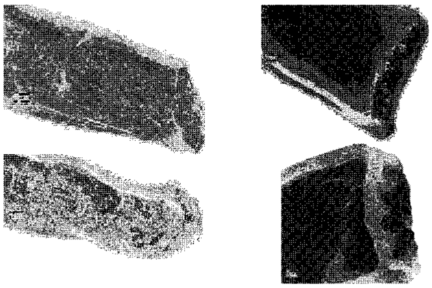
Wood species	Length of ray parenchyma, μm	Length of ray tracheid, μm
P. koraiensis	213.51	162.65
P. densiflora	195.44	73.44
P. rigida	203.95	102.40
L. kaempferi	166.54	103.51

3-1 Cross-field pit aperture

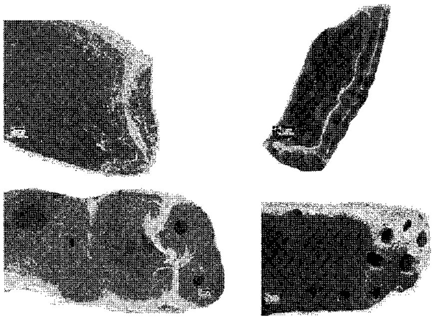
This feature is very important for explaining the tangential flow of liquid. Olsson et al. (2001) stated that the cross-field pits in pine sapwood can serve as an important role for flow path. Though the anatomical features for species were same in sapwood and heartwood but the size varied from pith to bark. In this experiment we considered the size and shape of ray parenchyma and ray tracheid but we did not consider the chemicals changes which can explain the reduced permeability in heartwood compared to sapwood. As for example, the transformation from sapwood to heartwood causes changes in the parenchymatous cells and polyphenols are laid down in the window-like pits and in the walls of ray parenchyma (Bauch et al., 1974; Bamber and Fukazawa 1985) which resist the flow of liquid. But those features can give us an idea about the structural variation among the four wood species. Because of its window-like pitting, the highest cross-field pit aperture in ray parenchyma was found in P. densiflora (24.41㎛) and the lowest pitting was found in L. kaempferi (4.61㎛) for piceoid type pitting 〈Fig. 2〉. Aperture diameter of cross-field pit gradually increased from pit to bark 〈Fig. 1〉.

3-2 Mean lumen diameter and 2wall thickness of ray parenchyma

The lumen diameter of ray parenchyma was found higher in *P. rigida* (11.41㎛) and lowest in P. koraiensis (8.09㎛). 2wall thickness of ray parenchyma was found highest in *P. koraiensis* (1.65㎛) and lowest in *P. rigida* (0.63㎛) which gives us an idea of lignification of the cell wall. Ray parenchyma and ray tracheid length and lumen diameter also determine how long in distance the liquid penetrates inward in radial direction.



⟨Fig. 3⟩ Clockwise from left to right: endwall pitting of ray parenchyma in 1. *P. koraiensis* 2. *P. densiflora* 3. *P. rigida* and 4. *L. kaempferi.*



⟨Fig. 4⟩ Clockwise from left to right: endwall pitting of ray tracheid in 1. *P. koraiensis* 2. *P. densiflora* 3. *P. rigida* and 4. *L. kaempferi.*

L. kaempferi has the highest number of endwall pits in ray parenchyma and ray tracheid ⟨Figs. 3 and 4⟩. But, the ray parenchyma endwall pit aperture was lower than in other species. Other wood species had one endwall pit in their ray parenchyma. As a result, those species seem to conduct more liquid in radial direction compared to *L. kaempferi.*

4. Conclusion

The longest ray parenchyma and ray tracheid was found in *P. koraiensis*. The shortest ray tracheid and ray parenchyma were found in *P. densiflora* and *L. kaempferi*, respectively. More than one endwall pit in ray parenchyma was found in *L. kaempferi* compared to other species. *P. densiflora* was found highest in pit aperture diameter for ray tracheid and aperture diameter in the cross-field pit. The lumen diameter of ray parenchyma and pit border width in ray tracheid was found the highest value in *P. rigida*. On the other hand, in *P. koraiensis*, the wall thickness of ray parenchyma and pit aperture diameter in endwall pit of ray tracheid was found the highest values. Further research is suggested about the radial penetration of liquid in pine wood considering those anatomical features.

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