# Ray Parenchyma and Ray Tracheid Observation by FE-SEM in Main Wood Species of Pinaceae Grown in Korea

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## Introduction

Wood is an important material for its wider range of application. Unfortunately it degrades biologically if certain condition like the supply of water, oxygen and nourishment and a suitable temperature range remain available (Richardson 1993). When impregnation in wood is concerned, it is related with the porosity and internal cavities at the microscopic level communicate each other. Capillary structures are very important to determine the liquid penetration. Main capillary structures consist of tracheids in softwood also 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 DeGroot 1996). Those cells play an important role for the impregnation of liquid in wood. The average diameter of pit pores is much smaller than that of tracheids lumen. Some studies have suggested that ray act as important flow paths for liquid during impregnation (Wardrop and Davis 1961). The ray tracheids usually situated at the outer most tunnels in a ray and are often found to serve as important liquid transport path during impregnation (Liese and Bauch 1967, Erickson and Balatinecz 1964). So this experiment was taken under consideration to know the different anatomical features of ray structure in Korean pine wood by electron microscopy. These features are directly or indirectly related with the variation of treatability among the Korean pine. In softwood tree, 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 in transverse surface. Both longitudinal and tangential flow paths are predominantly by way of bordered pits while the horizontal aligned ray cells constitute the principal pathway for radial flow (Comstock 1970). In this experiment anatomical features of ray cells were analyzed which will help us for the better understanding of liquid flow pattern in four Korean pine species in future.

## Materials and Methods

### Wood species used

Four kinds of wood block 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 Kangwon National University reserve forest at breast height. Immediately after collection, discs were made and kept in air tight cellophane bag to protect the moisture loss. Number of annual rings 27, 26, 35 and 18 ; range of juvenile wood 1-17, 1-14, 1-19 and 1-14; range of matured wood 18-17, 15-16, 20-35 and 15-18; range of heartwood 1-6, 1-6, 1-22 and 1-13; range of sapwood 7-27, 7-26, 23-35 and 14-18 were found in *P. densiflora, P. rigida, P. koraiensis and L. kaempferi* respectively. Radial sections (1cm width) of four wood species were dried under vacuum condition and coated with Pt+Pd. At different resolution and magnification, samples were observed under FE-SEM (Field Emission Scanning Electron Microscope). Macerated cells also observed by FE-SEM. Finally data were analyzed by statistical analysis software, SPSS (George and Mallery 2001).

## Results and Discussion

Field Emission Scanning Electron Microscope was used to find out the different anatomical features of 4 wood species which are shown in Table 3. Five features related with ray structures were taken under consideration for better understanding of safranine penetration difference in 4 wood species along the radial direction. Ray parenchyma and ray tracheid endwall pitting, cross field pit aperture are also important factors for lateral conduction. 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 (Olsson et al. 2001 and Stamn 1953). The permeability in softwood in radial direction is greater than tangential direction (Ahmed et al. 2005). In this experiment, all these features were taken under consideration for better understanding the variability of liquid penetration.

**〈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 |
| Wall 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

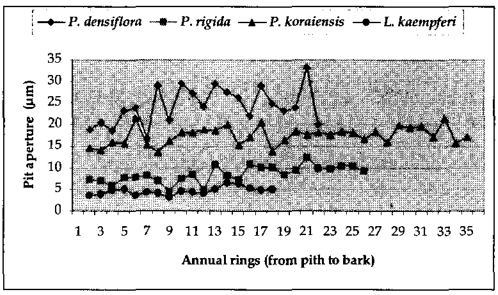
**〈Table 2〉** Average length of ray tracheid and ray parenchyma.

| 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 |

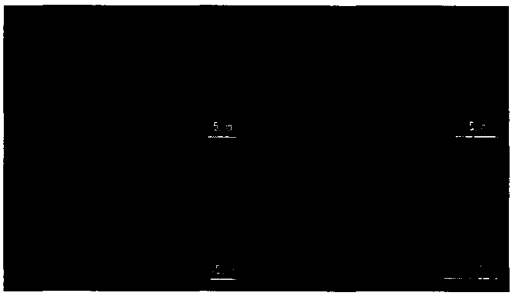
*P. koraiensis* has the longest average ray parenchyma and ray tracheid compared with other species (Table 2). But it was found the shortest in *L. kaempferi* for ray parenchyma and *P. rigida* for ray tracheid. Besides endwall pitting of ray parenchyma and ray tracheid also regulate the amount of liquid penetration in radial direction.

## 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 could serve as an important role for flow path. 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 and Bamber and Fukazawa 1985). Highest cross field pit aperture in ray parenchyma was found in P. densiflora (24.41μm) for it's window like pitting and lowest was found in L. kaempferi (4.61μm) for piceoid type pitting (Fig. 1 and 2).




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

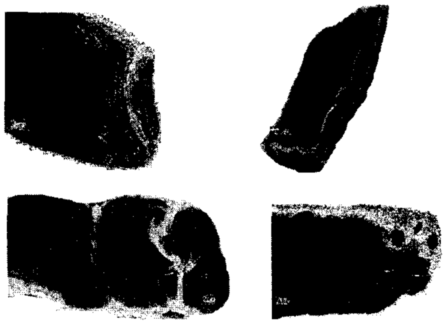


**〈Fig. 2〉** Cross field pit or ray parenchyma in A. *L. kaempferi* B. *P. rigida* C. *P. koraiensis* and D. *P. densiflora*.

## Mean lumen diameter and 2wall thickness of ray parenchyma

Lumen diameter of ray parenchyma was found higher in *P. rigida* (11.41㎛) and lowest in *P. koraiensis* (8.09㎛). Two wall thickness of ray parenchyma was found highest in *P. koraiensis* (1.65㎛) and lowest in *P. rigida* (0.63㎛). It gives us an idea of lignification of cell wall. Ray parenchyma and ray tracheid length and lumen diameter also determines how long distance safranine will penetrate to inward in radial direction. Below is the table showing ray parenchyma and tracheid length in different wood species.

**〈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.*

From optical microscope it was observed that *L. kaempferi* has the highest number of endwall pits in ray parenchyma and ray tracheid. FE-SEM observation also clarified that point. Above pictures taken from FE-SEM, it is also clear that *L. kaempferi* has highest number of endwall pits in ray parenchyma and ray tracheid (Fig. 3 and 4). But ray parenchyma endwall pit aperture was lower than other species. Other wood species had one endwall pit in their ray parenchyma. As a result, those species seems to conduct more liquid in radial direction compared with *L. kaempferi.*

## Conclusion

Longest ray parenchyma and ray tracheid was found in *P. koraiensis.* Shortest ray tracheid and ray parenchyma was found in *P. densiflora* and *L. kaempferi* respectively. More than one endwall pit in ray parenchyma was found in *L. kaempferi* compared with other species. *P. densiflora* was found highest in pit aperture diameter in ray tracheid and aperture diameter in cross field pit. Lumen diameter of ray parenchyma and pit border width in ray tracheid was found highest in *P. rigida*. On the other hand, in *P. koraiensis* wall thickness of ray parenchyma and pit aperture diameter in endwall pit of ray tracheid were found the highest. Further research work is suggested about radial penetration of liquid in pine wood considering those anatomical features.

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