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Longitudinal Conduction of Preservative Solution by *Larix kaempferi*[1]

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ABSTRACT

Moisture content of *Larix kapempferi* was maintained at 28% after air drying. 5% CCFZ solution penetration depth was observed through longitudinal tracheid and axial resin canal. Penetration depth was increased significantly from heartwood to sapwood and the penetration depth was found 1.3 times higher for sapwood measured at 15.0 second of penetration. On the other hand, liquid flow in sapwood and heartwood involved most liquid first entering the resin canals. Overall resin canal conducted 1.4 times more than tracheid. Latewood was found more permeable than in earlywood. At the beginning of penetration, the speed was high and then decreased in the course of time.

Key words: Preservative solution, longitudinal penetration, resin canal.

INTRODUCTION

In coniferous wood, the tracheids are imperforate, so there is general agreement that the principal longitudinal flow path is from tracheid to tracheid through bordered pit pairs (Siau 1984; Flynn 1995). Tangential fluid flow is also primarily through longitudinal tracheids and bordered pits between them (Erickson 1970; Keith and Chauret 1988). Air permeability measurements indicate that the total number of micro pores involved in tangential flow is approximately 103 times less than the number for longitudinal flow (Petty 1970; Flynn 1995). But the longitudinal flow is dependent upon the capillary structure of longitudinal tracheid and pit structure.

In the past, various models have been postulated to explain experimental observations of the axial permeability of conifer wood to fluids. It is usually assumed that axial flow concerns only longitudinal tracheids and resin canals. At one time it was thought that all significant resistance to flow was generated by the pit margo pores in the longitudinal tracheids. However, Petty and Puritch (1970) were able to show that at least two structural components offered resistance to flow: these components were identified as the tracheid lumina and pit margo pores. Similarly, Smith and Banks (1971) considered that two components offered resistance to flow, but in this case the components were identified as the tracheid lumina and the entire bordered pit system. Bailey and Preston (1970) suggested that the annulus bounded by the pit border, on one side, and the torus, on the other, should offer a finite and significant resistance to flow. Aside, Bolton and Petty (1975) were able to show

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that parts of the bordered pit system other than the pit margo pores contributed to the total resistance to flow. These authors were of the opinion that this third structural component was the pit aperture.

Different material and methods were used for measuring penetration depth. We are curious about the cause of liquid penetration depth variability. This variation could be for the liquid properties or for cell structure difference. To find out the reason, this is one of the series experiments which explain the flow depth of preservative solution in sapwood, heartwood, earlywood and latewood in longitudinal direction.

MATERIALS AND METHODS

Sample preparation and penetration depth measurement

Wood samples of *Larix kaempferi* Carr. were obtained from Jiamri, Sabukmeyon, Chunchon, Kangwon do, Republic of Korea (37°51′N, 127°36′E). From defect free tree, sample was collected and discs were made. Discs were dried in room condition until the moisture content was reached about 40%. 4 cm (longitudinal) x 0.5 cm (radial) x 1 cm (tangential) samples were prepared and were kept in a covered petridish. Frequent moisture checking was performed. When the moisture content of samples was reached at 28%, samples were kept in a desiccator and the experiment was performed instance. Penetration experiment was observed from root to top direction as in natural condition. Longitudinal penetration was observed on the tangential surface. So, except one cross and tangential surface, all surfaces were coated with silicon resin for preventing the leakage by other surfaces. With *i*-Solution software, the liquid impregnation video file was captured by *i*-camscope (SV32) and by using VitrualDub-MPEG2 software, the captured video file was divided in specific frames at 3.8, 7.5, 11.3 and 15.0 second (Ahmed et al. 2007). Microscopic slides and macerations were made according to standard techniques (Baas and Zhang 1986). Terminology and the method for determining quantitative features conform to recommendations from the IAWA Feature List (IAWA Committee 1989).

5% Preservative solution preparation

50 g of Chromium Copper Fluoride Zinc (CCFZ) was taken in 1 L of volumetric flask and was dissolved properly with about 500 mL of distilled water. Sufficient water was added to make the volume upto the mark. Surface tension of 5% CCFZ solution was also measured and it was found 71.467 dyne/cm.

Statistical analysis

The analyses of variance for the characters under study were performed by two-sample analysis (at alpha= 0.01 or 99% confidence level) to identify significant differences between sapwood –heartwood and earlywood- latewood.

RESULTS AND DISCUSSION

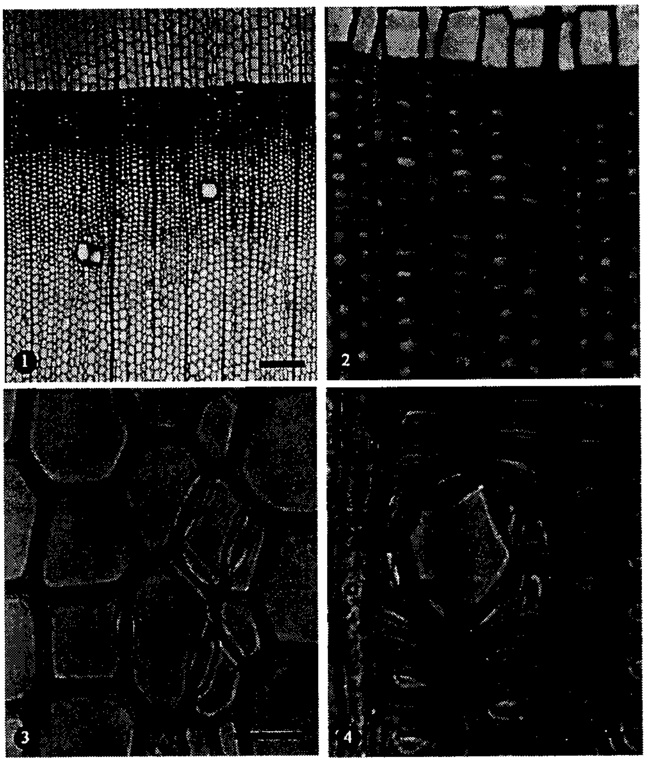
Microscopic feature of *Larix kaempferi* taking part in longitudinal penetration was characterized by distinct growth ring boundaries, abrupt transition from earlywood to latewood, uniseriate tracheid pitting in radial walls (in earlywood only), thick-walled latewood tracheid, presence of torus in tracheid pits and axial intercellular resin canal, piceoid type cross-field pittings, thick walled epithelial cells (Figs. 1-4).

Table 1. Preservative solution penetration depth unit: μm

Cell type	18.8 sec	37.6 sec	56.4 sec	75.2 sec
Longitudinal tracheid	322.84	478.25	595.09	659.88
Axial resin canal	626.18	748.11	862.81	927.69
Level of significance	**	**	**	**

** Significant at 1 % level of probability

This experiment was conducted to know the longitudinal flow of preservative solution. The moisture content in both sapwood and heartwood was maintained to 28%. As a result, in next series experiment, it will be easy to compare the data and to find out the reason of different penetration depth using different liquid. It is now generally accepted that conifer wood must be regarded as a heterogeneous medium with respect of axial permeability. Erickson and Crawford (1959) found that after air-drying; permeability to water was reduced to 1-3% of its value for green wood. This is due the pit aspiration (Bolton and Koutsianitis 1980), the collapse of wood in lumber drying, the reduction of mass liquid flow through intercellular passage way due to the blockage of pores by gas embolisms. In coniferous trees, water in sapwood is known to move longitudinally through the tracheid lumina, passing from one tracheid lumen to next through the bordered pits. The same pathway is also used by preservative liquid when penetrating wood. Both longitudinal and tangential flow paths in softwoods are predominantly by way of the bordered pits. The illustration of bordered pit type is explained by Ahmed and Chun (2006a) and Ahmed and Chun (2006b). Also the flow path of liquid in this species is described by Chong et al. (2007). In this experiment we will not explain the flow path rather to explain the penetration depth of preservative solution through longitudinal tracheid and resin canal. Fig. 1-4 shows the cross sections of *L. kaempferi* through which liquid permits radially. Latewood tracheid lumen diameter was much shorter than that in earlywood. Percentage of pit aspiration determines the liquid flow. Latewood is more permeable than earlywood in seasoned materials whilst the earlywood is more permeable the latewood in green wood (Petty and Peterson 1969) because of pit aspiration. This is for the greater tendency of latewood pits to resist pit aspiration to the greater rigidity of the latewood pit membrane



Figs.1-4. Cross sections of Larix kaempferi. Fig.1. Growth ring boundaries distinct. Fig.2. Thick-walled latewood tracheid wall. Fig.3. Presence of torus in bordered pit chamber. Fig.4. Thick-walled epithelial cells of intercellular canals. Scale bars of 1= 200μm; of 2= 50 μm; of 3 & 4= 20 μm.

(Phillips 1933; Liese and Bauch 1967). In our experiment we found that the latewood permeability was higher than earlywood (Fig. 5) and the difference was statistically highly significant, t(27)= 6.275, p= 0.000. Because when wood however is dried, the structure may be modified by the process of aspiration in which the torus moves across the pit chamber to seal off one of the pit apertures, thus preventing fluid flow through the pit. Besides lumen diameter can be an important factor for penetration depth. According to Chun and Ahmed (2006), lower the lumen diameter is, higher the penetration depth. If we use another liquid which has lower surface tension than 71.467 dyne/cm, penetration depth of that liquid will be high. Liese and Bauch (1967) showed that if water was replaced with liquids of lower surface tension, aspiration did not occur and concluded that pit membrane closed as a result of surface tension. The tracheids are imperforate while the resin canal is a perforated channel through which liquid can flow easily. In our experiment we found that resin canal played and important role for longitudinal penetration of preservative solution (Table 1). Resin canal conducted solution 1.4 times more than that in tracheid.

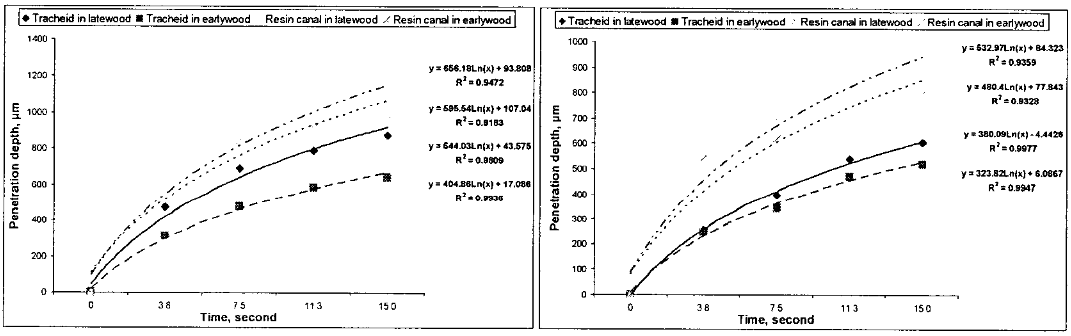


Fig.5. Longitudinal penetration of preservative solution in sapwood (left) and in heartwood (right).

The transformation from sapwood to heartwood causes changes in the pit tori position. In the case of green wood, most of the pit tori were in the unaspitated or central position for sapwood, while for heartwood most of the pit tori had already been aspirated (Bao et al. 2001). Cote (1963) explained that pit aspiration in green heartwood is attributed to heartwood forming in living tree. Also, as the moisture content in wood decreases from green to the fiber saturation point, most of the free-water in the lumen of tracheids removed. Therefore, a meniscus of free-water to air interface resulting a high capillary pressure is formed across the pit aperture. When the meniscus moves to the pit membrane openings in the margo, the resulting much higher tension due to smaller diameter can cause the membrane to become aspirated to where the tori close off the flow path. As a result the penetration depth of preservative solution in air dried sample increased significantly from heartwood to sapwood, t(27)= 8.073, p= 0.000 measured at 15.0 second of penetration. Therefore the aspiration of pits reduces the permeability of wood and increases the difficulty of fluid flow in heartwood.

In our experiment we found that the sapwood penetration depth was 1.3 times more than that in heartwood measured at 15.0 second of penetration. Latewood tracheid in sapwood was 1.4 times more permeable than earlywood, whilst the penetration depth was 1.1 times more for resin canal at 15.0 second of penetration. Furthermore, in heartwood, longitudinal tracheid was 1.2 times more permeable than earlywood while the penetration depth was 1.1 times more in resin canal. Latewood was found more permeable than earlywood. At the beginning of penetration in longitudinal tracheid and resin canal, the penetration speed of preservative solution was high and then the penetration speed was decreased. More research work has to be done to compare the penetration depth differences using different kind of liquid with different surface tension. Then the comparison can be made.

CONCLUSIONS

5% preservative solution penetration depth was measured in longitudinal tracheid and axial resin canal. Resin canal played and important role for the conduction of preservative solution both in sapwood and heartwood. Resin canal conducted solution 1.4 times more than axial tracheid and due to pit aspiration, heartwood penetration depth was 1.3 times less than in sapwood at 15.0 second of penetration. Latewood was found more permeable than earlywood. Initial liquid impregnation speed was high and then decreases eventually.

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