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Lateral Conduction of Preservative Solution in *Larix kaempferi* Woods[1]

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ABSTRACT

An experiment was conducted to observe the 5% CCFZ solution penetration depth through ray parenchyma and ray tracheid of *Larix kapempferi*. Moisture content was adjusted 28% for both sapwood and heartwood. Even though the moisture content was same, heartwood was 1.3 times less permeable than sapwood and the difference was found statistically significant. Due to anatomical differences between ray parenchyma and ray tracheid, ray parenchyma was about 1.3 times more permeable than ray tracheid. Penetration speed was high initially and it decreased rapidly in course of time.

Key words: Preservative solution, radial penetration, ray parenchyma, ray tracheid.

INTRODUCTION

Softwoods are relatively simple in structure, primarily (90% of volume) composed of one kind of axially elongated pointed cells of 2 to 5 mm in length called tracheids (Walker *et al.*, 1993). Softwoods are generally medium to low density timbers in the range of 350 to 700 kg/m^3 (basic density at 12% moisture content), as reported by Desch and Dinwoodie (1996). The technologies for the processing of softwoods (including conversion and drying) may be considered to be relatively easier, well established and implemented by many timber companies around the world compared with hardwoods. Many experiments have been conducted so far regarding preservatives solution treatment in different softwood species. But limited experiments were conducted regarding the reason behind for the penetration differences. It is natural that if we use same species, penetration depth in different cell will vary for different liquids. Liquid properties such as surface tension, viscosity, adhesion force with cell wall, contact angle with cell etc. are responsible for this variation. Besides, cell structure played a vital role for the difference of permeability (Ahmed and Chun 2007a; Ahmed and Chun 2007b; Chun and Ahmed 2006). It is well known that pressure treatment makes the species more permeable. For example, during high-pressure preservative treatment (McQuire 1970) and safranine solution (Ahmed et al. 2005) penetrated more in ray parenchyma. This penetration occurs as a result of capillary forces within the cell lumens. But without pressure, only capillary penetration is not explored much at atmospheric pressure.

It is curious how the liquid penetrates through ray parenchyma and ray tracheid from bark to pith direction. Therefore, the purpose of the present work is to study the capillary flow path of preservative solution radially. This experiment will help us to know the radial penetration depth of 5% CCFZ solution in *Larix kaempferi*.

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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). Wood disc were collected from a defect-free tree. Wood disc were dried in room condition until the moisture content was reached about 40%. 4 cm (longitudinal) x 1 cm (radial) x 0.5 cm (tangential) were prepared after microtome shaving. Samples were kept in a covered petridish. Frequent moisture content of samples was checked. When the moisture content was reached at 28%, samples were kept in a desiccator and the penetration experiment was performed instance. Penetration experiment was observed from bark to pith direction as in natural condition. Except one radial 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 18.8, 37.6, 56.4 and 75.2 second (Ahmed et al. 2007).

Preservative solution preparation

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

Statistical analysis

Differences in the penetration depth of preservative solution in different cells were tested by using a one-way ANOVA. When significant differences occurred ($P \leq 0.05$), the ANOVA procedure was followed by a Duncan significant difference post hoc test to separate the time and cell. Also 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 ray parenchyma- ray tracheid.

RESULTS AND DISCUSSION

Anatomically, the tissues that were found to take part in lateral conduction were ray parenchyma and ray tracheid. The main objective of this study was to know the liquid penetration depth in radial direction rather than the flow path. As a part of series experiment, this study describes the preservative solution penetration depth via ray parenchyma and ray tracheid. Therefore, the moisture content should be maintained properly for the comparison experiment. As we know the moisture content of wood plays a vital role for the liquid impregnation. Browning (1963) stated that above the fiber saturation point until the cell cavity are filled with liquid water; wood can still uptake water by absorption or capillary action. In addition, excess moisture in wood voids may also be able to a physical barrier for the flow of liquid (Wirspa and Libby 1950). In both sapwood and heartwood, moisture content was maintained 28%.

Table 1. Preservative solution penetration depth in radial direction unit: μm

Cell type	18.8sec	37.6sec	56.4sec	75.2sec
Ray parenchyma in sapwood	32.81a	40.01a	47.60a	51.23a
Ray tracheid in sapwood	26.02a	31.01b	35.68b	40.67b
Ray parenchyma in heartwood	25.48a	29.73b	35.01b	41.30b
Ray tracheid in heartwood	17.09b	21.05c	26.25c	31.47a

Note: Different lower case letters within in a column indicate significant difference (alpha≤0.05).

It is obvious that heartwood penetration is lower than in sapwood. In our experiment we found that overall, sapwood was 1.3 times more permeable than heartwood. Ray parenchyma was found easily conductible than ray tracheids. Because of anatomical features like cell length, diameter, endwall pit number and diameter differences, this kind of variation was occurred. Length of ray parenchyma and ray tracheid was found 166.54 μm and 103.51 μm considerably as mentioned by Ahmed et al. (2006). Ray tracheid was much smaller than ray parenchyma. If the cell (capillary tube) is small, it will face more obstacles by endwall compared with longer one. Consequently, penetration depth will be short. Another anatomical factors related to the variation of penetration depth is the endwall pit number and diameter. In this species, ray parenchyma had one endwall pits while several for the ray tracheid. As a result, preservative solution faced more obstacles while flowing through ray tracheid. Sapwood is known to be several times more permeable than heartwood (Erickson 1970; Krahmer and Cote 1963), and in conifers, the moisture content (MC) of sapwood is greater than the MC of heartwood (Bamber and Fukazawa 1985). The primary causes of permeability differences in heartwood and sapwood are due to differences in aspiration, and to the amounts and character of the extractives, especially in the heartwood in cases of liquid flow (Erickson 1970). This kind of variation can be seen especially for longitudinal penetration of liquid. But in radial penetration, this variation was also observed. Penetration depth of preservative solution increased significantly from heartwood to sapwood, $t(12)= 4.416$, $p= 0.001$ measured at 75.2 seconds of penetration.

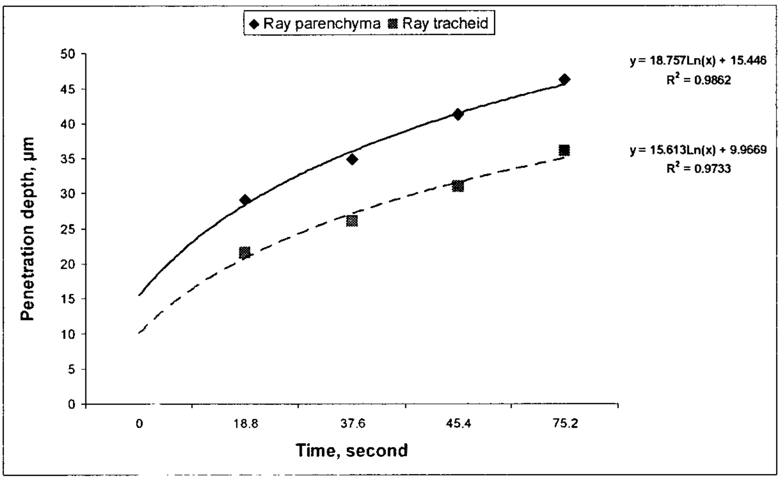

Fig.1. Line graph showing radial penetration of preservative solution though ray parenchyma and ray tracheid.

Radial permeability has been studied by various workers and there has been debated as to the contribution to flow in different species of dried softwood of ray tracheids and ray parenchyma. In certain pines (e.g. *Pinus sylvestris* L.) there is excellent radial flow and this is attributed to ray tracheids and ray parenchyma. In such pines flow is thought to be confined to larger pits between ray parenchyma cells, in addition to flow through cross-fields to axial tracheids and from there into adjacent ray parenchyma cells (Usta and Mike 2003). The results presented in Table 1, do not cover an exhaustive study on the variation between ray parenchyma and ray tracheid. This alone cannot fully explain the differences in the uptakes observed for the radial treatment by ray parenchyma and ray tracheid but the observed differences in pit sizes are likely to be of significance. A consideration of the physics of bulk flow through capillaries shows that the pore radius is the most important factor (i.e. the Hagen-Poiseuille equation, Eaton & Hale 1993). Cell with small diameter will have the higher capillary height of liquid compared to bigger one. In both sapwood and heartwood, ray tracheid was more likely to be slow for liquid conduction and the penetration depth was about 1.3 times slower for ray tracheid than ray parenchyma. Penetration depth of preservative solution was significantly high from ray tracheid to ray parenchyma, $t(8)= 5.85$, $p=0.000$ measured at 75.2 second of penetration. Surface tension of liquid is also an important factor to determine how much it will travel through cell capillary. More research work is suggested for measuring penetration depth differences using different liquids at same moisture content.

CONCLUSIONS

CCFZ (5%) solution penetration depth through ray parenchyma and ray tracheid was concluded as follows-

Sapwood was 1.3 times more permeable than heartwood measured at 75.2 second of penetration and the penetration depth differences was found statistically significant. The lower permeability in heartwood is believed to be deposits of extractives on the cell walls and in the ray cells.

Ray parenchyma was 1.3 times more permeable than ray tracheid and the penetration depth differences was found highly significant measured at 75.2 second of penetration. Endwall in ray cells was found the main obstacle for free liquid flow. As the ray parenchyma was longer than the ray tracheid and had only one pit in endwal, it conducted more than ray tracheid.

Initially penetration speed of preservative solution was found high and then gradually decreased.

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