# Longitudinal Flow Path of Safranine in *Populus tomentiglandulosa* T. Lee[1]

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## ABSTRACT

An experiment was conducted to observe the safranine flow depth in longitudinal direction of *Populus tomentiglandulosa*. Longitudinal flow of safranine was considered from bottom to top end of the tree. Vessel and wood fiber were considered for the measurement of safranine flow depth. It was found that sapwood conducted safranine 12.25% higher in longitudinal direction compared with heartwood. Vessel was found the main avenue for safranine flow. Vessel conducted safranine 41.94% higher than that of wood fiber. Safranine penetrated through vessel and fiber forming a curved meniscus.

*Key words:* Liquid penetration, Axial flow, Meniscus.

## INTRODUCTION

Various techniques and methods are used for liquid penetration in wood. It differs from species to species and that there are large differences among different families, genera and even within parts of same tree (Bao 1984). Also the permeability of wood is strongly dependent on its moisture content (Hansmann et al. 2002), as well as the principal direction of grain (Bramhall, 1971; Bolton 1988). Macro and micro structural differences were also observed in matured to juvenile wood and earlywood to latewood (Lu et al. 2006). Those structural differences can be responsible for the penetration of liquid. In longitudinal direction, the size, distribution and condition of the vessels are important factors for treating the hardwood. On the other hand, capillary structures are very important to determine the liquid flow which consists of vessel, wood fiber, ray cell and axial parenchyma. Kim and Park (1991) stated that pit membranes can play an important role in liquid penetration into wood. The amount of liquid penetration is not the same in sapwood and heartwood because the solution uptake by cells is affected by wettablility of the surface of the cell lumen (Iida et al. 2002). Factors of prime consideration governing the flow are the amount of pressure, fluid viscosity, solvent contact angle, wood pore radius and wood capillary length (Usta and Guray 2001).

This experiment was conducted to understand safranine flow in vessel and wood fiber of *Populus tomentiglandulosa*. As safranine is a colored solution, it is easy to observe the flow depth. Although flow depth of liquid is depend upon the surface tension of liquid to be permeated (Chun

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and Ahmed 2006), this research work was conducted to observe the vessel and fiber role in the non steady state of safranine flow.

## MATERIALS AND METHODS

*Sample preparation*

Wood samples of *Populus Tomentiglandulosa* T. Lee were obtained from Jiamri, Sabukmeyon, Chunchon, Kangwon do, Republic of Korea. Immediately after sample collection from defect free tree, discs were made and marked to identify top and bottom end. Discs were kept in air tight cellophane bag to protect the moisture loss. Among total 16 numbers of annual rings, range of heartwood was 1-10 and range of sapwood was 11-16. To observe the longitudinal safranine flow in tangential surface, 4 cm (long) x 1 cm (tangential) x 0.5 cm (radial) samples were prepared after microtome shaving from 8-9th annual ring from heartwood and 14-15th annual ring from sapwood. As we wanted to know the safranine flow in longitudinal direction from bottom to top, samples were marked to identify in those directions. Total 40 replications were made dividing sapwood and heartwood. In this case, except one cross and tangential surface, all surfaces were coated with silicon resin for preventing the leakage by other surfaces.
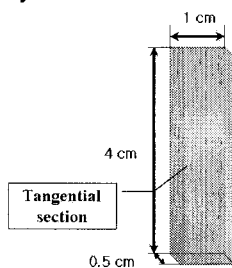


**Fig.1.** Sample size for measuring safranine flow depth along longitudinal direction.

*Estimation of moisture content*

Wood samples were weighed and dried in an oven for 24 hours at 105 $^{\circ}$C. Moisture content of wood block in terms of wet weight basis was calculated.

*Preparation of safranine solution*

10 g of safranine was taken in 1 L of volumetric flask and 500 ml 50% ethyl alcohol was added. Distilled water was added to make the volume 1000 ml. Thus 1% safranine solution was made.

*Camscope observation*

Samples moisture content were determined before safranine impregnation. While observing the safranine flow, the room temperature was 24 ℃, RH 60% and the wind speed was 0 m/s. Coated samples were fixed on a petridish and safranine was poured on it. With *i*-Solution software, the safranine impregnation video file was captured for 2 minute. The captured 2 minutes video file was divided into 600 image frames. Specific frames (125 images/second) were selected at 0.5, 1.0, 1.5 and 2.0 second by VitrualDub-MPEG2 software.

*Statistical analysis*

Safranine flow differences in vessel and fiber of sapwood and heartwood were tested by using a one-way ANOVA. When significant differences occurred (P≤0.05), the ANOVA procedure was followed by a Duncan significant difference post hoc test to separate the time effects (SPSS, Version 12.0.1, 2003).

## RESULTS AND DISCUSSION

Anatomical features of *P. tomentiglandulosa* is described by Lu et al. (2006) where the species is characterized by diffuse-porous wood having simple perforation plates, polygonal alternate non-vestured intervessel pit, non-septate thin walled libriform fibres, exclusively uniseriate procumbent rays, axial parenchyma absent or extremely rare.

Moisture content plays an important role for the liquid impregnation. Above the fiber saturation point until the cell cavity are filled with liquid water, wood can still take up water by absorption or capillary action (Browning 1963). But the permeability of some wood species decrease with an increased moisture content (Comstock 1968). Excess moisture in wood voids may also act as a physical barrier for the mass flow of liquid (Wirspa and Libby 1950). Moisture content of *P. tomentiglandulosa* was found in sapwood 23.50% and in heartwood 23.04%. In this experiment, we only estimated the flow depth in above mentioned moisture content level and the safranine flow difference in different moisture level were not considered. Safranine flow depths in longitudinal direction by vessel and fiber are presented in Table 1.

**Table 1.** Safranine flow depth in vessel and wood fiber                     unit: μm

| Time (seconds) | Vessel | | Wood fiber | |
|---|---|---|---|---|
| | Sapwood | Heartwood | Sapwood | Heartwood |
| 0.5 | 526.99a | 549.20a | 420.39a | 405.56a |
| 1.0 | 610.22ab | 657.78ab | 455.43a | 471.09ab |
| 1.5 | 684.00ab | 720.38bc | 482.94a | 488.71ab |
| 2.0 | 1020.12b | 804.64c | 516.10a | 543.38b |

Note: Different lower case letters within in a column indicate significant difference ($\leq 0.05$).

Vessels are connected end to end through perforation plate. The resulting vessel can be long and continuous. For example, vessels upto three meters in length have been reported (Thomas 1981). Various gummy, resinous and chalky exudates often form in vessel lumens with the heartwood (Hillis 1987) and the formation of these materials substantially reduces the treatability of heartwood (Kumar and Dobriyal 1993). Though the anatomical features are same in sapwood and heartwood but the micro structural features are different from juvenile wood to mature and earlywood to latewood. So, in the same wood species, the penetration of safranine can be differing from above mentioned areas.
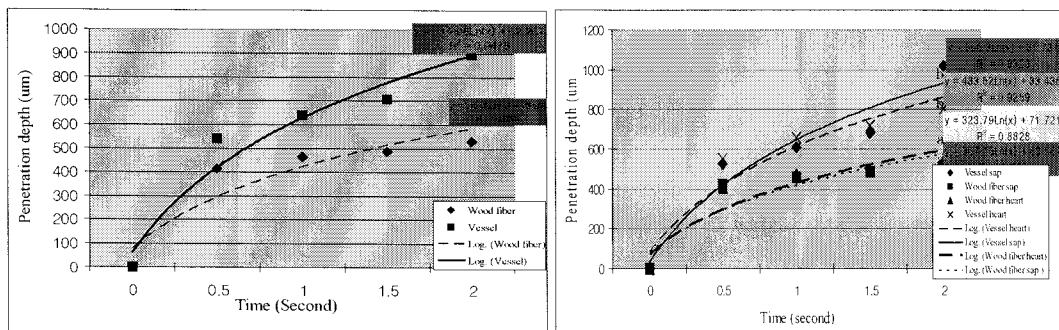


**Fig.2.** Comparison of safranine solution flow depth between sapwood and heartwood along longitudinal direction.
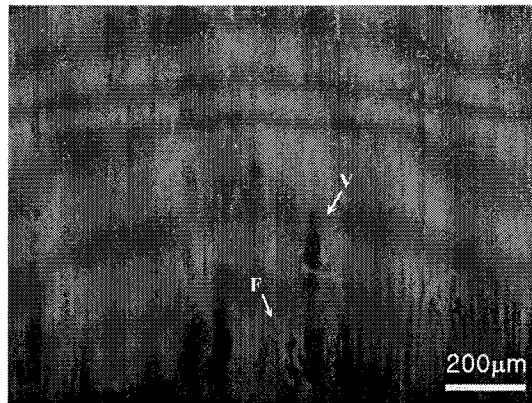
**Fig.3.** Safranine flow in vessel (V) and wood fiber (F).

From the anatomical features of *P. tomentiglandulosa*, we know that it has libriform wood fiber which trap air in the cell lumen more frequently than vessel while liquid penetration. On the other hand, vessel lumen is bigger than wood fiber and it has intervessel pittings through which liquid can diffuse to neighboring vessels. Vessels are connected together to form a tube and two vessels open through a simple perforation plate. Liquid can pass easily from one vessel to another through this plate. This kind of structures are absent in wood fiber. As a result, safranine penetration in vessel was found higher than wood fiber (Fig. 3).

In this experiment, heartwood vessel safranine penetration depth was found lower than the sapwood. Also wood fiber played an important role for safranine penetration. Though heartwood conducted safranine in higher depth than that of sapwood, no significant difference was observed (Fig. 2). This is because for considering short period of time to observe safranine penetration. The sapwood and heartwood penetration difference is thought to be expected for extended period of observation. The flow of safranine was done in an interconnecting network of vessel, ray parenchyma and fiber. Initially, safranine penetration was found high and gradually decreased with the course of time. At certain time, the safranine penetration will be stopped. In this point, the capillary pressure is thought to be same to the pressure created by compressed air inside the cell lumen. During the safranine flow in wood fiber and vessel, it formed a curved meniscus with the cell wall. Curved meniscus of safranine with cell wall is shown in Fig. 4.
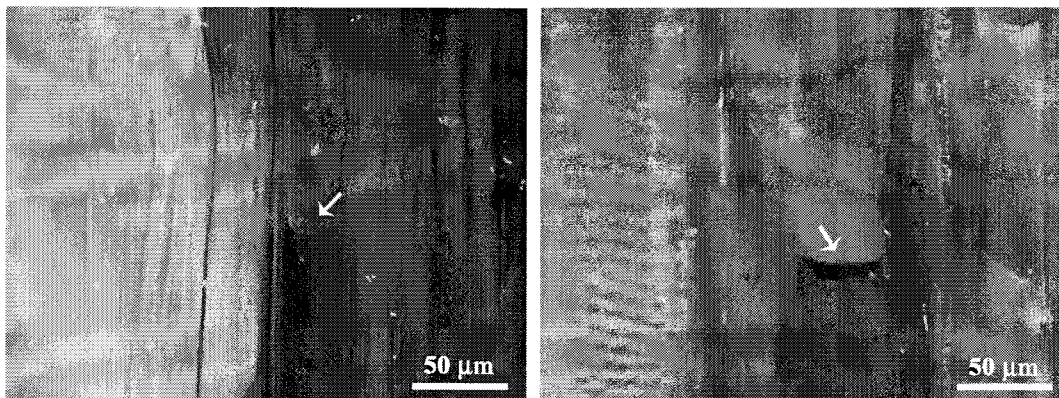


**Fig.4.** Meniscus formed in fiber (left) and vessel (right). Arrow showing curved meniscus of safranine.

In longitudinal direction, vessel conducted safranine in higher depth than in wood fiber. Vessel is the main avenue for liquid flow. Therefore, the size, distribution and condition of vessels are important factors affecting treatability (Wang and DeGroot 1996). The flow of safranine was done in an interconnecting network of vessel, ray parenchyma and fiber. Although significant difference was not observed in wood fiber and vessel present in sapwood & heartwood, safranine flow depth was significantly different from vessel to fiber. Vessel present in sapwood conducted safranine 49.41% higher than that of wood fiber. On the contrary, vessel present in heartwood conducted safranine 32.46% higher than wood fiber present in heartwood. On an average, vessel conducted safranine 41.94% higher than that of wood fiber.

## CONCLUSIONS

Vessel present in sapwood conducted safranine more than that in heartwood. Vessel conducted safranine in higher depth than that of wood fiber. Vessel and wood fiber conducted safranine forming a curved meniscus. Safranine had decreasing permeability with an increased in flow path length. Wood fiber present in heartwood conducted safranine more than wood fiber present in sapwood but that difference found statistically similar. Initial safranine flow rate was found high which gradually decrease with the course of time.

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