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Cellular Anatomy of Compression Wood and Opposite Wood in a Branch of *Taxodium distichum* Rich.[1]

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落羽松(*Taxodium distichum* Rich.) 枝材의 壓縮異常材 및 對應材에 관한 解剖學的 特性[1]

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ABSTRACT

Compression wood and opposite wood formed in a branch of *Taxodium distichum* Rich. is described and compared in qualitative and quantitative anatomical aspects. The qualitative features of compression wood appeared to differ from those of opposite wood in very gradual tracheid transition from earlywood to latewood, roundish tracheid shape on cross surface, tracheid tip distortion on radial surface, and existence of intercellular spaces and helical cavities. In quantitative features, compression wood tracheids showed shorter lengths than opposite wood. The ray density and the number of uniseriate rays were greater in compression wood than in opposite wood but the height of uniseriate rays in compression wood was smaller than in opposite wood.

Key words : Taxodium distichum, *branch wood, compression wood, opposite wood, anatomical features*.

要 約

본 硏究는 압축이상재가 현저하게 발달되어 있는 落羽松(*Taxodium distichum* Rich.)의 枝材로 부터 압축이상재율과 편심율 변이에 따른 압축이상재와 대응재의 解剖學的 特性을 比較하고자 실시하였다.

압축이상재의 組織學的 特性은 가도관의 둥근형태, 춘재로부터 추재로의 매우 점진적인 가도관 移行, 가도관 선단부의 뒤얽힘 및 螺旋腔과 세포간극의 존재 등에 있어 대응재와 다른 特性을 나타내었으며, 이러한 組織學的 特性은 압축이상재율과 편심률에 관계없이 유지하는 경향을 보였다.

數量的 특성에 있어서도 압축이상재는 假導管長이 대응재보다 짧은 특성을 보였으나 放射組織 密度와 單列放射組織의 數는 압축이상재가 대응재보다 많았다. 그리고 단열방사조직의 細胞高는 대응재가 압축이상재보다 더 큰 特性을 나타내었다.

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INTRODUCTION

As a rule, the inclined stems and branches of gymnosperms simultaneously form well-developed compression wood on the lower part and surpressed opposite wood on the upper part, and this eccentricity of radial growth might be caused by the result of growth hormones redistribution through the action of gravity (Onaka, 1949 ; Yamaguchi et al., 1983).

Compression wood is readily recognized as its reddish-brown color from surrounding tissues and occurs in Ginkgoales, Coniferales, and Taxales among the gymnosperms (Timell, 1986). Most of its anatomical features have been thoroughly investigated by many researchers. Despite coexistence of opposite wood with compression wood, however, less studies have been concentrated on the opposite wood or comparison of this opposite wood with compression wood.

Many studies on anatomical differences were reported between compression wood and opposite wood (Timell 1973, 1986 ; Park et al. 1979, 1980 ; Yoshizawa 1987 ; Lee and Eom 1988 ; Chung and Lee 1989) and normal wood was considered an intermediate between compression wood and opposite wood (Timell 1973).

This paper offers an anatomical comparison in qualitative and quantitative features between compression wood and opposite wood in a branch of *Taxodium distichum* Rich. according to the degree of compression wood based on growth eccentricity.

MATERIAL AND METHODS

The compression wood and opposite wood were obtained from the first branch of *Taxodium distichum* on the campus of the College of Agriculture, Seoul National University, Suwon. The respective three discs (B_1, B_2, B_3) were taken at 20cm interval along the branch direction from branch base. And cross, radial, and tangential sections of compression wood and opposite wood were mounted onto permanent slides following general laboratory techniques (Japan Wood Research Society 1985, Berlyn and Miksche 1976).

In the quantitative analysis the lengths of 200 randomly macerated tracheids were measured using an optical bench comparator. The ray density, the number of rays per mm on cross surfaces and the number of uniseriate rays on tangential surface per square millimeter were counted in 30 randomly selected parts. And the height of 100 randomly selected unseriate rays in number of cells were measured in tangential sections.

The observation and photomicrography were made from the prepared permanent slides by Axioskop Routine microscope, D-7082 Oberkochen, Carl Zeiss, West Germany.

For scanning electron microscopy, cross and radial surfaces were prepared through the procedure used in permanent slide preparation for light microscopy. The sections were left air-dried on a filter paper and mounted on specimen stubs with double-coated adhesives tape. Then the specimens were gold-coated in Polaron Autocoating Unit E 5200 and finally examined with a Cambridge Steroscan 250 Mark II microscope at an accelerating voltage of 10 kV.

RESULTS AND DISCUSSION

The degree of compression wood based on growth eccentricity decreases with increasing the distance from its base of the sampled branch (Table 1) as found in our previous study (Chung and Lee, 1989).

The tracheid transition from earlywood to latewood is very gradual in compression wood but abrupt in opposite wood (Fig.1) and thus demarcation between earlywood and latewood appears more ambiguous in compression wood. Timell (1973, 1986)

Table 1. Percentage of compression wood and eccentricity of the sampled discs.

Disc Number	1	2	3
Percentage of Compression Wood (%)	51.2	46.3	37.0
Eccentricity (%)	160	135	70

Note : Eccentricity (%) $= \frac{b-a}{a} \times 100$

where a : short radius, b : long radius.

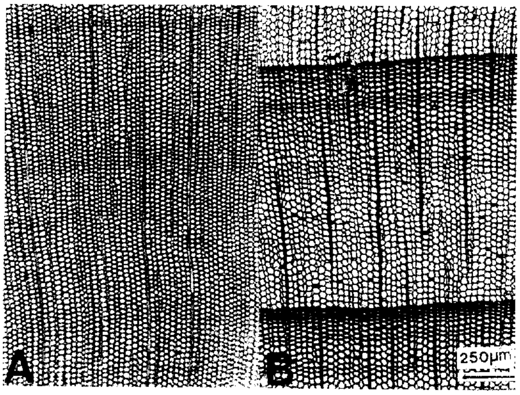

Fig. 1. Cross surfaces of *Taxodium distichum* Rich. showing very gradual tracheid transition from earlywood to latewood in compression wood(A) and abrupt in opposite wood (B)

and Lee and Eom(1988) reported that the tracheid transition was abrupt in opposite wood but very gradual in compression wood. The compression wood tracheids, when viewed on cross surfaces, disclose roundish outlines except for the vicinity of growth ring boundary(Fig.2 and 3) as mentioned by

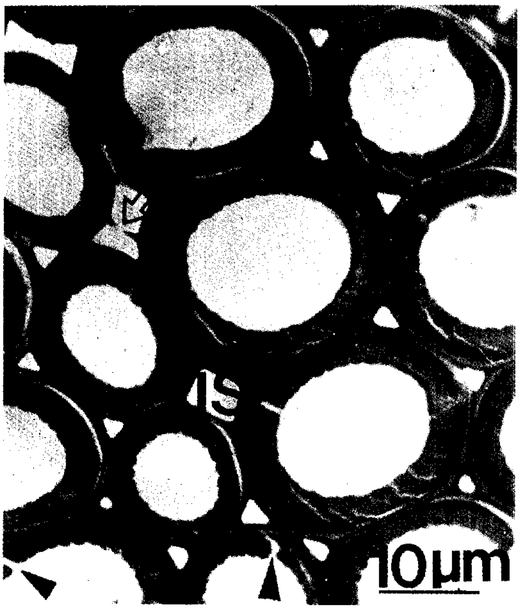

Fig. 2. Cross surface of compression wood showing the round, thick-walled tracheid and intercellular spaces(IS). Arrow heads point at helical checks ; arrow indicates a thin strip of lignified material.

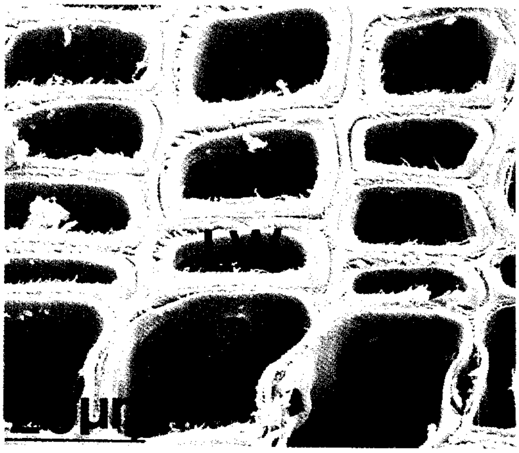

Fig. 3. Cross surface of compression wood tracheid showing more or less square and rectangular shapes in earlywood(EW) and latewood(LW) at the growth boundary. Note no helical cavity and intercellular space. Arrow indicates a bordered pit. Scanning electron micrograph.

Côté et al.(1967) and Yoshizawa(1987), but opposite wood tracheids showed more or less square and rectangular shapes in earlywood and latewood, respectively(Fig.4). In the comparison of opposite, normal, and compression wood, the outlines of tracheids were reported as square or rectangular in opposite wood, angular in normal wood, and round in compression wood by Timell(1973, 1986).

Intercellular spaces caused by the roundish shape of tracheids are numerous in compression wood

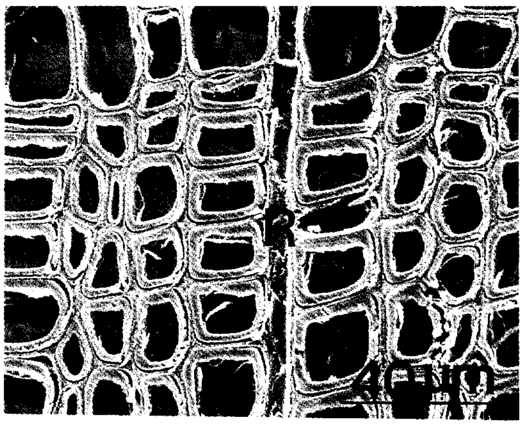

Fig. 4. Cross surface of opposite wood showing square and rectangular shapes of tracheid. R indicates ray. Scanning electron micrograph.

except for vicinity of the growth ring boundry but are absent in opposite wood(Fig.2, 3 and 4). Intercellular spaces are known to be present frequently in compression wood of *Larix*, *Picea*, *Pinus*, and *Pseudotsuga*(Timell 1981, 1986). Although the intercellular spaces may be of a useful diagnostic feature of compression wood, Butterfield and Meylan (1980), McGinnes and Phelps(1972), and Core et al. (1979) reported that caution must be exercised, for such longitudinal spaces also occur in normal wood of some coniferous genera such as *Agathis*, *Araucaria*, and *Juniperus*.

Helical cavities covered with sporadic warts are observed only in earlywood and latewood tracheids of compression wood(Fig.5) as found in Timell's report(1981). The formation of helical cavities has been a subject of considerable controversy for many years(Wardrop and Davies 1964, Côté et al. 1968, Timell 1979, 1986) but not clarified as yet.

Occasionally distorted tracheid tips occur in the contact area with rays in well-developed compression wood(disc B_1 and B_2) but are not found in weakly-developed compression wood(disc B_3) and opposite wood(Fig.6) similarly to our previous report(Chung and Lee, 1989). This tracheid distortion was indicated as one typical feature of compression wood by Onaka(1949) and Wardrop and Dadswell(1952) and believed to be caused by sliding or intrusive growth by Timell(1981) and Yoshizawa (1987).

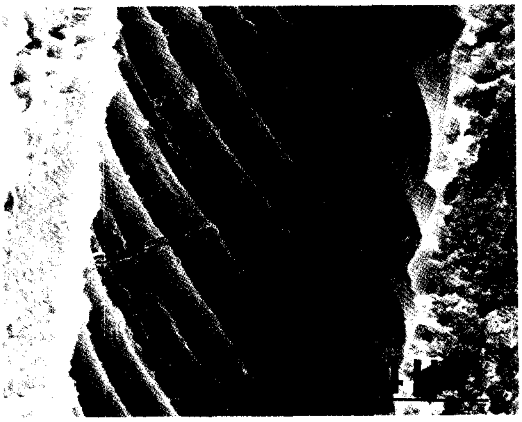

Fig. 5. Radial surface showing helical cavities covered with sporadic warts in compression wood tracheid. Scanning electron micrograph.

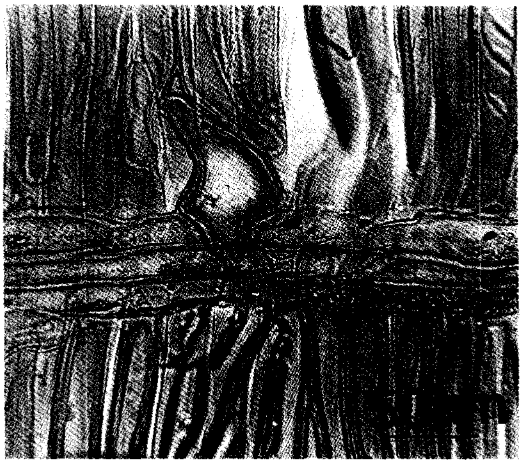

Fig. 6. Radial surface of compression wood showing tracheid tip distortion.

In quantitative features, tracheid lengths of compression wood are shorter than those of opposite wood(Fig.7) and their length in compression wood and opposite wood become larger with transition from lower to higher growth eccentricity. Shelbourne and Ritchie(1968) indicated that tracheid length of normal wood was greater than that of compression wood with an inverse relationship with compression wood intensity. Timell(1973) reported that the tracheids were relatively long in opposite wood, short in compression wood, and intermediate in

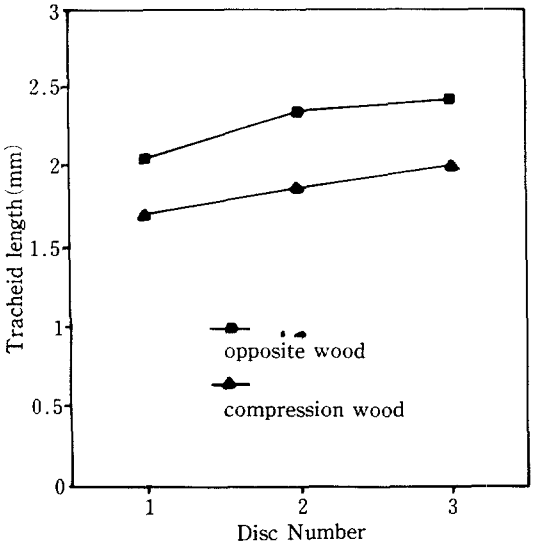

Fig. 7. Changes in tracheid length along disc number.

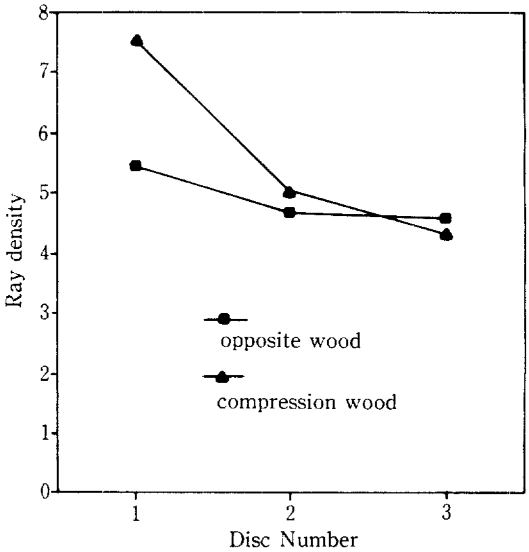

Fig. 8. Changes in ray density along disc number.

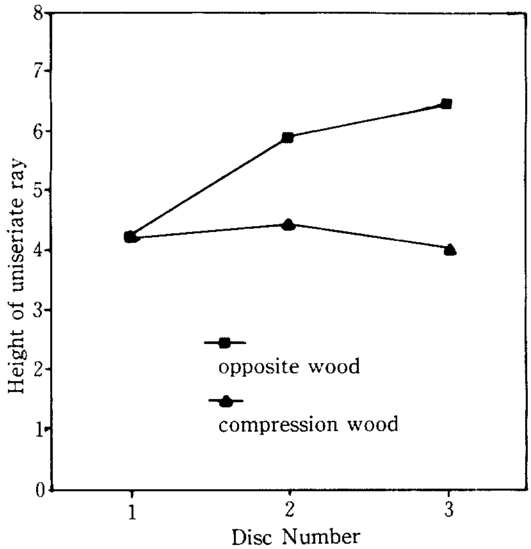

Fig. 10. Changes in height of uniseriate ray along disc number.

normal wood. Park (1984) also found that the length of latewood tracheids increased slightly from the compression wood side toward the lateral side but decreased thereafter to the opposite side in peripheral positions.

The ray density per mm in compression wood is more larger than that in opposite wood but the difference reduces with inverse intensity of growth eccentricity (Fig. 8). The number of uniseriate rays

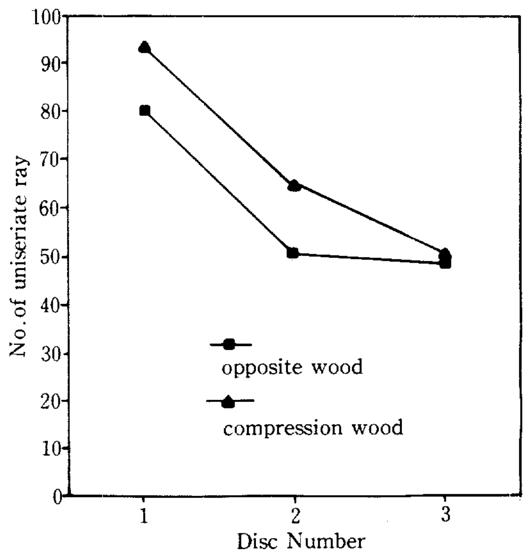

Fig. 9. Changes in number of uniseriate ray along disc number.

per mm^2 in tangential surfaces (Fig. 9) is larger in compression wood than in opposite wood and shows similar trends to the ray density. The difference of uniseriate ray heights between compression wood and opposite wood gradually increases with the intensity of growth eccentricity (Fig. 10). Verrall (1928) determined that rays were more frequent and considerably higher in compression wood than in normal wood, and Timell (1972) reported that the larger number and size of the rays occasionally observed in compression wood might be associated with rapid growth characteristics of this wood. Gregory and Romberger (1975) also pointed out that the number of rays were more frequent in compression wood and Lee and Eom (1988) reported that the uniseriate rays in compression wood were more numerous and higher than in opposite wood. The ray height in this study appear to be different from the results of Verrall (1928), Timell (1972), and Lee and Eom (1988) but accordant with the observation of Chung and Lee (1989).

CONCLUSIONS

Anatomical comparison between compression wood and opposite wood formed in a branch of *Taxodium distichum* Rich. was investigated.

In the qualitative features, the tracheid transition from earlywood to latewood in compression wood was more gradual than in opposite wood, which made demarcation between earlywood and latewood in opposite wood easier than in compression wood. When viewed on cross surfaces, the shape of tracheids was generally round in compression wood differently from the respective square and rectangular shapes in earlywood and latewood of opposite wood. Intercellular spaces, distorted tracheid, and helical cavities were observed only in compression wood.

In quantitative features, compression wood tracheids showed shorter lengths than opposite wood. The ray density and the number of uniseriate rays were more greater in compression wood than that in opposite wood. But the height of uniseriate rays in compression wood was smaller than that in opposite wood.

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