목재공학19(3) : 77~85(原著)
Mokchae Konghak.19(3) : 77~85. 1991

Anatomical Comparison between Compression Wood and Opposite Wood in a Branch of *Ginkgo biloba* L.*1

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은행나무 枝材의 壓縮異常材와 對應材에 關한 解剖學的 特性 比較*1

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摘 要

은행나무 枝材에 發達하여 있는 壓縮異常材와 對應材의 解剖學的 特性 差異를 組織 및 그 構成要素의 크기 면에서 서로 檢討 比較하였다.

組織的인 特性으로는 壓縮異常材가 年輪幅, 橫斷面上 假導管 形狀 및 放射組織 排列狀態, 細胞間隙, 假導管 先端의 屈曲, 螺旋裂 및 接線斷面上의 放射組織 形狀 면에서 對應材와 差異를 나타냈으며 構成要素의 크기에 있어서는 假導管의 壁厚 및 接線直徑, 單列放射組織의 높이, 二列放射組織의 數 및 放射組織 密度 면에서 壓縮異常材가 對應材와 差異를 나타내는 것으로 여겨졌다.

INTRODUCTION

Ginkgo biloba L., dated back to the Triassic of 210 million years ago, is one of the oldest still existing trees on earth and then has been of great interest in any attempt to trace the origin and evolution of compression wood in gymnosperms(Timell 1986). As in the conifers, the inclined stem and branch of *Ginkgo biloba* L. were known to form well-developed compression wood(Lämmermayr 1901; Böning 1925:Onaka 1949; Timell 1978, 1983; Yoshizawa *et al.* 1982)on the lower part and suppressed opposite wood(Bönning 1925) on the upper part.

The compression wood in *Ginkgo biloba* L. is distinguished easily by its dark brown color(Timell 1983) from surrounding tissues and may be induced by the action of indoleacetic acid(Onaka 1940) like the compression wood of conifers. The anatomical features in compression wood have been extensively investigated(Lämmermayr 1901; Böning 1925:Onaka 1949;Timell 1978,1981, 1983,1986;Yoshizawa

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et al. 1982) but those in opposite wood or comparison of this opposite wood with compression wood have not been of any interest despite coexistence of opposite wood with compression wood in *Ginkgo biloba* L.

This study was carried out to offer an anatomical comparison between compression wood and opposite wood in a branch of *Ginkgo biloba* L., a species hitherto not studied in this respect.

MATERIAL AND METHOD

The compression wood and opposite wood(Fig.1) were obtained from a branch of *Ginkgo biloba* L. and their subdivided blocks of 1 to 1.5cm^3 sizes were immediately softened in water in an autoclave. Cross, radial, and tangential sections of 20 to 30μm thickness were cut with a sliding microtome from the

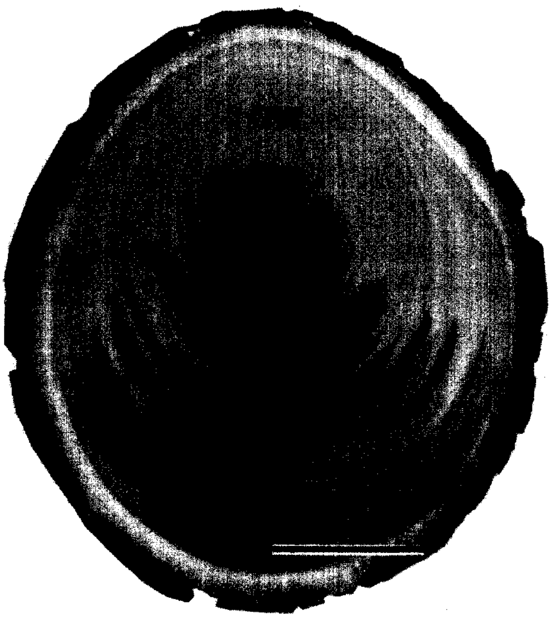


Fig.1. Compression wood(CW) and opposite wood(OW) in the branch of *Ginkgo biloba* L.

subdivided blocks and permanent slides were prepared following general laboratory techniques(The Japan Wood Research Society 1985). The observation and photomicrography of each tissue were conducted with Axioskop routine microscope, Carl Zeiss, D-7082 Oberkochen, West Germany.

For scanning electron microscopy, wood sections, 5 x 5mm^2 and 50μm thick, cut with the sliding microtome were air-dried on a filter paper under small glass cover(Tsoumis 1964) and mounted onto aluminium specimen stubs by means of double-coated adhesive tape. Thereafter, specimens were coated with a layer of gold 250Å thick in a Polaron Autocoating Unit E 5200 and photographed in a Cambridge Stereoscan 250 Mark II scanning electron microscope at an accelerating voltage of 10kv.

In the quantitative analysis of each tissue, the lengths of 150 randomly selected tracheids were measured from macerations obtained with Schultze's solution(Berlyn and Miksche 1976) by the aid of an optical bench comparator and wall thicknesses of 50 and tangential diameters of 100 randomly selected tracheids were measured on cross sectional photomicrographs. In the permanent slides, the numbers of uniseriate rays per mm^2 and biseriate rays in $4\pi mm^2$ were respectively counted in 30 and 10 randomly selected parts of tangential surfaces and ray densities, the numbers of rays per mm on cross surface, were counted in 30 randomly selected parts with the help of the optical bench comparator. The heights of 100 randomly selected uniseriate rays in number of cells were also counted on photomicrographs of tangential surfaces.

RESULT AND DISCUSSION

A branch of *Ginkgo biloba* L. used in this study(Fig.1) forms well-developed compression wood easily distinguished from surrounding tissue by its dark brown color on the lower part like Timell's observation(1983) and suppressed opposite wood on the upper part like Böning's description(1925) that a typical opposite wood was found in *Ginkgo biloba*.

The growth ring widths are in the range of 1.2 to 6.1mm(average 4.16mm) in compression wood and 0.7 to 1.6mm(average 1.26mm) in opposite wood, thus agreeing with the observation in compression wood and opposite wood in a branch of *Pinus koraiensis* by Lee and Eom(1988) that the ring width in compression wood was wider than in opposite wood and that was variable in both ring widths. On the other hand, Timell(1973) indicated that growth rings were narrow in opposite wood, intermediate in normal wood, and wide in compression wood.

The arrangement and size variation of tracheids in compression wood are similar to those in opposite wood but short secondary rays, when viewed on cross surface, occur more frequently in compression wood than in opposite wood(Fig.2). In the comparison between compression wood and normal wood in *Ginkgo biloba*, Timell(1978, 1983, 1986) reported that the arrangement of the tracheids was noticeably more regular in the compress-

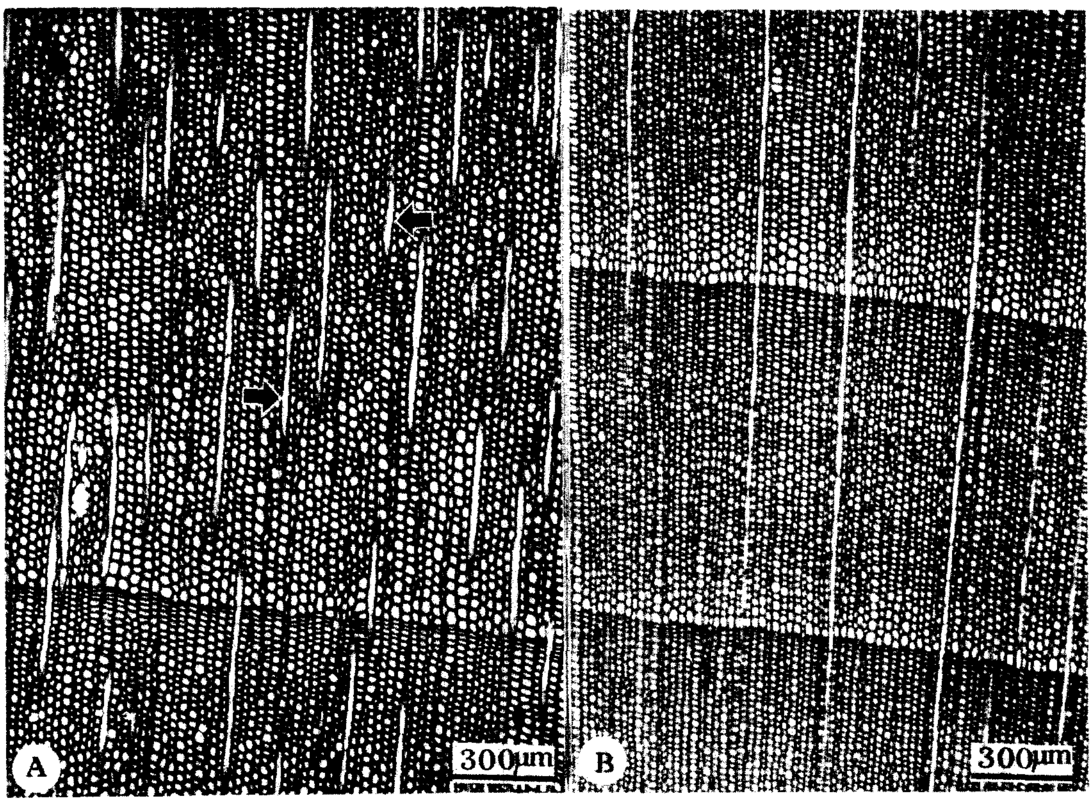


Fig.2. Cross surfaces of compression wood(A) and opposite wood(B). Arrow indicates short secondary ray.

ion wood than in normal wood and they also varied less in size than did the normal wood tracheids. The opposite woods in *Pinus resinosa* and *Picea rubens* were known to have regular arrangement of tracheids in both earlywood and latewood by Timell(1986).

The tracheids in compression wood have angular outlines with roundish trends but those in opposite wood show angular views on cross surface and intercellular spaces are frequently observed in compression wood differently from their rare occurrence in opposite wood(Fig.3). The tracheids in compression wood of *Ginkgo biloba* were known to exhibit more angular outlines compared to those in severe compression wood of the Coniferales by Timell(1978) and to be surrounded by intercellular spaces by Timell(1978, 1983, 1986) and Yoshizawa *et al.*(1982). Also, the intercellular spaces appeared to be occasionally present between tracheids in normal wood of *Ginkgo biloba* by Eicke and Ehling(1965). The outlines of tracheids, on the other hand, were reported to be square, rectangular, or angular in opposite wood, angular in normal wood, and round in compression wood by Timell(1973).

Distorted tracheid tips frequently occur in compression wood but they are uncommonly found in opposite wood(Fig.4). This tracheid distortion was indicated as a common feature of compression wood by Onaka(1949) and Wardrop and Dadswell(1952) and flattened and L-shaped tips of tracheids were believed to increase in number with the development of compression wood due to disturbed intrusive growth between adjacent cells by Yoshizawa *et al.*(1985).

The compression wood tracheids are occasionally fissured by long spiral check and frequently exhibit short checks associated with pit openings(Fig.5) but any checks are not observed in the opposite wood tracheids. Timell(1978, 1983, 1986) reported that the entire S_2 layer of compression wood tracheid in *Ginkgo biloba* evidently lacked the helical cavities, perhaps the most conspicuous feature of the compression wood in most gym-

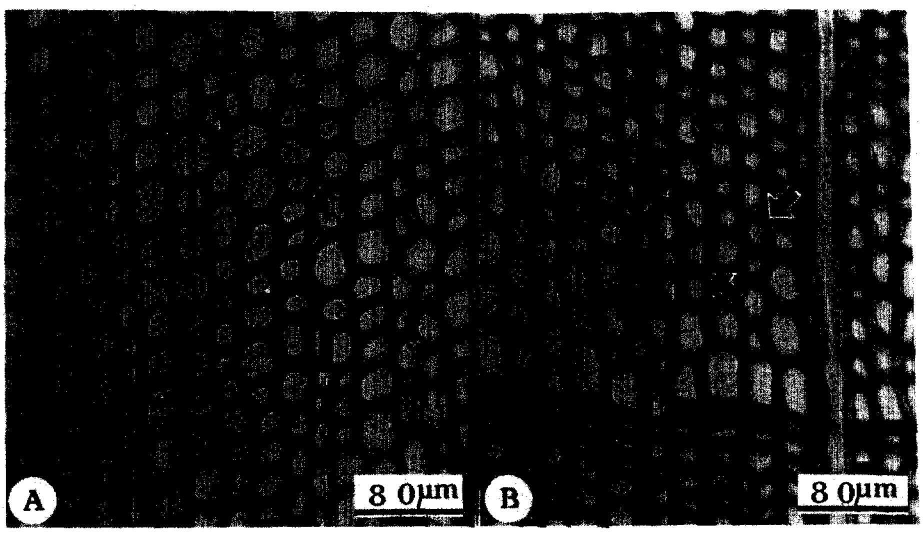


Fig.3. Cross surfaces of compression wood(A) and opposite wood(B). Arrow indicates intercellular space.

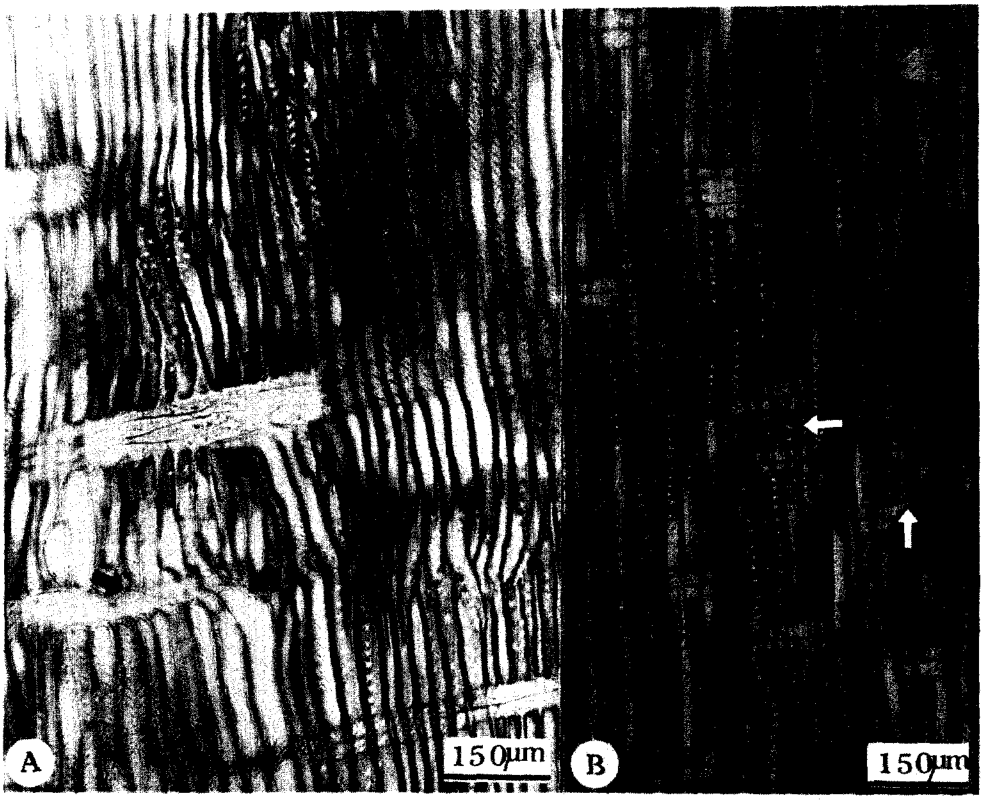
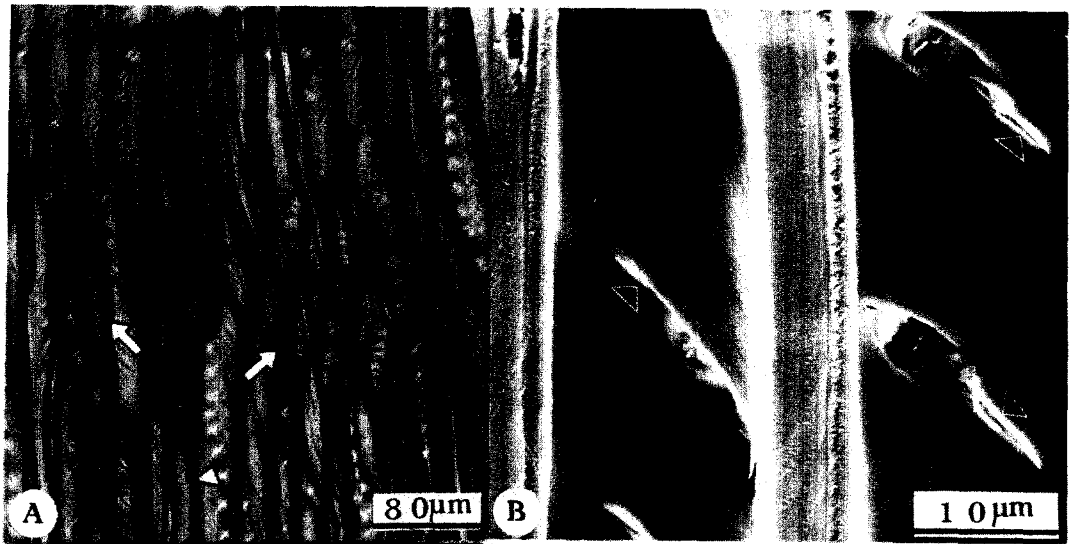


Fig.4. Radial surfaces of compression wood(A) and opposite wood(B). Arrow indicates tracheid tip distortion.

nosperms, but occasionally had deep spiral checks which were probably formed on drying and sometimes associated with pit openings.

The rays in compression wood show more or less rugged shapes differently from those in opposite wood, and biseriate rays occur frequently in compression wood but their detection is very difficult in opposite wood(Fig. 6) like the observation in compression wood and opposite wood in a branch of *Pinus koraiensis* by Lee and Eom(1988).

In the quantitative features, tracheid lengths are 720 to 2920μm(average 1907.5μm) in compression wood and 740 to 2900μm(average 1904.1μm) in opposite wood, and thus tracheids of compresson wood appear not to be shorter than those of opposite wood. Matsumoto(1950) found that the average tracheid lengths of *Chamaecyparis obtusa* and *Thujopsis dolabrata* were less in opposite wood than in compression wood as long as moderate amounts of compression wood were present and Mariani(1955) also indicated in *Larix decidua* that the tracheids were shorter in opposite wood than in compression wood. The tracheids in opposite wood, however, appeared to be longer than those in compressiom wood however, appeared to be longer than those in compression wood with only few exceptions(Timell 1986). The wall thicknesses of tracheids are 2.5 to 5.5μm(average 4.05μm) in compression wood and 2.0 to 4.5μm(average 3.15μm) in opposite wood and



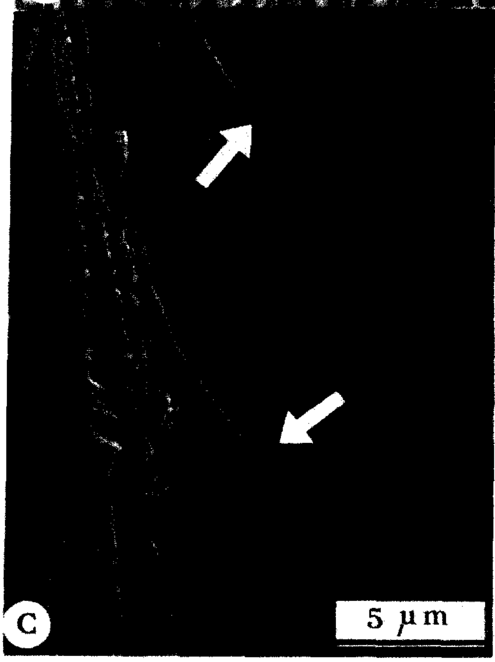


Fig.5. Radial surfaces of compression wood showing long spiral check(⇧in A, C) and short check associated with pit opening (△ in A, B).

tangential diameters of tracheids are 12 to 45 μm(average 26.04 μm) in compression wood and 10 to 32 μm(average 21.55 μm) in opposite wood, which means that compression wood tracheids are more or less thicker and wider than opposite wood tracheids. Cieslar (1896) mentioned that the cell wall in compression wood of *Picea abies* was 4 to 8 μm thick compared to 2 μm for earlywood and 4 μm for latewood in opposite wood, and Yoshizawa *et al.*(1981) reported in *Pinus thunbergii* that cell wall thickness in compression wood was greater than those in opposite wood. Park(1983) indicated that the tangential diameter and wall thickness of tracheids continuously decreased at a relatively steep rate towards the opposite side from compression side in *Pinus densiflora*. Also, Lee and Eom(1988) reported that wall thickness of compression wood tracheids was approximately twice that of opposite wood in *Pinus koraiensis*. Kienholz(1930) noted in *Tsuga mertensiana* that the tracheids in normal wood had a slightly larger tangential diameter than those in compression wood, but opposite wood and compression wood were very similar in this respect. Onaka(1949) reported that the respective wall thicknesses and tangential diameters in the tracheids of *Ginkgo biloba* were 3.0 μm and 30 μm for earlywood and 3.5 μm and 30 μm for latewood in normal wood, and 4.0 μm and 28 μm for earlywood and 3.0 μm and 24 μm for latewood in com-

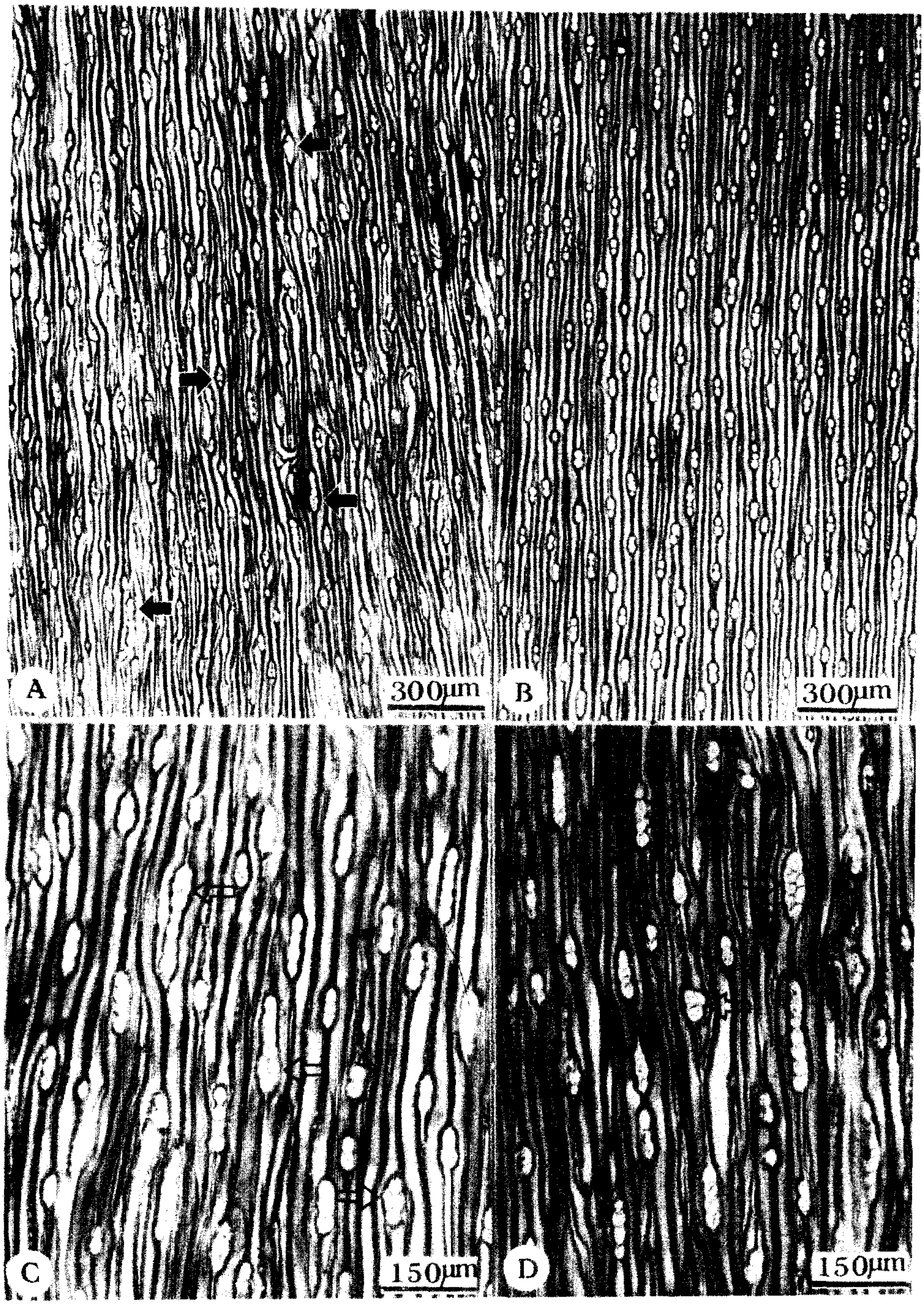


Fig.6. Tangential surfaces of compression wood(A, C, D) and opposite wood(B). Arrow indicates biseriate ray.

pression wood.

The numbers of uniseriate rays per mm^2 in tangential surfaces are 59 to 82(average 67.5) in compression wood and 60 to 77(average 67.2) in opposite wood and their heights in number of cells are 1 to 8(average 3.1) in compression wood and 1 to 6(average 2.4) in opposite wood. Cieslar (1896) found in *Picea* *abies* that opposite wood contained only 75% as many rays as did compression wood and Bannan(1937) noted that rays were more numerous on the lower than on the upper side in branches of *Tsuga canadensis*. Lee and Eom(1988) reported in *Pinus koraiensis* that the uniseriate rays in compression wood were more numerous and higher than in opposite wood. The numbers of biseriate rays, which were known to be found in all gymnosperm families except Ginkgoaceae(Greguss 1955), in tangential surfaces of $4\pi mm^2$ are 3 to 15(average 6.4) in compression wood and 0 to 2(average 0.9) in opposite wood, thus agreeing with the observation in *Pinus koraiensis* by Lee and Eom(1988) that they were numerous in compression wood but their detection was very difficult in opposite wood, and also ray densities, the numbers of rays per mm on cross surfaces, are 3 to 9(average 4.8) in compression wood and 2 to 6(average 3.7) in opposite wood. Kennedy(1970) observed biseriate rays in compression wood of *Pseudotsuga menziesii* but Timell(1972) failed to detect the biseriate rays in the compression wood of this species. Onaka(1949) in *Ginkgo biloba* reported that number of rays per mm^2 on tangential surface and average height of rays in number of cells were 54.4 and 2.23 in compression wood and 59.5 and 2.20 in normal wood, respectively.

CONCLUSION

Compression wood and opposite wood in a branch of *Ginkgo biloba* L. was compared in the qualitative and quantitative anatomical aspects.

The qualitative features of compression wood appeared to differ from those of opposite wood in growth ring width, tracheid shape and ray arrangement on cross surface, intercellular space, distorted tracheid tip, spiral check, and ray shape on tangential surface. In the quantitative features, differences between these two tissues occurred in wall thickness and tangential diameter of tracheid, height of uniseriate ray in number of cells, number of biseriate ray, and ray density.

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