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Histological Characteristics of Tumorous Wood Formed in a Stem of *Robinia pseudoacacia* L. by Artificial Fastening[1]

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人爲的인 結締에 의해 形成된 아까시나무 樹幹의 腫瘍材에 관한 組織特性[1]

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ABSTRACT

A tumorous wood formed in a stem of *Robinia pseudoacacia* L. by steel wire fastening was investigated and compared with normal wood in the anatomy of histological aspect.

The tumorous wood appeared to differ from normal wood in irregular orientations of some pores, most wood fibers, and rays deviated from normal direction, somewhat radially elongated pores on cross surface, occasionally distorted wood fiber tips between rays on radial surface, large ray width and height, commonly entangled arrangement of wood fibers on radial surface, frequent occurrence of pore multiples in the latewood, frequent occurrence of gelatinous fibers, and dark gummy substances partially enclosed in the lumina of wood fibers, rays, and axial strand parenchymas.

Key words : *Tumorous wood*, Robinia pseudoacacia *L.*, *histological characters*.

要 約

樹幹 둘레를 鐵絲로 結締함에 따라 人爲的인 被害를 받으므로써 形成된 아까시나무(*Robinia pseudoacacia* L.) 腫瘍材의 組織學的 特性을 考察하고 아울러 正常材와의 그 特性 差異를 究明하기 위하여 本 硏究를 實施하였다.

腫瘍材는 一部 管孔 및 大部分의 木纖維와 放射組織이 正常配列에서 離脫된 不規則的인 配列을 이루고 있는 점, 橫斷面上의 管孔이 다소 放射方向으로 伸張되어 있는 점, 先端이 屈曲된 木纖維가 放射斷面上의 放射組織 사이에서 가끔 觀察되는 점, 放射組織의 幅과 높이가 더 큰 점, 放射斷面上의 木纖維가 서로 交錯配列을 이루고 있는 점, 秋材部의 複合管孔 出現 頻度가 더 큰 점, 젤라틴木纖維의 發達이 더 一般的인 점 및 濃色의 검(gum)狀物質이 局部的으로 木纖維, 放射組織, 軸方向柔細胞의 內腔에 發達되어 있는 점에 있어서 正常材와의 組織 特性 差異를 나타내었다.

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INTRODUCTION

Tumorous wood, a tumescent overgrowth tissue in comparison with normal wood, may be formed in living trees when the cambium in the growing season is wounded or its normal activity is influenced by several causes.

The cause of tumorous wood has not been identified completely although some hypotheses suggestive of genetic instability, irritation of cambium by insect, bacterium, or sea water spray, or higher concentration of auxin have been proposed and none of these agencies has been known ever to produce the tumorous wood alone (White and Millington, 1954a, b ; White 1958a, b ; Peterson, 1961 ; DeTorok, 1967 ; Rickey *et al*., 1974 ; Kramer and Kozlowski, 1979).

The tumorous wood can be developed either by an increase in the rate of formation of new cells or by prolongation of growth period (White, 1958a ; Peterson, 1961 ; Tsoumis, 1965 ; White *et al*., 1967 ; Rickey *et al*., 1974).

In earlier studies the anatomy of tumorous wood has largely been confined to softwoods. White and Millington (1954b) in *Picea glauca* noted that tissues of tumor wood were composed of less regular tracheids having large lumina and bordered pits more often paired, and were characterized by a less regular formation of resin canal. White (1958a) described that cross sections might show many times as many cells in each growth ring in the tumor wood, counted radially, as in the corresponding normal parts and the only outstanding difference was a somewhat thinner secondary cell wall in the summarized report on the tumor wood of *Picea glauca*. Tsoumis (1965) found the tumor wood of *Picea glauca* to be characterized in anatomical aspects by wider growth rings, a greater number of cells per growth ring, variable width of adjoining cell files, abnormally large lumina, hazy walls and appearance of bordered pits on transverse sections as if seen in radial view, numerous traumatic resin canals arranged in tangential row, and irregular strand tracheids and tracheids. Rickey *et al*. (1974) indicated in *Picea sitchensis* that the tumor wood had short, curved, and twisted tracheids and numerous traumatic resin canals but did not show any apparent abnormalities in wood rays and barks.

Recently Tsoumis *et al*. (1988) found the briarwood, a hardwood tumor-like overgrowth occurred between root and stem in *Erica arborea*, to have shorter and irregular fibers, irregular tissue structure, and amorphous or crystal enclosures in cell cavities. Eom (1989) described abnormalities of the growth ring and cellular anatomy in detail in an artificially induced tumorous wood of a Korean hardwood species, *Ailanthus altissima*, by tight banding and subsequent removing treatment.

This study was intended to investigate tissue structure of the tumorous wood developed in a stem of *Robinia pseudoacacia* L. after steel wire fastening, a hardwood tumorous wood hitherto not studied extensively compared with the tumorous woods in the softwoods.

MATERIALS AND METHODS

The tumorous wood was obtained from a stem of *Robinia pseudoacacia* L. at Eodan-ri, Kujeong-myon, Myoungju-kun, Kangwon-do. This sample tree had been fastened by a steel wire, ca. 3mm in diameter, around the stem at 130cm above ground level and then left on growing under this condition. Such a damage by fastening let this tree bear well-developed massive tumorous wood at this part thereafter (Fig. 1A and B). As shown in Fig. 1C, three discs, ca. 2cm thick, were cut from center of tumorous part and 30cm above and below the center of tumorous part to examine the tissue structure of tumorous wood and also to compare this tumorous wood with normal ones in the histological aspect.

From these discs, blocks of 1 to 2cm^3 sizes were subdivided and softened in a mixture of equal volumes of ethyl alcohol, glycerine, and water in an autoclave and stored in the same mixture until sectioning (Berlyn and Miksche, 1976).

Transverse, radial, and tangential sections of 20 to 30μm thickness were sliced with a sliding microtome, stained with safranine solution, dehydrated in ethyl alcohol and xylene series, and finally mounted with Canada balsam (The Japan Wood

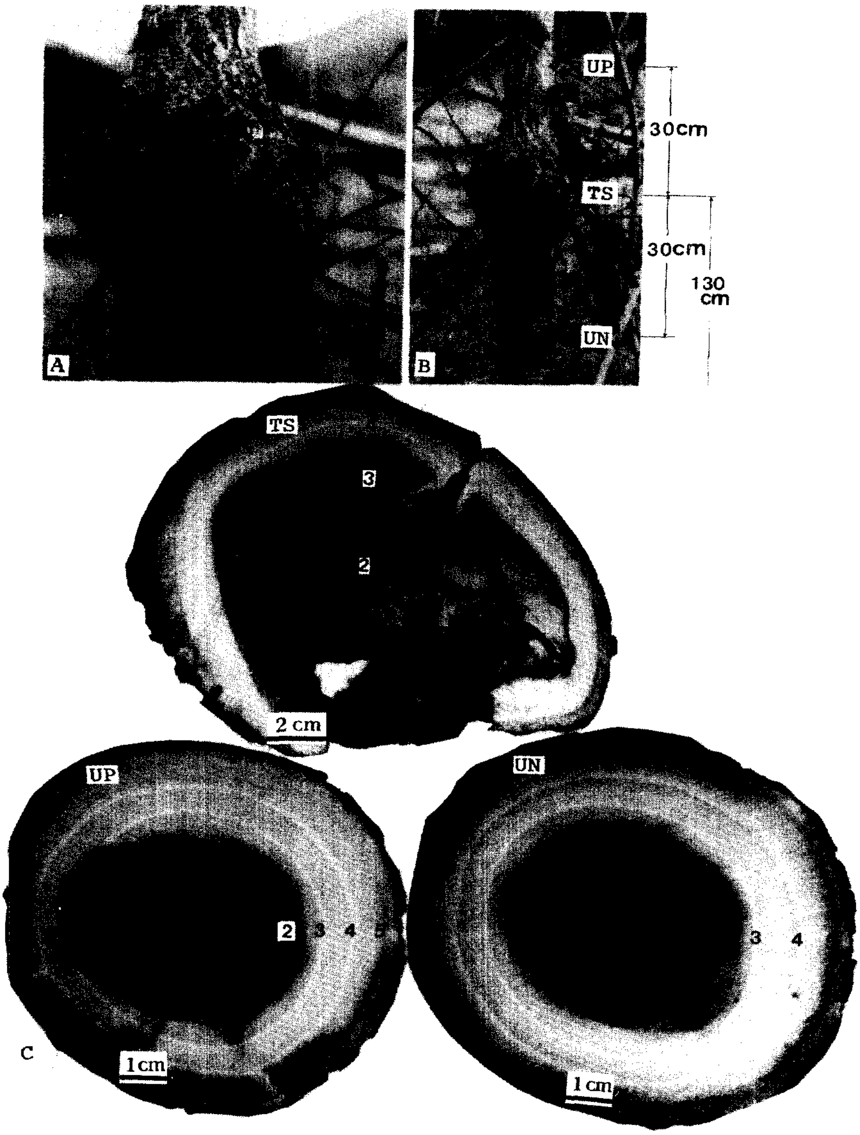

Fig. 1. Tumorous wood formed after steel wire fastening around the stem(A), and location(B) and cross sectional views(C) of each sample disc in *Robinia pseudoacacia* L. The 3rd and 4th growth rings in TS are tumorous wood, the massive overgrowth increments. TS : disc containing tumorous wood 130cm above ground level ; UP, UN : disc 30cm above and below center of TC, respectively.

Research Society, 1985).

Axioskop routine microscope, Carl Zeiss, D-7082 Oberkochen, West Germany was used for observation and photomicrography.

RESULTS AND DISCUSSION

Typical tumorous wood of the massive overgrowth increments, the 3rd and 4th growth rings, gives

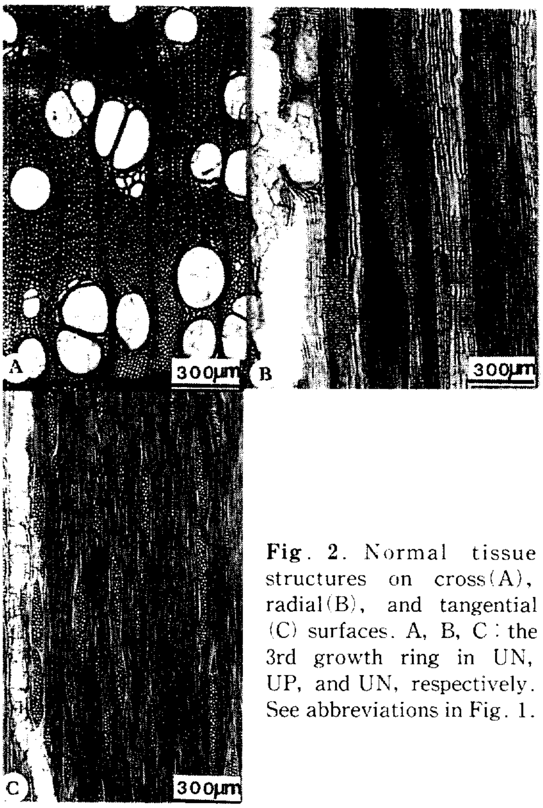

Fig. 2. Normal tissue structures on cross(A), radial(B), and tangential (C) surfaces. A, B, C : the 3rd growth ring in UN, UP, and UN, respectively. See abbreviations in Fig. 1.

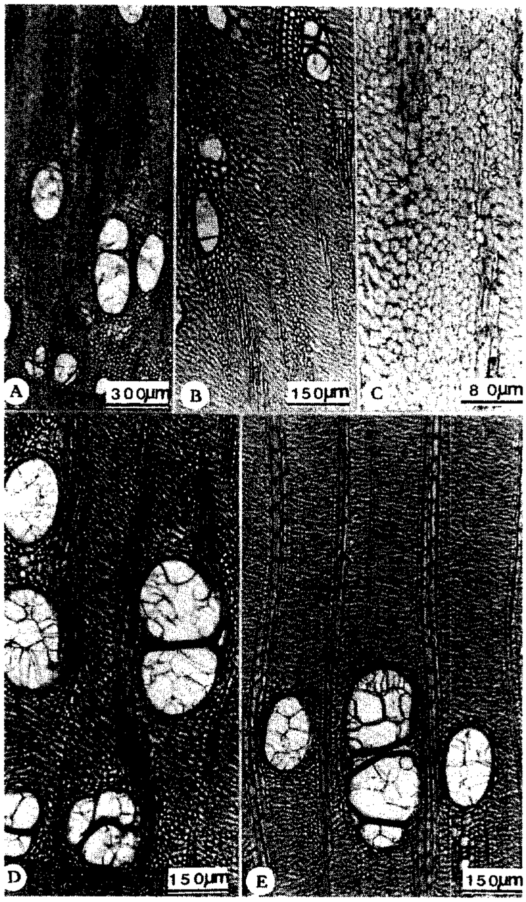

Fig. 3. Cross surfaces of TS showing radially elongated pores and disordered arrangement in rays and/or wood fibers(A, B, D, E), and gelatinous fibers(C). A, B, C : the 3rd growth ring ; D, E : the 4th and 5th growth ring, respectively. ⇧ indicate gelatinous fibers. See abbreviation in Fig. 1.

hemispherically swollen appearance to the tumorous part(TS) which developed after steel wire fastening. Also heartwood that has formed in the tumorus part reaches the 4th growth ring compared with the 3rd growth ring in the normal part(UN and UP) macroscopically(Fig. 1C). The wider growth rings in the tumorous wood caused by artificial banding and subsequent release was observed in *Ailanthus altissima* by Eom(1989). This overgrowth was known to occur from differences not in cell size but in cell number through consistently more tangential divisions and the greatly, at least in part, prolonged growth period of tumor wood in *Picea glauca* by White(1958 a, b). Rickey *et al*.(1974) showed that the tumored tissue of *Picea sitchensis* looked like normal wood in that it had annual rings and definite sapwood and heartwood zones.

The histological structures of tumorous wood are highly disordered when compared with normal woods(Fig. 2). The most outstanding deformities observed in the tumorous wood are the appearances of rays and wood fibers on cross surfaces as if seen on radial surfaces(Fig. 3). But most pores on cross surfaces only exhibit somewhat radially elongated shapes(Fig. 3), though some vessels on cross and radial surfaces appear like radial and cross sectional views(Fig. 4). These deformities are believed to be caused by perpendicular or near-perpendicular orientation of cells to the tree's long axis. Tsoumis(1965) found the appearance of bordered pits of tracheids on cross surfaces as if seen on radial surfaces in the tumor wood of *Picea glauca*. Rickey *et al*.(1974) pointed out that the longitudinal tracheids were often twisted within the tumor wood so that border-

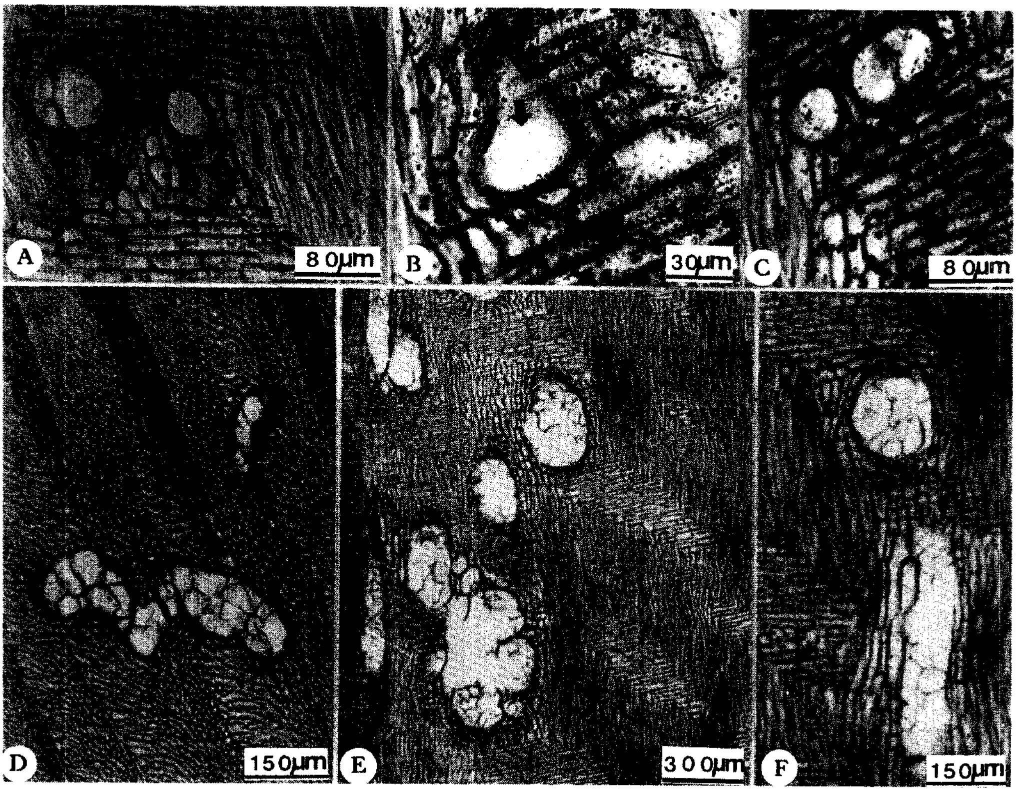

Fig. 4. The altered orientations of vessel elements in TS. A, B, C : the 3rd growth ring on radial surfaces ; D : the 3rd growth ring on cross surface : E, F : the 4th growth ring on radial surfaces. ↑ indicates simple perforation plate of vessel element. See abbreviation in Fig. 1.

ed pits occurred on cross as well as radial view in *Picea sitchensis*. On the other hand, Tsoumis *et al*. (1988) said that the cellular structure of briarwood, the tumor wood of *Erica arborea* developed between stem and root, appeared normal sometimes but as a rule was irregular, and this irregular structures resulted in an attractive figure of the briarwood. Eom(1989) reported irregular orientations of vessel elements, wood fibers, strands of axial parenchyma, and rays in an artificially induced tumorous wood of *Ailanthus altissima* as well.

In occasion distorted wood fiber tips(Fig. 5A) and horizontally oriented wood fibers showing round shapes(Fig. 5B) like the cross sectional view of normal wood ones(Fig. 2A) occur between rays on the radial surface in the tumorous wood but they are not found on the radial surface of normal wood. This distorted tips of wood fibers were believed to be caused by sliding or intrusive growth(Timell, 1981), and severely disturbed intrusive growth may result in the horizontal orientation of wood fibers, thus showing round outlines of wood fibers on radial surface like cross sectional views. The wood fibers on radial surface of the tumorous wood are generally entangled in longitudinal direction, differently from those on radial surface of normal wood(Fig. 2B and 4E, F). And gelatinous wood fibers(Fig. 3C) are more commonly observed in the tumorous wood than in the normal wood taken at 30cm above and below the tumorous wood. These gelatinous wood fibers were confirmed in normal woods of *Robinia pseudoacacia* L. by Lee and Eom(1987) and were known to occur in the tumorous wood of *Ailanthus altissima* caused by artificial banding and subsequent removing treatment by Eom(1989). Kramer and Kozlowski(1979) noted that the formation of gelatinous fibers was most probably a developmental response to auxin deficiency.

The rays on tangential surface in the tumorous wood formed by steel wire fastening are not signifi-

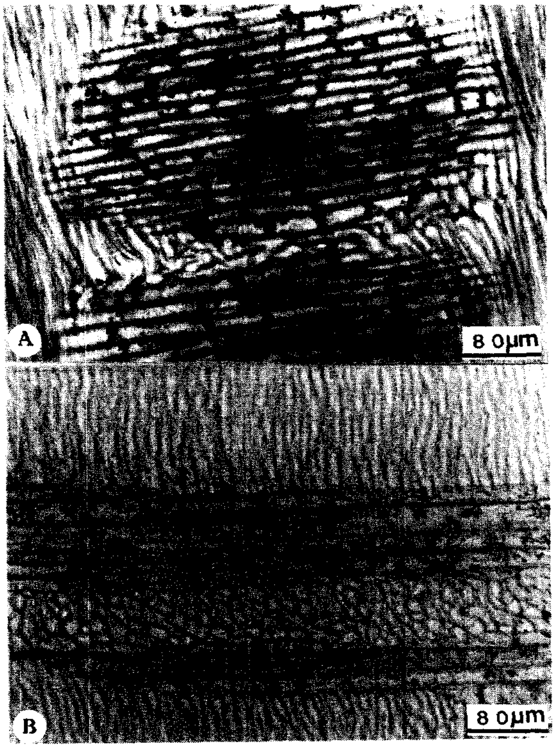

Fig. 5. Radial surfaces of TS showing distorted (↑) and abnormally arranged wood fibers as if seen on cross surface(⇑). A, B : the 3rd and 4th growth ring, respectively. See abbreviation in Fig. 1.

cantly altered in thier shapes except for the occasional occurrence of aggregate ray-like structures (Fig. 6A), but both the height and width of rays in the tumorous wood are somewhat greater than those in normal woods(Fig. 2C and 6). The rays of the tumorous wood formed by artificial banding and subsequent release in *Ailanthus altissima* were known to show irregular appearance deviated from the normal fusiform shapes and to be wider and taller in size by Eom(1989). In *Acer*, *Betula*, and *Fagus* which were artificially injured with a drill bit and harvested two years later, Rademacher *et al*. (1984) observed the increased ray width in the tissue formed after wounding compared with the tissue before wounding.

Other interesting characters in the tumorous wood formed after wounding are more frequent occurrence of pore multiples in latewood compared with latewood of normal woods(Fig.7) and partial presence of dark gummy substances of unknown origin in the lumina of wood fibers, rays, and strands of axial parenchyma(Fig. 8) differently from their absence in those of normal wood. The percentage of vessel grouping was known to be altered in the tissues formed after wounding by drill bits in *Acer* and *Betula* species by Bauch *et al*. (1980)

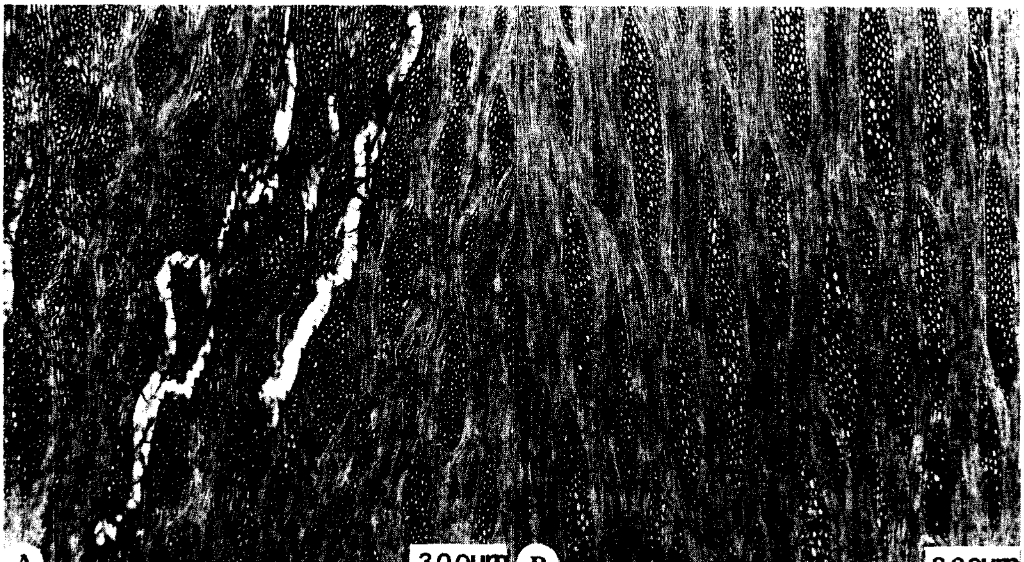

Fig. 6. Tangential surfaces of TS showing ray structures. A, B : the 3rd and 4th growth ring, respectively. ⇑ indicates aggregate ray-like appearance. See abbreviation in Fig. 1.

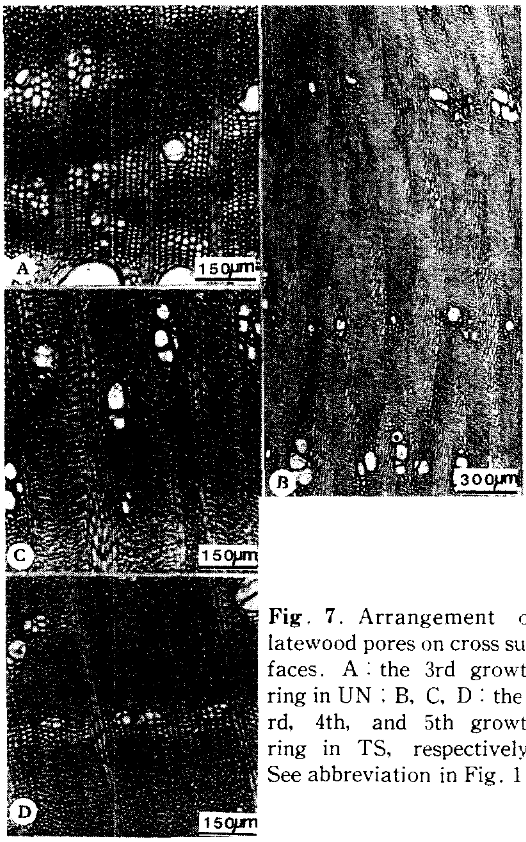

Fig. 7. Arrangement of latewood pores on cross surfaces. A : the 3rd growth ring in UN ; B, C, D : the 3 rd, 4th, and 5th growth ring in TS, respectively. See abbreviation in Fig. 1.

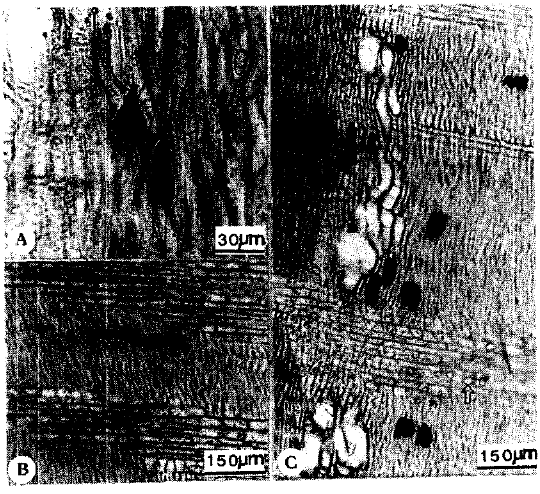

Fig. 8. Dark gummy substances in wood fibers(A, C), rays(B), and axial strand parenchymas(C) on radial surfaces of TS. A, B, C : the 4th growth ring. ⇧ indicates crystal. See abbreviation in Fig. 1.

and in *Liriodendron tulipifera* by Lowerts *et al.* (1986).

CONCLUSION

Histological difference between tumorous wood formed by steel wire fastening and normal wood was investigated in a stem of *Robinia pseudoacacia* L.

In the tumorous wood the rays and wood fibers on cross surfaces generally appeared as if seen on radial surfaces, but most pores on cross surfaces only exhibit somewhat radially elongated shapes although some vessels on cross and radial surfaces appeared like radial and cross sectional views.

Occasionally, distorted wood fiber tips and horizontally oriented wood fibers showing round shapes like the cross sectional view of normal wood ones occurred between rays on the radial surface in the tumorous wood. The wood fibers on radial surface of the tumorous wood were generally entangled in longitudinal direction and gelatinous wood fibers were more commonly observed in the tumorous wood.

The rays on tangential surface in the tumorous wood were not significantly altered in thier shapes except for the occasional occurrence of aggregate ray-like structures and their greater height and width than those of normal woods.

Other interesting characters observed in the tumorous wood were more frequent occurrence of pore multiples in latewood than in latewood of normal woods and partial presence of dark gummy substances of unknown origin in the lumina of wood fibers, rays, and strands of axial parenchyma.

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