The light is one of the main environmental attributes affecting carbon gain and consequently the developmental, structural and functional traits of the secretory systems [6]. So, we suppose that the higher density of secretory canals in *C. langsdorffii* seedlings growing under full light, as compared to those under shade, resulted from an increased supply of the secondary products used in the formation of such structures, as suggested by Lin et al. [6] to resin canals in *Pinus sylvestris* needles. There are numerous reports about light-inducible secondary metabolism in higher plants [3], but very little is known about the shade or dark conditions influencing the secondary metabolism [9].

The differential answer by cortical cavities and medullar canals in seedlings of *C. langsdorffii* concerning the different light conditions is a remarkable result of this work. In this sense, we can suggest that the peculiarities observed can be related to the distinctive origin of these structures as notified by Rodrigues et al. [7] who postulated that cortical cavities arise from the fundamental meristem and pith canals arise from the rib meristem. **(Financial Support: FAPESP; CNPq; PROPE-UNESP)**.

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ANATOMY OF MAZUR-LIKE WOOD IN FINNISH CONIFERS

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Abstract. In this study abnormal structure of several wood specimens of Norway spruce, *Picea abies* (L) Karst., and Scots pine, *Pinus sylvestris* L., have been examined. These structures resemble to some extent the well-known mazur wood structure of Karelian birch (curly birch*), Betula pendula* Roth var. *carelica* (Mercklin) Hämet-Ahti. Both conifers with this kind of abnormal wood are very rare in Finland and their wood anatomy has never been studied in detail.

The mazur wood of birch is characterized by a flower- or star-like figure which appears mainly as a vague and modified version on the cross planes of spruce and pine trunks. The xylem of conifers exhibits indentations in the growth ring boundaries in varying number and size. Similarly to Karelian birch, the darkest flecks in the conifers contain tissue of bark. Spruce has parenchyma flecks with dark deposits/content resembling that of the birch.

The radial light bands of the spruce and pine seen on the cross plane are related to the abnormal grain structure. The tracheids change abruptly their orientation, and often they form different kinds of loops and swirls. Their size and shape also varies. In addition to the normal uniseriate rays there are two and three cells wide rays without resin ducts. These rays are lower than normal rays, and they vary in shape and orientation, too. Traumatic resin ducts are common. After removal of bark, depressions of various shapes and sizes become visible on the wood surface of both conifers the same way as in Karelian birch.

Introduction. The aim of this study is to investigate abnormal wood structure in various wood samples of Norway spruce, *Picea abies* (L.) Karst., and Scots pine, *Pinus sylvestris* L., found in Finland. The focus is in those structures which resemble more or less the famous mazur wood structure of Karelian birch (curly birch), *Betula pendula* Roth var. *carelica* (Mercklin) Hämet-Ahti. As far as we know, these structures have not been studied in detail at anatomical level or their cell biology. The relationship of the coniferous mazur-like woods to the birch mazur is unclear but interestingly, in Finland both mazur spruce and mazur pine have been traditionally recognized.

The famous mazur wood of birch (*Betula*) is characterized by a flower- or star-like figure with radial V-shaped designs on the cross plane of a trunk. This figure is essentially a pigment figure. In longitudinal view brown figures are variable, some are like straight or curved streaks of varying lenght, some elliptical in shape. The xylem exhibits indented growth rings as well as irregular or wavy grain often forming swirls. Hence, the mazur figure is also a grain figure. Rays close to the brown streaks are abnormally broad. The darkest brown streaks found sometimes contain elements of phloem and are cracked. After removal of bark, depressions of various shapes and sizes become visible on the wood surface.

Some mazur birches lack the pigment figure altogether or, at least it is very weak. Actually, several different types of mazur birches have been recognized in Finland [11]. The highest quality mazur wood with prominent brown figure comes from the protuberance («paukura» in Finnish, P) and neck («kaula», K) types. Stripe («juomu», J) type most commonly lacks the brown pigment figure, but instead, on the cross plane there is grain figure with radial light-reflecting bands. In the ring («rengas», R) type there is no pigment figure and the grain figure is characterized by numerous light-reflecting patches; this type is commercially known as ice mazur. In addition, different mixed types are common [2, 13].

The anatomy and development of Karelia birch wood has been studied in detail [e.g. 3–10, 12].

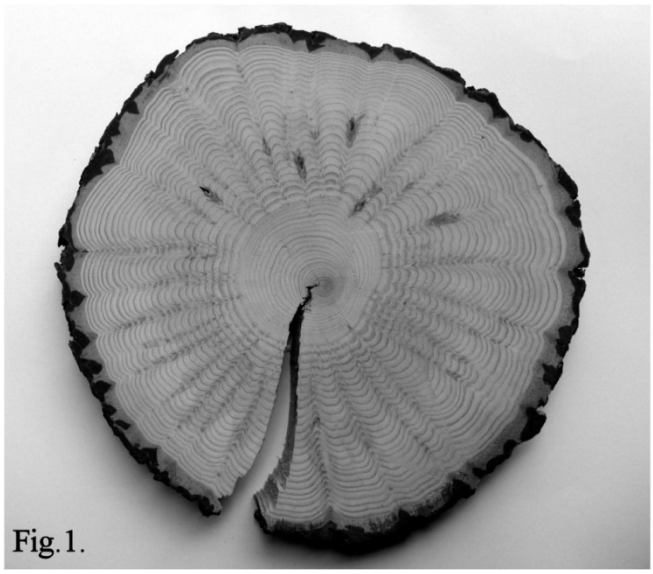
Material and Methods. The material has been obtained from the Finnish Forest Research Institute and Visaseura ry. (Finnish curly birch growers' association) where wood samples have been accumulated during the past decades. Four specimens of Norway spruce originating from two phytogeographic provinces of Finland (South Häme and North Karelia), and three specimens of Scots pine, one from South Häme and the two from unknown localities, were investigated.

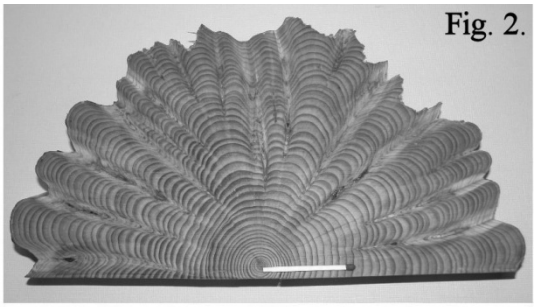
From each wood sample three different 18 μm thick sections (transverse, tangential and radial) have been prepared with a cryomicrotome, stained with safranin – alcian blue or left unstained and viewed under a microscope with ordinary and polarized light. For scanning electron microscopy (SEM) small wood blocks from each specimen were cut to observe the three planes, and the blocks were coated with ~ 25 μm thick layer of platinum. The SEM images were acquired at 5 or 10 kV. Hundreds of digital light and electron microscopic images have been taken.

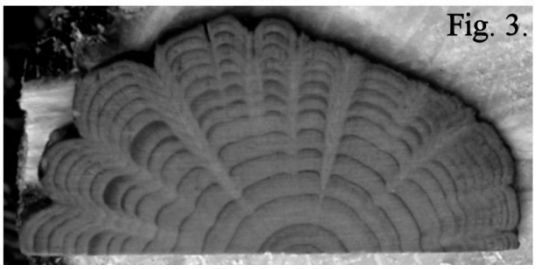
Description of mazur-like wood in Norway spruce. In Norway spruce the flower-like cross plane lacks V-shaped dark brown figure (Figs. 1–3). The outline of the xylem is shallowly, and densely or sparsely lobed, sometimes resembling a little bit of a gingerbread. In well-developed mazur of spruce the cross plane gives an illusion of being carved into deep radial furrows (Fig. 2). The «furrows» are lighter than the rest of the surface. The dark brown colour appears as scattered longitudinal flecks of various sizes in the furrows; the deeply coloured flecks are clearly pieces of bark (Fig. 1). The growth rings are undulating or indented; sometimes in the place of «furrows» the boundaries of growth rings may be so deeply indented that they penetrate deep into the neighbouring growth ring. The xylem surface under the bark is lightly covered with depressions of various sizes. The innermost growth rings have fairly normal structure (Figs. 1–2).

Description of mazur-like wood in Scots pine. Unfortunately we have not seen any very well-developed examples of the pine. From our scanty material we can conclude following. Instead of the «furrows» in Norway spruce, Scots pine has mostly narrow and light coloured strikes with only few sporadic brown flecks or the flecks are missing almost completely (Fig. 4). The undulation of growth rings

is less conspicuous than in spruce. After removal of bark the wood surface with numerous roundish or oval depressions becomes visible. In longitudinal view the beautiful grain figure with light-reflective patches is revealed (Fig. 5). The innermost growth rings show normal wood structure (Fig. 4).







Figures 1–3. Variability of the mazur-like wood structure of Norway spruce (*Picea abies*) on cross plane of the trunk. In the outer growth rings the boundaries are undulating. The light radial «furrows» are at the place of depressions. Note the dark bark containing flecks in Figs. 1–2. Photo: H. Saraja.

Figure 4. Mazur-like wood of the cross plane of Scots pine (Pinus sylvestris) showing light-reflective radial bands and patches. Photo: H. Saraja.

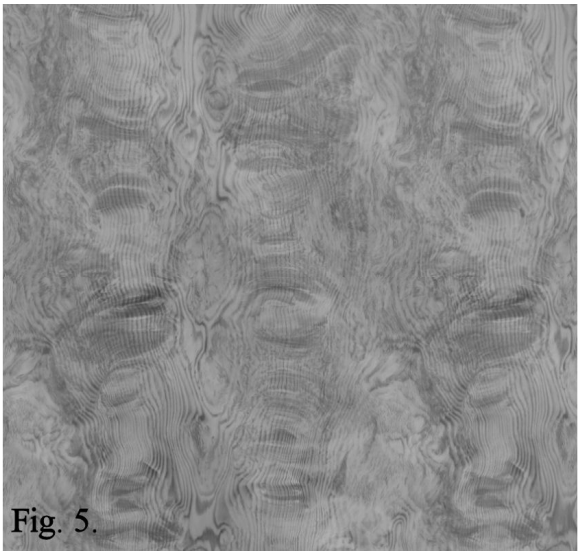
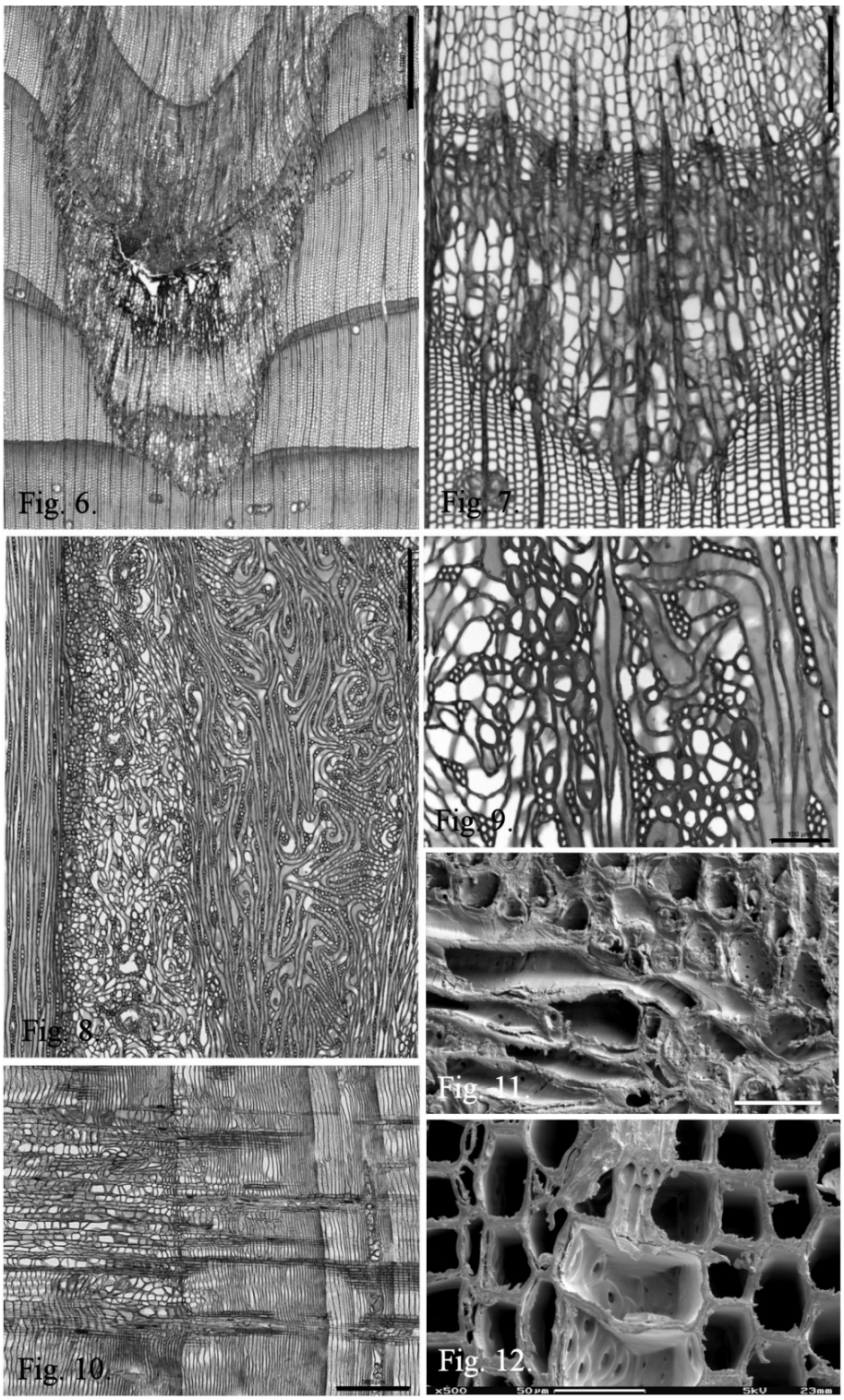


Figure 5. Mazur-like wood veneer from the same specimen as in Fig. 4. Photo: H. Saraja.

One of the examined Scots pine specimens turned out to have the «hazelwood» structure, not the mazur one.

Xylem anatomy of the mazur-like wood in the conifers. The anatomy of the mazur-like wood in both conifers is fairly similar. The growth rings are undulating (wavy) in an irregular manner and deeply indented at certain places. In the area of indentations the xylem structure is heavily distorted (Figs. 6, 8, 10, 13 and 15).



Figures 6–12. Mazur-like xylem of Picea abies.

Fig. 6. Cross section from the place of an indentation of the growth ring boundary with distorted xylem containing a lot of paranchyma. Normal xylem contains traumatic resin ducts. Fig. 7. Same enlarged. Parenchyma cell vary in size and shape and cell wall thickness. Fig. 8. Tangential view from the indentation showing disorientation of tracheids and rays as well as a parenchyma zone between the normal and abnormal xylem. Fig. 9. Previous enlarged. Note the very thick-walled parenchyma cells, short and abnormally wide rays and curved tracheids. Fig. 10. Radial view from of the indentation showing patches of parenchyma. Fig. 11. SE image from a similar area as in Fig. 9. Note parenchyma cells with simple pits and abnormally orientated tracheids. Fig. 12. SE image showing a three cell wide ray in the upper part of the image and in the lower part two abnormally orientated tracheids with bordered pits in tangled positions. The bar is 1 mm (6), 250 µm (7), 500 µm (8 and 10), 100 µm (9) or 50 µm (11 and 12).

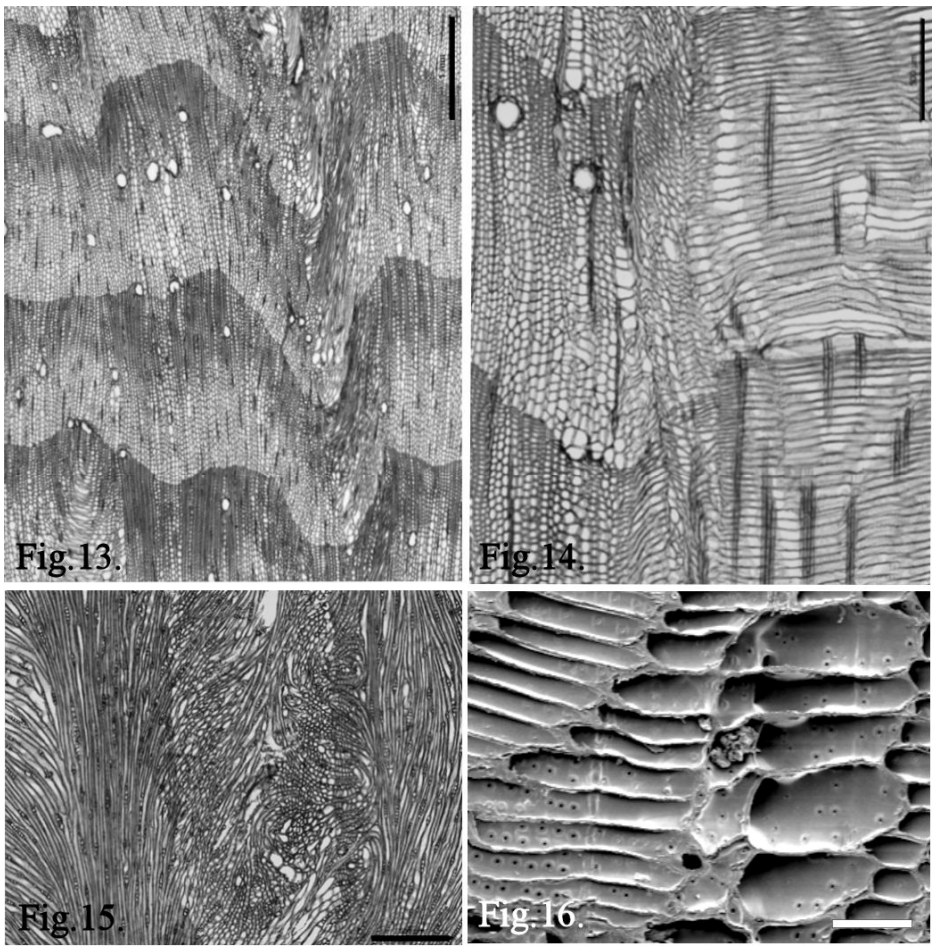
In the place of indentations the orientation of tracheids deviates from the normal axial one (Figs. 8 and 14–15). The orientation pattern often changes abruptly. This may also affect the growth ring boundaries so that they almost disappear (Figs. 6 and 13). In tangential sections the tracheids show abnormal shape and arrangement and often different kinds of loops and swirls are formed (Figs. 8 and 15). This change in the orientation of tracheids is the cause for the light radial «furrows» and bands.

In the disturbed xylem the tracheids vary in size and shape. They may be e. g. curved or branched and their pits are sometimes situated abnormally (Figs. 8, 12 and 16).

The spruce particularly has patches of parenchymatous tissue in the place of indentations (Figs. 6, 8 and 10). The amount and location this tissue varies, but most often it can be seen both centrally and marginally around the indentations. Parenchyma cells are of different sizes and shapes and some of them have exceptionally thick lignified cell walls (Figs. 7, 9 and 11). Some cells are brown or yellow in colour since they have dark deposits in the cell lumina and/or walls.

Within the abnormal xylem of Norway spruce and Scots pine tissue of bark can be found and it is they are often associated with a crack. These structures form the darkest flecks seen in wood.

In addition to the normal uniseriate rays there are commonly two and three cells wide rays without resin ducts (Figs. 8–9, 12 and 15). These abnormally wide rays are also lower than the normal ones and they are very variable in shape (Fig. 8). The orientation of rays deviates from the normal axial one in the disturbed xylem. The size and shape of parenchyma cells of rays is also very variable.



Figures 13–16. Mazur-like xylem of *Pinus sylvestris*.

Fig. 13. Cross section from the place of indentations with distorted xylem. Normal and traumatic resin ducts are present. Fig. 14. The same enlarged showing the abrupt change in the orientation of tracheids and rays. Fig. 15. Tangential view from the indentation with abnormally orientated tracheids and rays forming some loop designs. Fig. 16. SE image from a radial section revealing exceptionally wide tracheids with bordered pits in tangled positions. *The bar is 1 mm (13), 500 µm (14 and 15) or 100 µm (16).*

Outside the disturbed areas the xylem exhibits a normal structure. However, traumatic resin ducts are present and usually numerous (Figs. 6 and 13). Typical for the spruce is the occurrence of these resin ducts as long tangential lines in the normal wood (Fig. 6).

Discussion. The abnormal wood of Norway spruce and Scots pine share many characters with Karelian birch. Both conifers have depressions on the outer surface of wood and a radial flower-like figure on the cross plane of trunks. Some brown flecks contain bark. Their growth rings are undulating and in the indented parts the xylem structure is distorted due to the change in the orientation of xylem elements. Similarly to Karelian birch, Norway spruce has patches of parenchyma in the indented areas. The rays in both conifers may be abnormally wide. With respect to the mazur-like anatomy Norway spruce and Scots pine show within-species variation.

In this study only a few specimens of conifers have been examined due to the fact that these kinds of trees are very rare in Finnish nature. Some specimens were old without proper collection data but luckily, some were quite recent findings. It would be very useful to obtain some more samples of Scots pine and some other conifers for examination. Mazur-like wood structure has been reported also in Silver fir, *Abies alba* L. [1].

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