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# FORMAL-ANALYTICAL DESCRIPTION OF WOOD FOR THE PURPOSES OF THE CLASSIFICATION OF WOOD SPECIES. PART 1: QUANTITATIVE LEVELS

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## ABSTRACT

Wood is a product of woody plants, formed by a complex of tissues - conductive, mechanical, reserve and secretory. However, it is not just a mechanical mixture of chemical compounds, but a complex biological and physico-chemical system composed of polymers, monomers, made up of cell walls and cell cavities (lumens). The knowledge of its structure allows the tree species to be determined, the conditions under which it is formed, as well as its behavior under different loads.

The paper examines the variation of the quantitative indicators of individual tissues and the possibility of using it to classify individual species.

**Key words:** structure, levels, vessels, wood rays, fibers, parenchyma.

## INTRODUCTION

In each section (especially in the transverse section), under the appropriate magnification, the three main tissues can be observed – conducting, mechanical and reserve, which form the internal anatomical structure of plants. The conductive and mechanical cells are usually easily identified in most tree species. This is important because the fibers have different characteristics depending on their location relative to the vessel. The wall thickness along the length of the fibers varies both in fibers adjacent to the vessel and in vessels distant from it. The wall thickness is the greatest in the centre and gradually decreases towards the top of the fiber (Yahya Ridwan et al., 2015). The cells of the parenchyma are often more difficult to distinguish from those of the fibers due to their similar size, but the cell wall thickness and sometimes the presence of cellular contents allow their differentiation. Wood rays are elements that are also very easy to determine, because of their size and structure in longitudinal sections (Bardarov, 2014).

They are precisely defined, always making the same figures, which, depending on their location, form a large number of combinations, so these tissues form all of the 100 000 tree species. In chess, there is a specific notation (way of writing the moves and the position of the pieces). A similar way of formal-analytical writing of the individual tree species can probably be found. In chess, the similarity of certain moves unites them in groups called debuts. The chemical formulas also have similarities in the formulation of the compounds, but the way of formal-analytical writing in chemistry shows the difference between the individual chemical compounds.

Such records (profiles, formulas) are not novelties. In addition to chess and chemistry, botany uses the spelling of the so-called colour formula, which are essentially finite, cyclic, algebraic groups. In wood, there are tree species with equal amounts of tissues that construct them. Therefore, as a result of the work it can be expected that the tree species will be subdivided into groups, as each species will be written similarly to the ones from the respective construction group and subgroup.

The problem here is that these records (if possible and applicable) may have a local nature. In Bulgaria the transition between early and late wood in Scots pine is different than the same transition in Central Europe species. The structure of ash and walnut, as representatives of the ring-porous and semi-ring-porous species, is also different in these two habitats. The location of the resin channels and fluctuations in the construction of the annual rings is also local (Bardarov, 2014; Greguss, 1955; Wagenführ, 1984).

The aim of the work is to find a way to analytically define and write the wood structure, showing the main groups of anatomical structure and each species individually.

The study applies both to the well-studied species, which anatomical structure has been fully studied, and to the species that will be described in the future. The present work is focused only on the quantitative description of the most important and clearly visible features.

## NECESSARY CONDITIONS FOR THE RECORD

In order for any formal-analytical wood record to be effective and accurate, it should meet several conditions and requirements for the classification of species by the structure of their wood, as follows:

1) To give an accurate and comprehensive classification of the species according to the structure of their wood;
2) To describe the transition between early and late wood. If there is a clearly distinguishable transition between early and late wood, then this transition could have its clear visual and graphic interpretation allowing a definite identification.
3) To describe the type of resin channels (presence and condition), as a main feature of coniferous wood;
4) To describe the type of late vessels, as a main qualitative feature of ring-porous wood;
5) To describe the wood rays (size, density and location) as a main feature of the diffuse-porous wood;
6) To describe the disposition of the vessels (size, density and location, i.e. whether they are paired (coupled) or located individually), as a characteristic qualitative mark of tropical tree species;
7) To describe the size and cell wall thickness of the fibers;
8) To describe the wood density as a basic mechanical characteristic of the quality of wood, depending on the properties of some groups of construction.

When this classification is available, it will be easier to build a profile of the individual species.

Under the **first condition**, it can be suggested that the record of the wood should start as follows:

I – coniferous wood;
II – ring-porous wood;
III – diffuse-porous wood;
IV – tropical wood;
V – wood with a transitional structure.

This is possible and easy to be done by anyone who describes the wood, given the minimum qualifications required for this job. Recording this way will not confuse coniferous species with deciduous species, which have equal amounts of woody tissues. However, it is important to mark the group of wood construction, because in its absence, for example, in Douglas fir (*Pseudotsuga menziesii*) and Honey locust (*Gleditsia triacanthos*) wood will have the same (or at least very close) first three indicators - the amount of early, late and transitional area, which would make the record inapplicable.

According to some authors (Enchev, 1984) the group of tropical trees can be distinguished by the absence of a boundary between the annual rings (or it is very difficult to be noticed). In addition, the vessels do not differ in density and diameter within the growth ring. The density of the vessels is usually low and the distance between them is relatively large. The proposed record can be successfully accepted as a separate construction group.

The **second condition** is related to the quantitative evaluation showing the exact amount of transition zone or the size of the transition zone in three or five categories. For the convenience of the wood descriptor, photographic material showing examples from each of the categories may be offered. Assuming that the wood is coniferous, the proposed record is fully applicable. In coniferous species, the record of late wood coincides with the record of mechanical tissue. In this way sequentially are recorded: early wood (conductive tissue), transition zone (both conductive and mechanical tissue) and late wood (mechanical tissue). However, if the species are deciduous, then the three zones are determined by different appearance and number of vessels, i.e. only by the conductive tissue.

Thus, another type of record must be selected for the mechanical tissue. Also, the question how to record the wood of the diffuse-porous species, where the difference between these three zones is minimal or even missing according to some authors, arises. The same problem applies to tropical species, where there is no difference between these areas. It is true that the symbols 'I', 'II', 'III' and 'IV' distinguish the species in someway, but the difference must be clearer. In addition, the parenchyma must be distinguished whether it is apotracheal or paratracheal.

Under the **third condition**, it is more difficult to indicate the location of the resin channels than their type. Previous research has shown that large resin canals (such as those of pine trees) are formed of thin-walled parenchymal cells and are usually torn or "hollow" (Wagenführ, 1996; Enchev, 1984; Blaskova, 2009). The small resin channels (such as in spruce, Douglas fir, larch, etc.) are usually composed of thicker-walled parenchymal cells which are strong and well formed.

Regarding the location of the resin channels, the notation ⅓, ½, ⅔ or ¾ can be applied, depending on which part of the beginning of the ring the channel is located. And for the state of the channels, it can be suggested to add the index "r" (from strong, rugged) or "t" (from torn, torn) to "$St_{1,5}$".

Under the **fourth condition**, the location of the late vessel can be recorded, and appropriate photos with a typical location may be offered to the descriptor, accompanied by an accurate description. In that way, the location becomes both a quantitative and qualitative sign (mark), which can be typified with the letters from "a" to "e".

a) first subgroup – single-located or paired late vessels, e. g. late vessels in ash, walnut;
b) second subgroup - late vessels located in nests (mulberry and acacia);
c) third subgroup – the late vessels are in tangential wavy stripes (elm and nettle);
d) fourth subgroup – the late vessels are located around the early vessels or mixed with them (vines –vine, wisteria);
e) fifth subgroup – the late vessels are collected in radial funnel-like

groups called dendrites (oak and chestnut).

Under the **fifth condition**, the core rays can be described by many characteristics – type, size, location. The groups should be indicated in advance (most likely again with photos), for example according to the mutual arrangement, the rays can be divided into the following groups:

a) only single-row (alder, chestnut, poplar, etc.);
b) mainly narrow (hawthorn, ash, linden, etc.);
c) mainly medium wide (maple, mulberry, elm, etc.);
d) mainly wide (county, yong, oak, etc.);
e) from single-row to narrow (birch, apple, pear, etc.);
f) from single row to medium wide (…, etc.);
g) from narrow to medium wide (maple, citrus, medlar, etc.);
h) from narrow to wide (ivy, gel, sycamore, etc.);
i) only single-row and broad (oak, beech, mahogany, etc.);
j) presence of aggregation (hornbeam, alder, hazel, etc.).

Depending on the ray density, the following classification could be accepted:

I. very low density <5 rays/mm (traveller's joy, sycamore, linden, etc.);
II. low density – 5–10 rays/mm (maple, islet, ebony, etc.);
III. average density – 10–15 rays/mm (hornbeam, chestnut, eucalyptus, etc.);
IV. high density – 15–20 rays/mm (birch, hickory, walnut, etc.);
V. very high density – > 20 rays/mm (field maple, citrus, willow, etc.).

Under the **sixth condition**, the vessels can be described quantitatively only by size and density. Both indicators should be described with one of the six groups:

a) very small – <50 µm (chestnut, pear, boxwood, etc.);
b) small – 50–100 µm (maple, alder, birch, etc.);
c) medium – 100–150 µm (aphormosia, eucalyptus, diabetes, etc.);
d) large – 150–200 µm (okume, rosewood, sapeli, etc.);
e) very large – > 200 µm (iroko, paduk, ilomba, etc.);
f) hyper large – > 250 µm (faro).

Photographic material can also be used. Here it is possible to describe the simultaneous presence of cells of different sizes. The dispersion value or the coefficient of variation can be used. The smaller coefficient accounts for more uniform vessels and vice versa, i.e. the bigger it is the more different they are.

Following our preliminary studies, the use of a three-point scale can be suggested - "1", "2" and "3". While diffuse-pores generally have very similar vessels and the dispersion will be less than "1", in ring-porous species the dispersion will be the highest - "3". Tropical species may have a variance between "1" and "3".

The vessels density could be described in the following way:

I. with very low density – <5 cell/mm$^2$ (ako, iroko, walnut, etc.);
II. with low density – 5–10 cell/mm$^2$ (okume, sapeli, eucalyptus, etc.);
III. with average density – 10–20 cell/mm$^2$ (ash, oak, ebony, etc.);
IV. with high density – 20–50 cell/mm$^2$ (chestnut, nettle, cherry, etc.);
V. with very high density – > 50 cell/mm$^2$ (hornbeam, alder, birch, etc.);
VI. with super high density – > 100 cell/mm$^2$ (maple, poplar etc.);

VII. with hyper high density – > 200 cell/mm$^2$ (plane tree, alder, pear etc.).

The arrangement of the vessels can also be classified in groups (quantitative and qualitative features):

A) evenly; B) unevenly; C) obliquely; D) radially; E) tangential.

Under the **seventh condition**, the fibers can be described quantitatively as size and cell wall thickness. According to the dimensions, the fibers are:

a) very small – <12 µm (ebony, cherry, acacia, etc.);
b) small – 13–17 µm (maple, if, pear, etc.);
c) medium – 18–23 µm (chestnut, sycamore, walnut, etc.);
d) large – 24–28 µm (mackerel, teak, avodire, etc.);
e) very large – > 29 µm (ramin /*Gonystylus*/, laurel /*Laurelia*/, baboen /*Virola*/, etc.).

According to its cell wall thickness (2W: L), the fibers are:

I. very thin-walled – < 0.2 (Ozigo /*Dacriodes*/ Faro /*Danielia*/ etc.);
II. thin-walled – 0.2–0.4 (alder, chestnut, poplar, etc.);
III. medium thin-walled – 0.5–0.7 (chestnut, duka, teak, etc.);
IV. thick-walled – 0.8–1.2 (maple, ebony, beech, etc.);
V. very thick-walled – > 1,2 (hornbeam, wenge, elm, etc.).

The **eighth condition** considers the wood density. It is an important feature that strongly depends on the wood structure. If the wood structure is known, the density and porosity of the wood can be determined at each point of the annual ring. With modern methods of scanning or examining wood, it is possible to obtain values for density and porosity at any point of the annual ring.

That is why these values for each of the three zones can be added to the record. However, this will complicate the record too much and will make it difficult to use. Even if there is a clear boundary between early and late wood (as it is in coniferous and ring-porous species), the resulting density value should be recorded as a total number. The wood density could be recorded with the symbol "Dt" (from density). Depending on the wood density, tree species can be divided into:

a) very light – up to 450 kg.m$^{-3}$;
b) light – from 460 to 550 kg.m$^{-3}$;
c) medium weight – from 560 to 650 kg.m$^{-3}$;
d) heavy – from 660 to 800 kg.m$^{-3}$;
e) very heavy – over 850 kg.m$^{-3}$.

## CONCLUSION

Quantitative levels represented as conditions are intended to lay the foundations of a new formal-analytical description of wood. The wood of each tree species falls into some of these levels of variation. Although the inhomogeneity of wood is one of its major characteristics, the variation in the properties of the cells that form it is not so great, which allows to describe the wood structure more completely and accurately.

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