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STUDY OF THE STRUCTURE OF WOOD WITH THE HELP OF MATHEMATICAL MATRICES

In cross section, the wood of each tree species is unique. Even if its structure varies within certain limits (due to the conditions of habitat or location in the stem), the picture formed by the cells is very characteristic of each species. The parameters that can be measured are the diameter and density of the vessels and their exact location as Cartesian coordinates. Using the methods of matrix calculation and analytical geometry, an attempt was made to present some important characteristics of the structure of wood, for the purposes of classification of tree species.
Keywords: *wood structure, vessels in wood, mathematical matrice.*

ИССЛЕДОВАНИЕ СТРУКТУРЫ ДРЕВЕСИНЫ С ПОМОЩЬЮ МАТЕМАТИЧЕСКИХ МАТРИЦ

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Древесина каждой породы деревьев в поперечном сечении уникальна. Даже если ее структура изменяется в определенных пределах (из-за условий среды обитания или расположения в стволе), картина, формируемая клетками, очень характерна для каждого вида. Параметры, которые могут быть измерены, – это диаметр и плотность сосудов и их точное местоположение в декартовых координатах. Была предпринята попытка, используя методы матричного расчета и аналитической геометрии, представить некоторые важные характеристики структуры древесины для целей классификации пород деревьев.
Ключевые слова*: структура древесины, сосуды в древесине, математические матрицы.*

Introduction

In cross section, the wood of each species is unique. Even if its construction varies depending on environmental conditions, position in the stem, the size of the stem, etc., it is within certain narrow limits. The ratio and location of the three main types of tissues (conductive, mechanical and reserve) are genetically set and serve to perform the physiological and mechanical functions in the stem. In addition, they help to identify tree species (Wagenführ R. 1984). The location and the quantitative ratio of the conducting cells (vessels) carry the most diagnostic information (Bardarov N. 2014).

The location of the vessels is set in the cambial layer, during the formation of the wood, changing greatly in the height of the stem (Burggraaf P. D. 1972). This change may meet some geometric or biophysical requirements, but to a greater extent depends on the amount and proximity of auxins. This leads to an increase in the size of the vessels and a decrease in their density from the leaves to the roots (Aloni R., Zimmermann M. H. 1983). Various mathematical models have been prepared for the quantification of the optimal number of vessels. It is assumed that wood has different ways of optimizing the number of vessels, depending on both the type and the environmental conditions (Ewers, et al. 2007).

In recent years, attempts, using computer vision techniques to automatically recognize tree species, have been made. However, such recognition requires a formal analytical description of the wood structure.

The aim of this research work was to find a characteristic number that corresponds to a certain tree species or basic anatomical structure, using the techniques of matrix calculation.

Methodology

If the field of view (shown in Fig. 1) is divided into strips with a width and height of 60 µm, then a table of 18 rows and 23 columns will be obtained. An anatomical structure indicator can be recorded in each cell of this table. In order to be able to calculate the parameters of the matrix, it is represented as a square with 18 rows and 18 columns.

In the process of working on a formal-analytical description of the wood, it became clear that its construction can be recorded in different ways. It is important to note that each record must meet certain conditions. The size of the cells (ie these 60 µm) must be chosen so that two or more vessels do not fall into one cell. In practice, the accuracy of recording the center of the vessels here is ± 30 µm. It is not necessary to record with high accuracy, so if a vessel is not recorded correctly with its Cartesian coordinates, but with a close deviation, this does not greatly affect the result. This achieves continuity of the spatial arrangement of the vessels. A site for automatic matrix calculation http://matrixcalc.org/" was used.

When compiling the matrices, different information about the structure of the wood is applied, starting with the simplest variant.

1 option. An incidental matrix of the spatial arrangement of the vessels is created. In the cells in which the center of the vessel falls, a value of 1 is recorded, and in those which do not fall, nothing is recorded.

Option 2. A characteristic matrix of the distribution of the vessels by diameters is created. In the cells in which the center of the vessel falls, the value of its diameter is recorded, and in those which do not fall, nothing is recorded (Fig. 2).

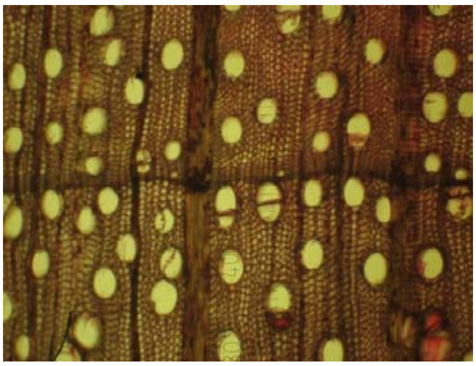

Fig. 1. Anatomical structure of maple (Acer sp., Cross section at 100x magnification)

		T_1	T_2	T_3	T_4	T_5	T_6
Acer 1		60 µm	120 µm	180 µm	240 µm	300 µm	360 µm
R_1	60 µm						
R_2	120 µm					56	
R_3	180 µm		70				
R_4	240 µm						
R_5	300 µm	55	79				
R_6	360 µm						70
R_7	420 µm						54
R_8	480 µm		51				
R_9	540 µm	42					
R_{10}	600 µm	50					63
R_{11}	660 µm	73				42	

Fig. 2. Characteristic matrix of the distribution of vessels by diameters (fragment)

Option 3. A characteristic matrix of the distribution of vessels and fibers by diameters is created. In the cells in which the center of the vessel falls, the value of its diameter is recorded, and in those which do not fall, the value of the average diameter of the fibers is recorded. The fibers are recorded with their tabular values of 18 µm, as they vary slightly and it is not necessary and impossible to measure them all.

4 option. A characteristic matrix of the distribution of the vessels and the fibers according to their wall is created. In anatomy, the „cell wall thickness“ indicator is often used when working with mechanical tissue (in German Wandigkeit; Wagenführ R., 1996). This is the ratio of the diameter of the wall (2W) to the diameter of the cavity (L) of the cell. This is considered a good characteristic number, although it is mainly used for fibers (ie mechanical fabric). Then the matrix proposed above will take the form.

The main doubt in this work is whether the result obtained does not show the average value of the area of the vessels. Then the studied characteristic numbers will be very close for all trees growing close to each other in a given habitat. This will not determine the difference between tree species, but between the conditions (especially the amount of water) under which they grew.

The second thing that is very likely from an anatomical point of view is to record a vessels in the adjacent cell (but not further away). Then the matrices must achieve continuity of the spatial arrangement of the vessels, ie. there should be no big difference in the values. However, option 1, 2 and 3 thus proposed showed large differences in the random transfer of values to adjacent cells.

Following what has been said so far, we have taken a different approach. If only parts of the annual ring are measured, typical wood structures such as radial groups, clusters, tangential bands or dendrites can be examined (Fig. 3). That is why we turned our attention to the ring-porous tree species – ash, mulberry, elm and oak.

Ring-porous is this wood in which there is a clear division of early-large and late-small vessels (Wagenführ R., 1989). Thus, we examined only the areas of late wood, measuring the structures that form the vessels there.

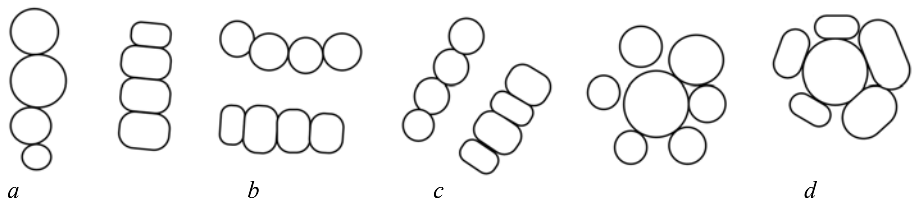

Fig. 3. Main groups in the mutual arrangement of the vessels:
a – radial; b – tangential; c – diagonal; e – clusters. In some vessels they touch only at one point, while in others the border is in a significant part of the wall

For a more detailed description of the wood, it is necessary to include the other tissues of the wood. We have already included the fibers as values of their diameter and wall. Now it remains to turn on the cells of the tree parenchyma and the wood rays. However, they are much smaller. Therefore, it was necessary to change the size of the cells of the matrix. The current 60×60 µm was reduced to 20×20 µm. In this way, each of the wood structures can be covered. Disadvantages here are the reduced study area and the description of cells that are significantly larger in size than the vessels. If the area of the wood studied so far was 1080×1080 µm, now it has been reduced to 360×360 µm. This is provided that the size of the matrix is preserved. However, larger matrices are really very difficult to calculate.

		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
		20 µm	40 µm	60 µm	80 µm	100 µm	120 µm	140 µm	160 µm	180 µm	200 µm	220 µm
R_1	20 µm	2	2	4	2	2	2	3				3
R_2	40 µm	2	2		2	2	2	3				3
R_3	60 µm	2	2	4	2	2	2	3		1		3
R_4	80 µm	2	2		2	2	2	3				3
R_5	100 µm	2	2	4	2	2	2	3				3
R_6	120 µm	2	2		2	2	2	3				3
R_7	140 µm	2	2	4	2	2	2	3				3
R_8	160 µm	2	2		2	2	2	3		1		3
R_9	180 µm	2	2	4	2	2	2	3				3
R_{10}	200 µm	2	2		2	2	2	3				3
R_{11}	220 µm	2	2	4	2	2	2	3				3
R_{12}	240 µm	2	2		2	2	2	3				3
R_{13}	260 µm	2	2	4	2	2	2	3		1		3
R_{14}	280 µm	2	2		2	2	2	3				3
R_{15}	300 µm	2	2	4	2	2	2	3				3
R_{16}	320 µm	2	2		2	2	2	3				3
R_{17}	340 µm	2	2	4	2	2	2	3				3
R_{18}	360 µm	2	2		2	2	2	3		1		3

Fig. 4. Detailed matrix covering all fabrics in the wood:
1 – vessels; 2 – fibers; 3 – parenchyma; 4 – wood rays

Conclusions

– For now, the difficulties in describing the structure of wood are more technical than mathematical

– With the advent of computer technology, in particular computer vision techniques, it will be possible to analyze and measure the cells of the various tissues that make up wood. This will lead to the use of cell wall as an input value with high accuracy.

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ЭКОЛОГИЧЕСКИЕ АСПЕКТЫ СТРОЕНИЯ ДРЕВЕСИНЫ – часть 1

Анатомия древесины не в полной мере учитывает влияние динамики факторов окружающей среды на анатомические характеристики древесины. До сих пор в структурной науке о древесине этой проблеме не уделялось должного внимания из-за отсутствия соответствующих методов и инструментов для ее изучения. Это сложный междисциплинарный вопрос, в котором следует искать и находить адекватные теоретические, методологические и практические подходы и решения. Использование и синтез арсенала как минимум нескольких наук и научно-практических дисциплин. (например, ботаника, систематика, экология, физиология) эту проблему можно решить.

В статье исследуется степень, в которой анатомические особенности конкретного образца и / или вида, а также некоторые экологические особенности среды обитания являются значимыми, повторяющимися и предсказуемыми факторами формирования внутренней структуры древесины. Предметом исследования является систематическая информация, предоставляемая нам различными анатомическими структурами, а также установленная связь между некоторыми факторами окружающей среды и изменениями в структуре древесины, которые они вызывают.

Ключевые слова: *древесина, структура, анатомические особенности, окружающая среда.*

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ECOLOGICAL ASPECTS OF WOOD STRUCTURE - PART 1

The anatomy of wood does not fully take into account the influence of the dynamics of environmental factors on the anatomical characteristics of wood. Until now, the structural science of wood has not paid enough attention to this problem due to the lack of appropriate methods and tools to study it. This is a complex interdisciplinary issue in which adequate theoretical, methodological and practical approaches and solutions should be sought and found. Using and synthesizing the arsenal of at least several sciences and scientific and practical disciplines (for example, botany, systematics, ecology, physiology), this problem can be solved.

The article examines the extent to which the anatomical features of a particular specimen and / or species, as well as some environmental features of the habitat, are significant, repetitive and predictable factors in the formation of the internal structure of wood. The subject of the study is the systematic information provided to us by various anatomical structures, as well as the established relationship between certain environmental factors and the changes in the structure of wood that they cause.

Keywords: *wood, structure, anatomical features, environment.*

Экологическая анатомия древесины

Экология – это наука, изучающая взаимоотношения организмов с окружающей их средой (Калинков, В. 1969). Хорошее знание экологии растений основано на выяснении влияния факторов окружающей среды – абиотических, биотических и антропогенных на физиологию и анатомию растений, рассматриваемых индивидуально или как членов сообщества. Экологическая анатомия древеси-