

DETERMINATION OF THE SPECIES STRUCTURE OF PHYTOCENOSES OF THE NATURAL AGE OAK FOREST OF THE DENDROLOGICAL PARK “OLEXANDRIA” OF THE NATIONAL ACADEMY OF SCIENCES OF UKRAINE

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Abstract

The modern species composition of woody plants of the centuries-old oak grove of the State Dendrological Park “Olexandria” of the National Academy of Sciences of Ukraine was studied.

The work was carried out as part of the study of the dynamics of stands of oak phytocenoses under conditions of anthropogenic load, technogenic pollution and weather fluctuations.

It has been established that the oak grove of the arboretum with an area of 446 hectares out of 2000 oaks is a complex multi-species planting. The floristic core of the oak forest consists of the main forest-forming species characteristic of the Right-Bank Forest-Steppe of Ukraine: *Quercus robur*, *Acer platanoides* L. and *Acer campestre* L., *Fraxinus excelsior* L., *Tilia cordata* Mill., *Carpinus betulus* L., *Ulmus scabra* Mill. The role of the dominant species and edificator was retained by *Quercus robur*. In the worst growing conditions, monodominant stands are formed. In more favorable ecotopes in the upper tree layer, the participation of *Quercus robur* is 70–100 %, and its codominant satellites (*Acer platanoides*, *Tilia cordata*, *Fraxinus excelsior*) are 10 % each. All oak forest phytocenoses have a well-developed multi-species second tree layer: *Acer platanoides* (15–80 % in various phytocenoses), *Acer campestre* (10–30 %), *Tilia cordata* (10–60 %), in some phytocenoses *Fraxinus excelsior* (10–20 %), *Ulmus scabra* (10–20 %), *Carpinus betulus* (30 %).

The group of asectators is diverse and is represented by small species, local and adventive species, introducers, including invasive species.

A characteristic feature of the oak forest is its exorbitant crushing, which, along with the massive introduction of introduced species, caused a powerful ecotonization of the oak forest and formed the cells of the greatest mortality of *Quercus robur*.

The conducted studies establish the modern species composition of the oak forest and are the basis for the study of succession processes in oak forest phytocenoses.

Keywords: dendrological park “Alexandria”, natural age-old oak forest, species structure, cenopopulation, hierarchy of species, representativeness.

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1. Introduction

Oak forests are the most valuable forest formations and one of the richest forest ecosystems in the temperate zone of Europe, they are important centers of biodiversity, including settlements of many species of rare plants. A catastrophic decrease in the areas of oak forests has been observed in recent decades throughout the world, and, which is of particular concern, the areas of natural oak forests are decreasing in Ukraine [1].

The natural oak forest, which more than 230 years ago became the basis for the creation of the homestead park of the Counts Branitsky, today is the territory of the State Dendrological Park “Olexandria” of the National Academy of Sciences of Ukraine and still retains the role of the main landscape of the park. The modern oak forest area is 44.6 ha; up to 2000 copies of *Quercus robur* at the age of 200–250 grow here, some specimens under the age of 350 years. The oak forest of the Dendrological Park “Olexandria” is a great floristic and artistic and aesthetic asset and consists of sections of different landscape, phytocenotic and spatial-compositional structures of varying degrees of disturbance [2]. The uniqueness of the oak grove is emphasized by the presence in its composition of components characteristic of fore-oak forests and a large number of rare Red Book plant species [3].

Age natural oak grove has always been the central theme of fundamental scientific research of the Dendrological Park “Olexandria”. The issues of its dying off and the development of methods for conservation and renewal were studied [4, 5]; phytocenotic composition of oak forests [2, 4]. The consequences of long-term anthropogenic intervention in the integrity of the oak forest, the main features and patterns of differentiation of the oak forest during the period of increased economic activity were studied [6].

The aim of the research is to establish the modern species composition of woody plants in phytocenoses of mature oak forests and its structural features.

2. Materials and methods

The objects of study are the cenopopulation of the main forest-forming PLU species: *Quercus robur*, *Acer platanoides*, *A. campestre*, *Fraxinus excelsior*, *Tilia cordata*, *Carpinus betulus*, *Ulmus scabra*.

The structural unit of the study was the quarters into which the territory of the arboretum is divided (in contrast to the landscape-taxation sections, the object of studies of the predecessors [2, 7]). The idea of this approach is that in the historical past the oak forest was a continuous plantation. During the work on the arrangement of the park, the integrity of the oak forest was lost and at present the territory of the oak forest is a very dissected plantation. Around the oak forest and on its territory there are 40 alleys of different lengths – from several tens to several hundred meters. They divide the oak forest into 15 quarters, and within the quarters – into 32 separate sections (**Fig. 1**) with an area of 0.6 to 11.2 ha. Within the quarters, the area of local growth of *Quercus robur* is 0.2–6.3 ha. The studies covered 8 quarters, the vast majority of the territory of which is occupied by the forest stands of *Quercus robur* (quarters 6, 8, 13–15, 19, 25, 29). However, the 12th quarter is not included in the study data, since it features a park-type oak grove – *Quercus robur* and a lawn with a predominance of cereal grasses.

Let's consider each quarter as a separate phytocenosis, based on the definition that a phytocenosis is characterized by a certain species composition and its inherent ratio of species of different systematic categories. In addition, in the modern science of phytocenoses, it is customary to name only a specific section or a specific area of vegetation cover [8, 9].

They followed a population approach to the study of the structural organization of phytocenoses [2, 10], understanding a population as a set of plants of the same botanical species that freely interbreed with each other and occupy a certain territory in a phytocenosis, and populations associated with certain phytocenoses – cenopopulations, [12].

Several categories were distinguished in the species hierarchy. Given a number of interpretations of these categories, let's adhere to certain definitions. Dominant is a species that dominates (predominates) in the main tree layer; subdominants – the second largest species after the numerous one, which dominates in the group [12]. An edificator is a type of plant in a plant group that

determines its characteristics, creating a bioenvironment in the ecosystem and playing an important role in shaping its structure. Asectators are other species in the group that have little effect on the creation of the phytogenic environment of the group, minor representatives in the cenosis [13].



Fig. 1. Modern oil grid of the Dendrological Park “Olexandria” of the National Academy of Sciences of Ukraine with the numbering of quarters (the century-old oak forest is highlighted in green)

A numerical method for counting trees was carried out. Each tree was taken into account taking into account the age and taxation indicators. The quantitative ratio between the species was expressed in numbers and as a percentage. Smaller species are combined into a common group. Introducers and invasive species were also combined into separate groups. Trees were taken into account from the age of poles (20 years) to overmature – 200 years, in *Quercus robur* up to 350 years.

3. Results and their discussion

Oak forests are a typical broad-leaved forest, which is characterized by a complex mosaic-tiered structure and high species richness. One of the most important indicators of phytocenoses is their species composition, determined by the floristic richness of the natural and climatic zone. However, the conditions for the existence of phytocenoses at a particular time allow only a part of the species of the floristic list to live in a given area; therefore, local floras are formed that correspond to the characteristics of ecotopes and their abiotic parameters [8, 14].

The studies revealed the numerical species composition of oak forest phytocenoses of the Dendrological Park “Olexandria” (**Table 1**). In each quarter, all the studied species of woody plants are represented, which are the main forest-forming species of PLS, they form a grouping of *Quercus robur* and prevail over other species growing in these quarters.

Other researchers also point to such a pattern – the main place in forest ecosystems belongs to forest-forming tree species: they determine the architectonics of phytocenosis, its main structural and functional features [10].

Each quarter has a different number of local species that do not belong to forest-forming species, and those that belong to forest-forming ones, but are few in number. The total number of specimens of these species was insignificant (2–71). The total number of species and the number

of their specimens were determined by the ecological conditions of the ecotope, and adventitious species belonged to this group to a lesser extent. The group of introduced species was more numerous (4–18 species) and represented by a significantly larger number of specimens (23–188 in phytocenoses). The appearance of these species in each quarter is due solely to human activity – when creating decorative compositions within the oak forest or planting individual ordinary specimens. The 14th quarter is especially saturated with introducers, both in terms of the number of species and the number of specimens. Until recently, this number was much larger – 17 copies fell out. *Pinus strobus* L. (depending on age) and 145 specimens of *Picea abies* (L.) Karst. (destroyed by a bark beetle-typographer).

The number of invasive species was insignificant – 1–3 species. The number of specimens varied significantly – from 7 to 98 (0.7–6.4 %) of the total number of trees in the quarter). Numerical populations of invasive species were recorded in 4 quarters located in hard-to-reach areas near the ponds of the Western Balka. Such invasive species as *Quercus rubra* and *Robinia pseudoacacia* L. grew dispersed in the territory, had a good recovery and the ability to influence the species composition of phytocenoses. *Acer negundo* was concentrated mainly in boring – dense groups, linear, often “bouquet” plantings. Due to its fragility, it does not spoil the species composition of phytocenoses.

The studied main park-forming species form a grouping of *Quercus robur* and absolutely prevail over other species in almost every quarter. However, in each quarter (phytocenosis), species groups differ, as does the ratio of species.

In the western part of the oak forest in the upper and middle of the Zakhidna Balka and in the adjacent flat areas (quarters 6, 19), the core of the predominant species is formed by *Acer platanoides* (39.5 % and 22.4 % by quarters), *Acer campestre* (22.0 % and 21.2 %), *Tilia cordata* (15.5 % and 15.1 %). And *Fraxinus excelsior*, *Carpinus betulus*, and *Ulmus scabra* can be considered few species here (**Table 1**). Below the gully (quarter 25), *Acer campestre* (30.0 %) predominates – this is the only ecotope where this species predominates numerically, *Ulmus scabra* (26.4 %), *Acer platanoides* (15.1 %). In the 13th quarter (the central part of the oak forest), the most numerous are 2 species – *Acer platanoides* (29.7 %) and *Acer campestre* (19.9 %). *Fraxinus excelsior*, *Tilia cordata*, and *Ulmus scabra* are much less represented, while *Carpinus betulus* can be classified as a rare species (**Table 1**). In the 14th quarter (the central part of the oak forest), the most numerous are *Tilia cordata* (23 %) and *Acer platanoides* (18.5 %). The share of other satellites of *Quercus robur* (*Acer campestre*, *Fraxinus excelsior*, *Ulmus scabra*) is much smaller, and that of *Carpinus betulus* is scarce (**Table 1**). The ratio of species in this quarter was actively influenced by anthropogenic activity. The vast majority of *Tilia cordata* is the offspring of the artificially created Linden Alley about 200 years ago, which formed a powerful ecotone and displaces the main species, *Quercus robur*. In the eastern part of the oak forest (quarter 15), *Acer platanoides* (24.6 %) and *Fraxinus excelsior* (13.9 %) are most represented. The remaining 4 species are represented approximately commensurately, but in much smaller numbers (**Table 1**). This is the only quarter where *Carpinus betulus* is represented by natural plantations in a fairly large amount (10 %). The 8th quarter is located in the central part of the park. *Acer platanoides* completely prevails here (38.0 %), while *Acer campestre* and *Fraxinus excelsior*, with almost the same number, are represented by a much smaller amount. *Tilia cordata* in this quarter is represented mainly by artificial plantations (Linden Alley), but here it did not give numerically competitive offspring. The 27th quarter is located in the central part of the oak forest, on the slopes of the ponds of the Central beam and areas of the flat type. A quarter with significant anthropogenic interference, the introduction of a large number of introduced species, in which *Acer platanoides* (23.3 %) and *Fraxinus excelsior* (18.4 %) predominate in plantations. *Acer campestre*, *Tilia cordata*, and *Carpinus betulus* (artificially planted) are represented by a much smaller number (**Table 1**), *Ulmus scabra* can be attributed to small species.

The plantation of the oak forest is two-tiered. In some quarters, a few 3rd tiers can be distinguished. The first tree layer is dominated by *Quercus robur* (70–100 %), the subdominants of the 1st layer are *Tilia cordata* (10 %), *Acer platanoides* (10 %), *Fraxinus excelsior* 10 %. In the second tree layer, 4 species are dominant: *Acer platanoides* and *A. campestre*, *Tilia cordata*, *Fraxinus excelsior*; in the 1st quarter of *Ulmus scabra* (**Table 2**).

There are asectators in every quarter of the oak forest and are represented as local forest-forming species (*Ulmus laevis* Pall., *Alnus glutinosa* (L.) Gaerth., *Salix alba* L., *Populus x canescens* (Ait.) Smith, *Pyrus communis* Mill., *Malus sylvestris* (L.) Mill., *Padus avium* Mill. *Prunus divaricata* Ledeb., etc.), and introducers (*Aesculus hippocastanum* L., *Betula pendula* Roth, *Pinus nigra* Arn., *Pinus sylvestris* L., *Pinus pallasiana* D. Don, *Picea abies*, *Picea pungens* Engelm., *Larix decidua* Mill., *Larix sibirica* Ledeb., *Quercus palustris* Muench., *Abies alba* Mill., etc.), among which there are invasive species (*Acer pseudoplatanus* L., *Robinia pseudoacacia* L., *Quercus rubra* L., Ar.).

Oak forest of Dendrological Park “Olexandria” is presented as a hierarchical system, the floristic core of which is made up of the main forest-forming species typical of the PLU: *Quercus robur*, *Acer platanoides* and *A. campestre*, *Fraxinus excelsior*, *Tilia cordata*, *Carpinus betulus*, *Fraxinus excelsior*, *Alnus glutinosa*, *Pyrus communis*, *Malus sylvestris*, *Ulmus laevis* and *U. scabra*, *Salix alba*, *Populus x canescens*, *Cerasus avium* (L.) Moench; as well as introduced species artificially introduced into oak landscapes from the moment the park was founded and throughout its existence.

Table 1

The ratio of species of woody plants in the phytocenoses of the century-old oak forest of the Dendrological Park “Olexandria” of the National Academy of Sciences of Ukraine

Species composition		Quarters						
The main park-forming types	6	8	13	14	15	19	25	27
<i>Quercus robur</i>	324/11.9	59/13.3	252/13.9	218/14.9	198/7.9	181/11.7	34/5.4	63/15.4
<i>Acer platanoides</i>	1078/39.5	169/38.0	537/29.6	270/18.5	613/24.6	345/22.4	95/15.1	95/23.3
<i>Acer campestre</i>	601/22.0	58/13.1	359/19.8	136/9.3	452/8.1	327/21.2	188/30.0	28/6.9
<i>Fraxinus excelsior</i>	57/2.1	54/12.1	192/10.6	124/8.5	346/13.9	24/1.6	5/0.8	74/18.4
<i>Tilia cordata</i>	418/15.3	42*/9.4	161/8.9	336*/23.0	200/8.0	233/15.1	36/5.7	32/7.8
<i>Carpinus betulus</i>	27/1.0	18*/4.0	59/3.3	13/0.9	250/10.0	11/0.7	2/0.3	35/8.6
<i>Ulmus scabra</i>	106/3.9	9/2.0	157/8.7	124/8.5	249/10.0	146/9.5	166/26.4	15/3.7
Local small**	6/26/1.0	1/2/0.4	9/51/2.8	7/25/1.7	5/39/1.5	12/125/8.1	9/44/7.0	11/15/3.7
Introducers**	7/71/2.6	11/27/6.1	4/38/2.1	16/188/12.8	18/119/4.8	7/51/3.3	4/23/3.7	18/40/9.8
Invasive**	2/20/0.7	2/7/1.6	1/7/0.3	3/28/1.9	1/30/1.2	2/98/6.4	2/35/5.6	3/11/2.7
Σspecies/spec.	23/2728	22/445	22/1813	34/1462	32/2496	29/1541	29/628	40/408

Note: * – offspring from mother trees artificially introduced into phytocenoses; ** – total number of species/total number of specimens/percentage of the total number of specimens of this group from the total number of trees in the quarter.

Table 2

Hierarchy of woody plants in the phytocenoses of the age-old oak forest of the Dendrological Park “Olexandria” of the National Academy of Sciences of Ukraine

No. of quarter	1 tier		2 tier	
	Dominant, subdominant		Dominant	
6	<i>Quercus robur</i> 100 %		<i>Acer platanoides</i> 50 %, <i>Acer campestre</i> 30 %, <i>Tilia cordata</i> 20 %	
8	<i>Quercus robur</i> 90 %, <i>Tilia cordata</i> 10 %		<i>Acer platanoides</i> 80 %, <i>Tilia cordata</i> 10 %, <i>Acer campestre</i> 10 %	
13	<i>Quercus robur</i> 90 %, <i>Acer platanoides</i> 10 %		<i>Acer platanoides</i> 40 %, <i>Acer campestre</i> 20 %, <i>Fraxinus excelsior</i> 15 %, <i>Tilia cordata</i> 15 %, <i>Ulmus scabra</i> 10 %	
14	<i>Quercus robur</i> 80 %, <i>Acer platanoides</i> 10 %, <i>Tilia cordata</i> 10 %		<i>Tilia cordata</i> 50 %, <i>Acer platanoides</i> 20 %, <i>Acer campestre</i> 10 %, <i>Fraxinus excelsior</i> 10 %, <i>Ulmus scabra</i> 10 %	
15	<i>Quercus robur</i> 70 %, <i>Acer platanoides</i> 10 %, <i>Tilia cordata</i> 10 %, <i>Fraxinus excelsior</i> 10 %		<i>Carpinus betulus</i> 30 %, <i>Fraxinus excelsior</i> 20 %, <i>Acer campestre</i> 20 %, <i>Tilia cordata</i> 15 %, <i>Acer platanoides</i> 15 %	
19	<i>Quercus robur</i> 100 %		<i>Tilia cordata</i> 60 %, <i>Acer platanoides</i> 20 %, <i>Acer campestre</i> 20 %	
25	<i>Quercus robur</i> 100 %		<i>Acer campestre</i> 50 %, <i>Acer platanoides</i> 30 %, <i>Ulmus scabra</i> 20 %	
27	<i>Quercus robur</i> 100 %		<i>Acer platanoides</i> 70 %, <i>Tilia cordata</i> 10 %, <i>Acer campestre</i> 10 %, <i>Fraxinus excelsior</i> 10 %	

The role of the dominant species was retained by *Quercus robur*, whose share in the first tree layer is 70–100 %. Monodominant plantations of *Quercus robur* formed in the western part of the oak forest, in the territory with the highest technogenic pollution over the past half century [15] and significant irregularities in the mesorelief, and in the central part of the arboretum near the ponds of the Central Balka (quarters 6, 15). In large quarters of the central part, the subdominants of *Quercus robur* in stage I are *Acer platanoides* and *A. campestre*, *Tilia cordata*, *Fraxinus excelsior*, and only in the first quarter are *Carpinus betulus* and *Ulmus scabra*. The dominants of the second layer are *Acer platanoides* (15–80 %), *Acer campestre* (10–50 %), *Tilia cordata* (10–60 %), in the central and eastern parts of the oak forest *Fraxinus excelsior* (10–20 %), in 13 and 14 quarters *Ulmus scabra* (10 %), in 15 *Carpinus betulus* (30 %).

Introducer species also make a significant contribution to the diversity of the species composition of oak forests. All of them were artificially introduced into oak forest phytocenoses, starting from the time of the foundation of the park and throughout its history. Almost all introducers give offspring, but within the oak forest it is insignificant. The asectators also include invasive species. Within the oak forest, there are 3 species of invasive woody plants; according to phytocenoses, they grow alone and do not affect the species composition of the oak forest.

That is, the dominant species *Quercus robur* retains the functions of a strong edificator, it contains the floristic core of phytocenoses, and practically does not allow “strangers” – adventitious species, including invasive species – to oak forest groups.

The difference in the species composition between oak forest phytocenoses is determined by the quantitative ratio of the species of the floristic core. Monodominant phytocenoses and phytocenoses are formed with a different number of subdominant species, the presence and composition of the second tree layer, as well as the diversity and number of introduced species, invasive and adventitious species.

Associated forest-forming species and invasive species are represented by single specimens and do not affect the ratio of species in phytocenoses. The introduction of introduced species, which was massive in some quarters, led to negative consequences – the formation of powerful ecotones and increased extinction of their main species – *Quercus robur*. 95 % of the current mortality of *Quercus robur* occurs in ecotones. The introduction of local species into oak forest phytocenoses and the creation of landscape compositions from them led to the same consequences. For example, in the 14th quarter, the artificially created Linden Alley gave a large population of its offspring, formed a strong ecotone and displaces the edificator species *Quercus robur*.

The floristic richness of phytocenoses is associated with the floristic representativeness of nature reserves [16]. Representativeness is a kind of measure or standard of typicality of individual phytocenoses with respect to zonal, regional or local identification of one or another type of vegetation [11]. Oak forest is one of the main plant formations of Ukrainian forests [1]. According to the scheme of geobotanical zoning of Ukraine [17], the territory of the Dendrological Park “Olexandria” belongs to the Starokostiantynivka-Bila Tserkva district of the European-Siberian forest-steppe zone. It is dominated by pure forests of *Quercus robur* [5, 18], and oak-hornbeam forests (are less common. According to other sources [18], southwest of the city of Bila Tserkva, oak-hornbeam forests are most often found. According to the latest forest inventory, plantations of *Quercus robur* of the Bila Tserkva forestry belongs to the oak-hornbeam forests [7], it is described [19] relatively closely located oak, oak-birch and oak-linden forests in the park. » is extremely interesting in the floristic sense and is located on the verge of pure oak, oak-hornbeam and, possibly, oak-linden-maple subformations.

Studies have shown that the floristic richness of the centuries-old oak grove of the Dendrological Park “Olexandria” fully represents it as a combination of typical subformations characteristic of regional and zonal forest plantations of Ukraine.

An analysis of the results of studies by a number of authors [7, 2, 4, 20] and their own observations [6] indicate active succession processes in the mature oak forest. They are manifested by a change in subdominant species or a change in the ratio of dominant and subdominant species, the displacement of the dominant species in oak forest phytocenoses – *Quercus robur*. The trigger for this process was the exorbitant fragmentation of the territory of the oak forest, the introduction

of introducers into its composition, the creation of decorative compositions within it. The second negative factor is the technogenic pollution of a significant part of the territory of the oak forest and the aridization of the climate. A more detailed analysis of the structure of the oak forest, taking into account the dynamics of the confectors, will more accurately show the magnitude and direction of successional processes in the oak forest and predict them for the future.

The article reflects individual results of a comprehensive study of the main price generators of the oak forest of the arboretum – the establishment of the modern species composition of woody plants and its structural features. The work did not include data from studies of the age composition and assessment of the state of populations of the main park-forming species, issues of self-organization and features of the formation of floristic nuclei in oak forest phytocenoses. Issues of the phytosanitary status and current mortality of the studied species are not included.

The results of the research presented in this paper and other data from a comprehensive study of the main price-formers of the mature oak forest will become the basis for studying the succession processes of oak forest phytocenoses in the Dendrological Park “Olexandria”.

4. Conclusions

Thus, the natural age-old oak forest of the Dendrological Park “Olexandria” of the National Academy of Sciences of Ukraine is a complex multi-species plantation, the floristic core of which is made up of the main forest-forming species characteristic of the PLU. The role of the dominant species and edificator in all oak forest phytocenoses was retained by *Quercus robur*, forming monodominant phytocenoses or with the participation of *Quercus robur* satellites in the first tier in various combinations and ratios. All oak forest phytocenoses have a well-developed multi-species second tree layer. The group of asectators is diverse and is represented by both small species belonging to forest-forming species and adventitious species, including invasive ones. A characteristic feature of the oak grove in the historical part of the Alexandria arboretum is its exorbitant grinding, which, together with the massive introduction of introducers, caused its powerful ecotonization and formed cells of the greatest extinction of *Quercus robur* in the Dendrological Park “Olexandria”.

Conflict of interest

The authors declare that there is no conflict of interest in relation to this paper, as well as the published research results, including the financial aspects of conducting the research, obtaining and using its results, as well as any non-financial personal relationships.

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