

Preservation and optimisation of ‘Dubynka’ historical planting of National dendrological park ‘Sofiyivka’

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Abstract

In the course of coenosis development, changes in the quantitative and species structure took place in certain areas of ‘Dubynka’ historical planting. The aim of the study is to find out possible ways to optimise and propose measures to restore the quantitative structure of *Quercus robur* in it. The research was carried out by field (continuous inventory), analytical and mathematical, and statistical methods. Throughout the historical development of the coenosis, *Carpinus betulus* has been the dominant species in the tree stand. The low number of *Acer platanoides* and *Fraxinus excelsior* in certain age groups indicates an unbalanced removal of trees during felling. It was proved that the beginning of the decay of the primary planting of *Q. robur* began 100–118 years after its establishment. A stable tendency to reduce its quantitative indicators in the structure due to the death of trees and weak natural recovery during the last 109–127 years was revealed. The loss of the ability to natural recovery of *Q. robur* during the last 54–72 years was also revealed. The impracticality of using artificial measures to reduce the mass fraction of dominant species at the planting in favour of self-regeneration of *Q. robur* has been proven. It was found that under the conditions of this coenosis *Ulmus laevis* is unpromising. The care strategy for the area of the historical planting, which takes into account the coenotic features of development, has been determined. Recommendations are made for restoring the proportion of *Q. robur* to return the historic planting to its appropriate status.

Key words: age groups, artificial origin, dominant species, natural recovery, park coenosis, species composition.

Introduction

Park coenoses, which at the time were artificially formed from native plants, are currently the basis of the National dendrological park ‘Sofiyivka’ of the National

Academy of Sciences of Ukraine. Historically, the planting ‘Dubynka’ was created in 1796–98 by seedlings of native species. In scientific works, it was indicated that from the very beginning of the construction of the park, this entire territory was

planted mainly with oaks, with addition of such species as hornbeam, ash, maple, linden (Lypa 1948, Kosarevsky 1951, Kosenko et al. 1996). Unfortunately, mass share of each species in the structure of planting was not reported. Monitoring of plantations and detection of undesirable changes made it possible to adjust the structure of the coenosis in time to restore the historical composition of plantations.

As a result of a regular inspection of the plantations, in 2019 we noted a sharp deterioration in the phytosanitary condition of pedunculate oak (*Quercus robur* L.) plantations on the plateau, which led to accelerated tree mortality. At the same time, on the slope of the valley, no such trend of its accelerated die-off and massive appearance of recently deceased oak trees was detected (Rumiankov 2019).

Over the past hundred years, in Europe, *Q. robur* has been characterised by a weakened resistance to diseases and pests, and is not competitive in forest communities, so as a result of these trends, it is subject to accelerated extinction (Gensiruk 2002, Doležal et al. 2016).

The last decline in the number of *Q. robur* was observed in Europe in 2011–2020. A study conducted over several decades has shown that the number of living oaks has been declining since 1935. It was also found that the death of plantations along with the disruption of natural regeneration can threaten not only the oak population, but also species dependent on it (Larsson 2021). Since 2013, the death of *Q. robur* has been observed in the Ardennes region of Belgium. Given the direct and delayed effects of the extreme drought of 1976 and the subsequent disruption of the water balance due to winter frosts and moderate spring droughts, the condition of the scrub oak is of concern in the context of climate change (Losseau et

al. 2020). The projected increase in temperature and extreme summer droughts, which negatively affect the growth of *Q. robur*, contribute to the decline of its local population in the warm southeastern part of the Czech Republic. In addition, such oaks are often infested with mistletoe (*Loranthus europaeus* Jacq.) and suffer from competition from neighbouring trees (Zlatanov 2006, Doležal et al. 2016). In the temperate forests of Europe, the die-off of *Q. robur* and reduced growth were caused by extreme climatic events, such as dry and cold periods, the negative impact of which was intensified by the general climate warming (Bose et al. 2021, Camarero et al. 2021, Vospernik et al. 2023). It has been found that in Europe, after a series of seasonal droughts without any obvious consequences, already weakened *Q. robur* trees can die as a result of another minor drought. The cumulative effect of the negative impact of droughts is associated with the low ability of oak trees to reduce the impact of the initial drought, which causes the risk of high tree loss in the context of global climate warming (DeSoto et al. 2020, Harvey et al. 2020). According to many experts, the reason for the massive drying out of oak forests may be the influence of a complex of factors: global climate change; long-term, selective felling of the best oak trees for economic needs; and the growing anthropogenic load (Kelly et al. 1989, Lutsyshyn and Lavnyy 2012).

The first observations of the accelerated dying off of gully forests in Ukraine were recorded in the 1940s (Borodaevsky 1909). In studies conducted in three typical ravine forests of the southern part of the Ukrainian Steppe in Zaporizhzhya, recreational impacts revealed a slight decrease in regeneration potential and an increase in the proportion of generative and

post-generative individuals in the coenopopulations of Generalka and Khortytska beams. However, in Shyroka Gully, due to the reduction of anthropogenic impact, all coenopopulations of *Q. robur* are young and have significant adaptive potential (Yakovlieva-Nosar and Bessonova 2021).

In a study on the vital status of the dendroflora of Nemyrivskyi Park in Vinnytsia region, was found that the age-old park plantations of *Q. robur* were in good condition, the trees had normal shoot growth without signs of weakening, but the leaf blade had a slight fungal infection, and they bear fruit (Vitenko et al. 2022).

The experience of forestry specialists showed that oak regeneration in the Ukrainian Steppe is hopeless. In the specific climatic and anthropogenic conditions of the southeast of Ukraine, the viability of woody plants was significantly reduced, and their durability was shortened (Levon 2008, Matusyak 2016, Kopyi et al. 2017).

Under unfavourable conditions, the course of ontogeny changes, the periodisation of which may proceed according to a shortened program (Rabotnov 1950, Sklyar 2013).

The age structure of woody plantations determines the dynamics of structural diversity, the ability to self-renewal and the degree of resistance to the impact of natural and anthropogenic factors. Monitoring the age spectrum of park plantations is the basis for a substantive assessment and forecast of the feasibility of developing and implementing certain optimization measures (Fizyk et al. 2016, Zvarych et al. 2016).

Natural regeneration process in plantations is largely determined by natural and climatic factors, and specific conditions of coenosis (Ostapchuk 2013, Ischuk 2017).

Therefore, the study of the species and age structure of the artificial plant-

ing of the same climatic zone, but under individual coenotic conditions in different parts of the massif is relevant.

In the process of development of the artificial coenosis of the historical planting, there were changes in its species structure, the scale and trends of which differed depending on the forest and vegetation conditions of individual areas of the planting and the degree of anthropogenic impact (Rumiankov et al. 2021). Currently, our task is to determine the species and age structure of the stand and its undergrowth on the slope of the valley, which is characterised by a better hydrological regime and minimal impact of anthropogenic factors on the development of coenosis, and to identify the reasons for the lack of natural oak regeneration in sufficiently optimal conditions for many species in this area. Therefore, the aim of our study is to provide practical recommendations for plantation care, and propose measures to restore share of oak. The scientific novelty of the work is to determine the characteristic features of the development of the coenotic structure of a separate section on the slope of the valley, which will allow us to propose a specific direction of the plantation care strategy to restore share of oak.

Object and Methods

The object of our research was historical planting 'Dubynka' of the National dendrological park 'Sofiyivka'. Its geographic coordinates are 48°45'36" N, 30°13'59" E (Fig. 1).

The subject of our research was the species and age structure on the slope of the valley. In June 2023, a study of the species and age structure of the plantations was carried out using the continuous inventory method. The named method

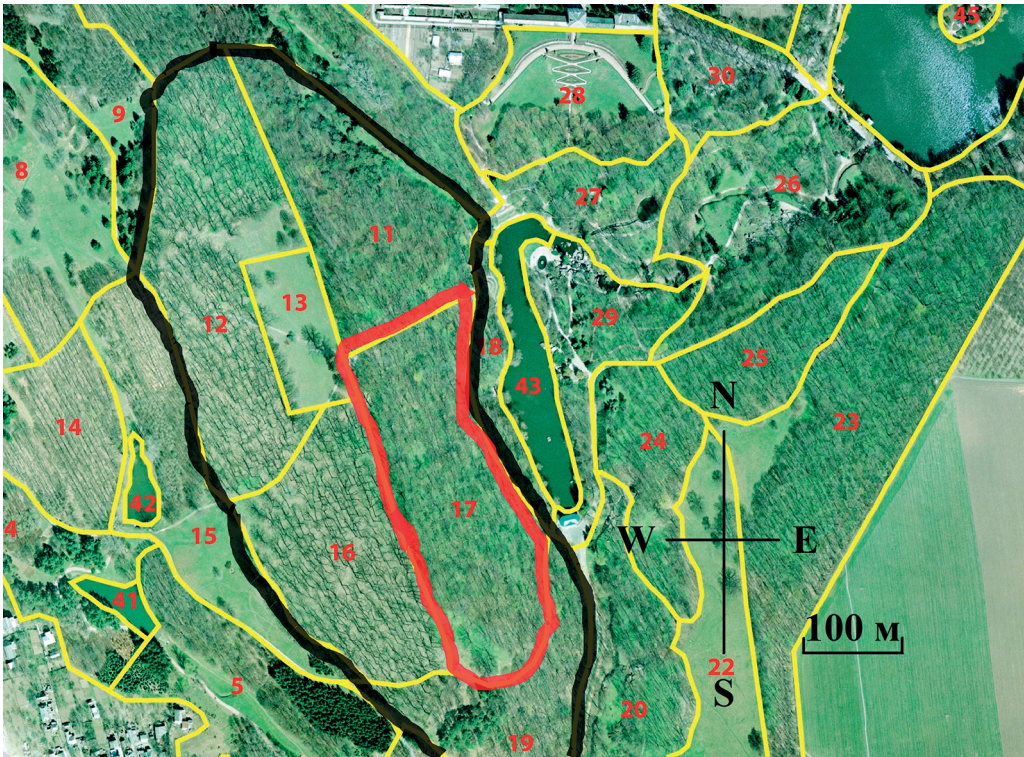


Fig. 1. Planting 'Dubynka' of quarter No 17 of the National dendrological park 'Sofiyivka' of NAS of Ukraine.

Note: black line – the entire plantation, the red line – the valley part of the plantation (object of our research).

involves the individual enumeration of all trees, bushes and self-seeding plants of each species in a continuous manner on an area of 4.1 ha, which was highlighted on the map with a red line. To achieve this goal, we used methodical instructions for conducting field work on the inventory of forests of the Polissky region of Ukraine (Storozhuk 2006), methodical recommendations for inventorying, taxation and monitoring of perennial plantings in historical parks of Ukraine (Kosenko et al. 2014). We analysed the species and age structure of the plantations using the scientific works of: Lypa (1948), Kosarevsky (1951), and Kosenko et al. (1996). We determined the approximate age of oak

trees by counting annual cambial layers of the trunk of cut dry trees. When analysing the age structure, we determined the age of the tree indirectly through the trunk diameter, since its thickness depends on the tree's life expectancy. The trees were conventionally divided into age groups, where each subsequent group contains trees 10 cm larger than the trunk diameter of the previous one. Self-seeding of trees was divided into three age groups by plant height. The first age group includes plants which height is from 0.1 to 1 m, the second – from 1 to 5 m, and the third – from 5 to 10 m.

The climate is characterised as moderately continental, with an average annual

air temperature of 7.3–9.4 °C. The coldest month is January with an average temperature of -5.6 to 6.1 °C, and the warmest is July with an average temperature of 19.2–20.8 °C. The absolute minimum air temperature is -34 to -38 °C. The absolute maximum temperature of 36–39 °C is observed in July–August. The transition of the average daily temperature through 0 °C occurs on March 15–16 and November 22–24. There are 242–255 days in a year with an air temperature above 0 °C. The average annual rainfall is 570–630 mm, of which only 300–310 mm falls during the period with a temperature of more than 10°C. During the year, precipitation is unevenly distributed, the most falls in June–July (90–100 mm), and the least in January–February (Shkvaruk and Zapatiy 1960, Lipinsky et al. 2003).

The soil cover of the park is dominated by regraded chernozems and dark gray forest podsol. The acidity varies between pH 4.8–7.3, but the majority of soils have

a neutral reaction. Most of dark gray forest soils are heavy loamy by mechanical composition. The content of humus in a 30-centimeter layer of soil is 2.7–3.8 %; nitrogen content – 8.9 mg per 100 g; of mobile compounds of phosphorus and potassium, respectively, 10.8–12.5 and 14.3–16.4 mg per 100 g. Groundwater lies at a depth of 1.7 to 22.0 m. In general, the soils are highly fertile (Shkvaruk and Dele-menchuk 1969, Shlapak 2021).

Results and Discussion

As a result of stand species structure analysis, based on the size of the quantitative share, species were conditionally divided into two categories. The first category includes species which share from 5 to 36 %. The second category includes species with a share of only 0.8 % of the total number of trees (Fig. 2).

The first category includes *C. betulus*,

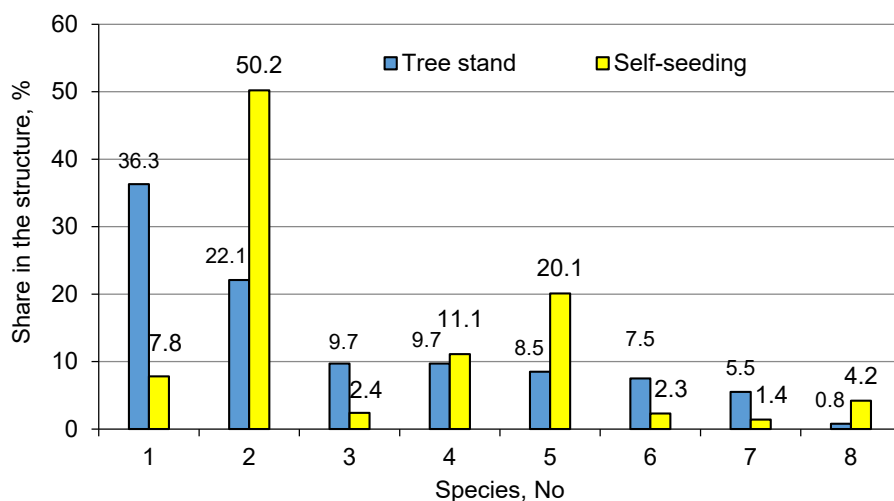


Fig. 2. The species structure of the tree stand and self-seeding.

Note: 1. *Carpinus betulus* L., 2. *Acer platanoides* L., 3. *Quercus robur* L., 4. *Acer campestre* L., 5. *Fraxinus excelsior* L., 6. *Ulmus laevis* Pall., 7. *Tilia cordata* Mill., 8. species that are found in single specimens.

A. platanoides, *Q. robur*, *A. campestre*, *F. excelsior*, *U. laevis*, *T. cordata*.

The second category includes single specimens of: *Prunus padus* L., *Quercus rubra* L., *Prunus avium* L., *Picea abies* L., *Celtis occidentalis* L., *Crataegus oxyacantha* L., *Prunus cerasifera* Ehrh., *Sorbus torminalis* L., *Acer pseudoplatanus* L., *Morus alba* L., *Styphnolobium japonicum* (L.) Schott, *Juglans cinerea* L.

Currently, species of the second category, have a minimal impact on this park coenosis, but their presence determines a certain reserve in case of loss of perspective of any species from the first category as a result of climate changes. In addition to the reserve function, species of the second category in the plantation can also perform the role of decorative elements. For example, *M. alba*, which adaptive potential in studies was assessed as high (Vitenko et al. 2023), acquires a higher decorative effect with the use of grafted forms. The method of grafting mulberry trees directly in the stand itself allows to avoid such an operation as transplantation, thereby maintaining the growth rate of the rootstock, and also lengthen the life of the grafted tree. *M. alba* trees of the forms 'Pendula', 'Globosa', 'Pyramidalis', 'Contorta', 'Macrophylla' were grafted by the method of improved copulation according to the conclusions of Vitenko et al. (2019) quickly fuse, and the grafting sites are completely covered with protective tissue. The use of single *M. alba* trees of various grafted forms on the edges of forests will help to enrich the park's dendrostructure and, bringing local colour, will increase the decorative effect of the planting.

C. betulus and *A. platanoides* occupy the largest mass share in the plantation (36.3 and 22.1 %, respectively). The smallest share in the first category is oc-

cupied by *T. cordata* — 5.5 %. *Q. robur*, *A. campestre*, *F. excelsior* and *U. laevis* have the average mass fraction (9.7, 9.7, 8.5 and 7.5 % respectively).

The identified main species composition of the plantation generally coincides with the structure formed at the beginning of the park construction (1796), except for *U. laevis*, which was not mentioned in historical sources. Taking into account the existing quantitative composition, the investigated plantation only partially corresponds to the original composition, since instead of *Q. robur*, which is mentioned in historical sources, the structure of the tree stand is dominated by *A. platanoides* and *C. betulus*. Describing the tree stand in 1948, Lypa (1948) wrote that 'hornbeam dominates here, forming almost everywhere a single tree massif. Only very rarely and in small quantities, other species occur: ash, oak, maple, pear, linden and others' so now we have every reason to confirm the relevance of the dominance of *C. betulus* in this coenosis. In addition, given the dominant position of hornbeam described by Lypa in 1948 and the fact that we have found its dominant position in the tree stand over the past 90–110 years, we consider the trend of *C. betulus* dominance in the park's coenosis to be historical. It is also interesting to note that as of 1948, oak, ash and maple occupied an insignificant part in the structure of the tree stand, which at that time also did not allow this plantation to be called a oak tree stand, and therefore did not correspond to its historical name.

Among the species composition of the self-seeding, *A. platanoides* and *F. excelsior* have the largest mass fraction (50.2 and 20.1 %, respectively) (Fig. 2). *Q. robur*, *U. laevis* and *T. cordata* have the smallest share in self-seeding (2.4, 2.3 and 1.4 %, respectively). *A. campestre*

and *C. betulus* (11.1 and 7.8 %, respectively) have average values of the mass share of self-seeding in the plantation.

The largest amount of self-seeding in all three age groups was found in *A. platanoides* (Table 1).

Table 1. Quantitative characteristics of age groups of self-seeding.

Species	Number by plant height			Total number of self-seeding
	I / 0.1–1 m	II / 1.1–5 m	III / 5–10 m	
<i>Acer platanoides</i> L.	2656	732	408	3796
<i>Fraxinus excelsior</i> L.	1361	142	16	1519
<i>Acer campestre</i> L.	489	313	35	837
<i>Carpinus betulus</i> L.	442	112	33	587
<i>Quercus robur</i> L.	181	0	0	181
<i>Ulmus laevis</i> Pall.	113	90	11	214
<i>Tilia cordata</i> Mill.	43	27	33	103

In age group I, the quantitative index of maple self-seeding (2656 pcs.) is twice as large as that of such a strong edificator as ash (1361 pcs.).

The biggest difference between the quantitative indicators was determined in age group III, where the maple is 25 times more than the ash. The highest number of self-seeding in all three age groups of *A. platanoides* convincingly demonstrates the significant natural potential of the species, which leads to a high ability to self-renewal, competitiveness in the park coenosis and provides the possibility of a corresponding dominant position in the stand.

F. excelsior also has a large amount of viable self-seeding (1519 pieces) (Table 1). However, there were no ash trees in age groups I and II (trunk diameter from 10 to 30 cm), and only 2 trees in age group III.

The introduction of measures to regulate the proportion of *A. platanoides* and *F. excelsior* in the past was not unreasonable, given that such a strong unifier as *Q. robur* in this forest community has reduced its influence due to natural causes. For example, in the presence of 181 oak self-seeding plants (Table 1), no *Q. robur*

trees were found in age groups I and III, and only a tree in age group II (Fig. 3).

The absence of a sufficient number of *Q. robur* trees in age groups I–III in a row indicates a decrease in competitiveness and leads to the loss of the edificator function in the coenosis.

At first glance, the presence of 181 pcs. self-seeding of oak should guarantee its presence, as in the case of linden, when even the smallest number of self-seeding ensures a full-fledged age structure (Table 1). However, the type of placement of self-seeding plants of these species on the plantation territory is somewhat different. Linden self-seeding, as in most species, is distributed fairly evenly over the entire area, while in oak it is only on one side of the plantation. It was found that the oak seeds germinated on the border of the forest edge-park alley on the northern side, where direct sunlight only gets in the morning and evening, but there is enough diffused light during the day. Of course, such a place will be more humid, because it is close to the park alley. The alley is lined with bricks, under which moisture easily gets and stays. According to our observations, outside the stand tent, in conditions of partial shade and moderate soil

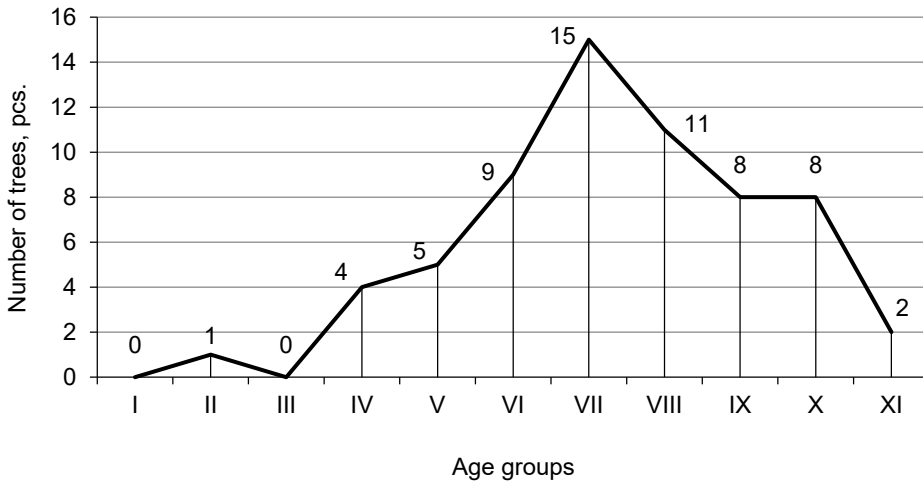


Fig. 3. Quantitative characteristics of *Q. robur* trees by the age structure.

moisture, *Q. robur* seeds can germinate, but young plants are not able to survive.

Studying the regularities of the reforestation process under the canopy of oak-hornbeam plantations in fresh oak forests of the Korsun-Shevchenkivskiy forestry, Ishchuk (2017) determined that low illumination under the canopy of high-completeness oak-hornbeam forests reaches 0.5–3.0 % of total illumination and leads to the gradual death of self-seeding and oak undergrowth in the second or third year of life. Taking into account the author's conclusions, the conditions of natural oak-hornbeam groups do not contribute to the success of oak restoration due to insufficient lighting under the dense canopy of hornbeam. Therefore, if we take into account the dominant impact of hornbeam found in our research – 36.3 % in the species structure (Fig. 2), it should be stated that the dense canopy of hornbeam becomes an obstacle to the successful restoration of oak. It is certain that such a statement should be put in the form of a question.

A similar situation was described in studies on the regeneration of *Q. robur* in

deciduous and mixed forests, where the level of photosynthetically active radiation under the tent rarely reaches 15 %, which is insufficient for the successful growth and development of oak self-seeding (von Lüpke 1998). Comparing the findings of Ishchuk (2017), who believed that 0.5–3.0 % of total illumination leads to the gradual death of self-seeding and undergrowth of oak, with the findings (von Lüpke 1998) that the level of photosynthetically active radiation in natural forests 15 % (this is 5 times more than the previous value) was still insufficient for the development of oak, we can note that the limiting factor for the restoration of oak is most likely not the amount of light. For example, in our research, even in completely open areas under the crowns of oak plantations, self-seeding of oak was not detected at all. In other words, how, with all components being equal, did the oak still continue to regenerate in natural forests when it was so critically lacking in light?

Studies of reforestation processes in 110–165-year-old oak forests of 'Roztochia' Nature Reserve have shown that

the undergrowth of common oak, compared to other species, is more sensitive to insufficient light and other factors of the under-tent environment (Zvarych et al. 2016). The authors established that on most of the area, almost all oak self-seeding was very weakened and unsustainable, therefore, no plants taller than 25 cm and older than 2–3 years were found on the territory of the reserve. It should be noted the similarity of the results obtained in our study, when analysing the age structure of oak self-seeding in the stand, it was established that it was absent in age groups II and III (Table 1). The presence of self-sowing oak of only the age group I indicates that one of the limiting factors of the viability of oak growth is insufficient lighting under the tree canopy. In order to discuss this question from the other side, the following seemingly similar situation should be considered.

Accordingly, with a decrease in the efficiency of photosynthesis in leaves, which are often affected by the fungus *Phytophthora* de Bary, according to Bobiec et al. (2018), young oaks could lose their former ability to survive and grow in forest conditions, but at the same time, they remained strong competitors in well-lit non-forest areas. In our research, sufficiently well-lit areas (clearings, gaps, glades) were also found on the territory of the forest stand, in addition, the sunny edges of the plantation perimeter were examined, but no self-seeding oak plants were found. Therefore, well-lit areas do not guarantee young oak plants the opportunity to show their competitiveness.

Taking into account the formation of the stand mainly from common oak, in the future, even in the absence or minimised influence of competing tree species, according to observations by a number of authors, oaks are not able to regenerate

themselves directly under their own canopy (Palmer et al. 2004, Strandberg et al. 2005, Perrin et al. 2006), which was also proved by previous research (Rumiankov 2019), that established the absence of natural regeneration in artificially created oak plantations, where the undergrowth of other species was regularly removed. For now, it should be noted regarding our debatable question about the importance of lighting conditions, from the point of view of the degree of illumination of this area, we can confidently state that in relation to this factor, the possibility of oak restoration was not limited.

At the same time, research in the artificial plantations of the Sinytsky Forestry of the 'Uman Forestry' State Enterprise showed their high productivity in the composition of 48 % of common oak, 19 % of common ash, 19 % of European beech, 9 % of sharp-leaved maple, and less than 5 % of such as elm, aspen, hornbeam and linden (Koval et al. 2022). In plantations dominated by *Q. robur* under the conditions of its simultaneous planting and a uniform placement scheme, oak trees received the first class of quality assessment. Comparing the specified structure of the plantation with the structure in our plantation, it should be noted that the species structure of our object of research corresponds to a greater extent to the structure of natural oak-hornbeam communities (Fig. 2), which should contribute to the restoration of oak, but as it turned out, the plantation formed as a natural oak-hornbeam coenosis does not yet ensure the success of oak restoration.

The only continuous tree canopy which conditions could allow oaks to regenerate is a translucent crown architecture that can leave young oak plants with enough photosynthetically active radiation to grow and develop. This semi-permeable prop-

erty of the canopy is possessed by pine stands, which are widely cultivated by forestry in most European biogeographic regions, often in an ecological niche for deciduous forests (Kuiters and Slim 2003, Onaindia et al. 2013). Taking into account the openwork of the crown of pine plantations, we consider it expedient to introduce *Pinus sylvestris* L. into the planting as an alternative for enriching the dendro-structure, which could realise the natural potential of oak regeneration. Therefore, we recommend the establishment of scots pine plantations in certain areas stand, which will open up new prospects for research, observing in the future how this measure will remain justified in the individual conditions of the existing coenosis for both oak and pine.

Studying the reproduction of oak stands naturally in forestry in Ukraine, it was found that in forest areas with clearfelling, where the stand was cut after the acorn fell in a harvest year, the lowest decline of self-seeding oak (19.3–28.5 %) is typical (Kopiy et al. 2017). Analysing the areas of clear-cutting of oak forest stands in Podillia, Matusyak (2016) shows that under optimal conditions it is possible to ensure the natural regeneration of common oak at the level of 3000–5000 pcs. per ha in the next 1–2 years after clear-cutting. These studies have shown that oak self-seeding in areas of the forest with clearfelling was characterised by much faster growth. In our opinion, this indicates that in the presence of fresh fallen oak seeds under favourable lighting conditions, there is a real opportunity to obtain self-seeding of oak, which can quantitatively ensure the full reproduction of oak plantations. Taking into account the fact that there is an opportunity to obtain viable oak plants in the open area and the proven fact of the failure of natural regeneration in our case, leads us

to use an artificial means of restoring the species structure of *Q. robur* by planting young trees.

It should be noted, that in temperate climates, there are forest habitats where oaks retain their dominant position due to their stress resistance over other species that cannot withstand boreal and arid conditions. Harsh natural biotic factors specific to acidophilous oak forests on silicate rocks, xerophilous oak forests on limestone, Euro-Siberian steppe forests, Pannonian-Balkan oak forests, and old-growth oak forests of the British Isles (habitats 9190, 9110, 91M0, 91A0 – European Commission 2013) reduce interspecific competition and prevent the development of dense shade-tolerant stands, and therefore promote the regeneration of *Q. robur*. In our opinion, the existence of the listed habitats shows that the oak feels more comfortable even in harsh conditions of high soil acidity or on limestone outcrops, without a sufficient amount of water and without the structure of officially recognised associations, which were obliged to perform the functions of preserving species diversity. In difficult conditions for most species, the oak is able to form a coenosis with a full-fledged age structure, which indicates regular natural regeneration. If we mention the presence of the habitat of the old-growth oak forests of the British Isles, then this fact indicates that even in such conditions *Q. robur* is able to maximally show its potential as a long-lasting species. In addition to the above, we can note that similar conclusions were also reached by other researchers, for example Johnson et al. (2009), who gave oak culture a special ecological niche, as the formation of similar habitats with the natural regeneration of oak without the influence of exogenous factors they called by a separate term

such as 'intrinsic oak accumulator'.

Analysing the discussion of the views of the presented researchers regarding the possibility of oak restoration in the conditions of tree groups, we can conclude that the oak plantation should not be perceived as a self-regenerating formation, but only as an initiating forest grouping, in which the oak in the process of historical development of the coenosis no longer finds an ecological niche for its development. Taking into account the contradictions of the data presented by a number of scientists and forestry specialists regarding the determination of the conditions for the natural restoration of oak, it should be recognised that it forms a special category of plantations with artificial support for the conditions of its cultivation and reproduction function. Therefore, taking into account the special status of oak given by individual scientists, it becomes clear why, according to researchers (Bobiec et al. 2018), the problem of successful restoration and replenishment of oak habitats is solved by creating modern oak formations, represented mainly by non-forest natural or artificial habitats.

Currently, on the territory of the planting, we can only state a complete loss of the ability of *Q. robur* to regenerate naturally, as evidenced by the absence of oak trees for three consecutive age groups, except for a single specimen in age group II (Fig. 3). However, the fact that there is an ecological niche that still allows the formation of single specimens of *Q. robur* gives us reason to recommend the use of existing glades in the stand for artificial planting of young oak trees. The event involves the use of not only existing glades, but also other open spaces that do not contain full-fledged trees with the obligatory clearing from self-seeding, shrubs and grass vegetation to ensure proper

light conditions young oak plants. Given that only one out of 181 oak self-seeding plants survives (often none) (Table 1) and the reduced moisture supply of open areas, we recommend that in addition to clearing, which should be done during the growing season, regular watering should be provided. The proposed possibility of restoring the quantitative structure of *Q. robur* is quite relevant for returning the appropriate status to the historical planting.

As a result of age structure analysis, the two oldest trees of *Q. robur* in age group XI were found (Fig. 3). We found that the growth of oak in the trunk diameter in this area is on average 5.5 mm per year. The trunk diameter of these trees is 115 and 117 cm, which is about 209- and 212-year-old, respectively. Given that from the very beginning of the park's construction, this entire area was planted mainly with oaks (Lypa 1948, Kosarevsky 1951, Kosenko et al. 1996), only two of these trees remain in the planting. We can conditionally consider these two trees to be contemporaries of the construction of the park, which is now 227-years-old. It is planned to install commemorative plaques on granting the status of historic trees to two long-lived specimens of *Q. robur*.

The highest number of common oak trees was recorded at the age of 127–145 years – 15 trees (age group VII) (Fig. 3). Probably 127–145 years ago, oak was still the dominant species in the community. That is, for 80–98 years from the establishment, the oak still held a quantitative advantage. A 40 % decrease in the number of oak trees 109–127 years ago (age group VI) indicates significant losses in the structure of the stand and determines the beginning of the decay plantation of oak in the structure of the coenosis.

It is important to note that the decline in the quantitative characteristics of oak in

relation to other dominant species began in an overripe state, which it reached in the 100–118th year of the planting existence. After that, there was a steady downward trend in the quantitative structure due to the death of old trees and weak natural regeneration. This makes it possible to state that at the initial stage of the park coenosis development, the dominance of *Q. robur* was based only on a quantitative advantage during the establishment of planting.

The next reduction in the quantitative composition occurred 90–109 years ago (age group V) by 44 %, which confirms the tendency of a decrease in quantitative indicators 116–135 years after the establishment plantation of *Q. robur* (Fig. 3).

The presence of oak trees (4 pcs.) aged 72–90 (age group IV) in the stand certainly indicates some natural regeneration (Fig. 3), but its intensity and viability were already declining and could not ensure the proper quantitative share of *Q. robur* as the dominant species. Over the past 54–72 years (age group I–III), only one oak tree has grown, which indicates a critically low capacity for natural regeneration of *Q. robur* trees.

Analysing the age structure of self-seeding, we can note the presence of its full-fledged structure in the form of three age groups for all the listed species, but this pattern does not apply to *Q. robur*. In the age structure of *Q. robur* self-seeding, there are no plants of age groups II and III, while there are 181 plants in age group I (Table 1).

The detected self-seeding of oak only in age group I indicates a sufficient intensity of fruiting trees and the quality of acorns that formed this self-seeding, and at the same time insufficient stability of self-seeding of age groups II and III (Table 1). If we take into account the inability

of the oak tree to self-regenerate on the territory of the planting in our time and the revealed steady tendency to reduce its quantitative structure throughout the entire development of the coenosis, then hypothetically, there is every reason to think that self-seeding *Q. robur* was not competitive enough from the establishment.

The quantitative advantage of the maple over the ash in the age groups is preserved only in the I one (Fig. 4). If we analyse their age structure from age groups II to IX, *F. excelsior* takes quantitative priority. In addition, its maximum one-time quantitative indicator in age group V (19 pcs.) testifies its high potential viability in the park coenosis in the absence of control by anthropogenic factors over the quantitative structure of species with a high reproduction rate. Therefore, given the significant potential for self-seeding of maple and ash, low quantitative indicators in age groups II and III are not typical, which indicates active anthropogenic interference in the development coenosis.

We consider the decrease in the number of *A. platanoides* and *F. excelsior* in age groups II and III as the implementation of measures to artificially reduce their dominant potential in this coenosis.

Taking into account the loss of the status of *Q. robur* as an edificator in the past, measures to artificially reduce the mass fraction of *A. platanoides* and *F. excelsior* as potentially dominant species were carried out in order to improve the lighting regime and creation of a favourable microclimate for self-regeneration of *Q. robur*. However, at the moment we can observe the impracticality of using artificial measures to reduce the mass share of dominant species in the planting, which could contribute to the natural recovery of *Q. robur*. In connection with this, we are planning to implement measures to regularly

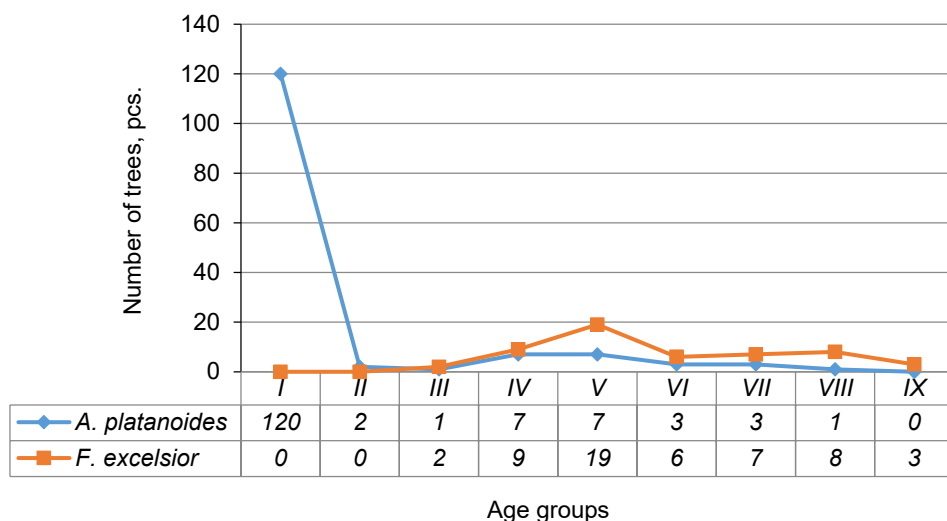


Fig. 4. Comparative characteristics of *A. platanoides* and *F. excelsior* number in the age structure.

control the quantitative indicators of competitive young trees *A. platanoides* and *F. excelsior* to maintain the mass share of dominant species in the park coenosis at the level of 20–25 %.

The quantitative composition in age group I of self-seeding *A. campestre* and *C. betulus* is almost the same: 489 and 442 pcs. respectively (Table 1). In age group III of self-seeding, the ratio of these species remained in the same balance, but quantitatively decreased by 14 times (35 and 33 pcs., respectively), showing the same degree of viability. However, if we analyse the quantitative characteristics of the age groups of *A. campestre*, it turns out that the field maple very quickly loses its quantitative share with each subsequent age group, and it was not detected already in age group IV (Fig. 5), which indicates the insufficient longevity of *A. campestre* in the conditions of this coenosis.

Compared to *A. campestre*, the quantitative characteristics of *C. betulus* age groups in the tree stand differ in a more

gentle and uniform decline, keeping high indicators (from 89 to 26 pcs.). It should be noted that even in the last age group, the number of hornbeam trees remains quite high, whereas for all the studied species the presence of senescent trees in single specimens is more typical. Therefore, the absence of long-lived trees in *C. betulus* is determined by the massive death of a large number of old trees in the last age group.

U. laevis and *T. cordata* are characterised by the lowest quantitative self-seeding potential, with indicators in age group I of 113 and 43 pcs. respectively (Table 1). Compared to linden, elm loses its quantitative indicators much faster, because in self-seeding of age group III, 10 times fewer plants were found than at the beginning.

A similar trend of rapid loss of quantitative indicators of *U. laevis* is also observed in the tree stand, when already in age group III there are only two trees left (Fig. 6), which is 15 times less than in the first.

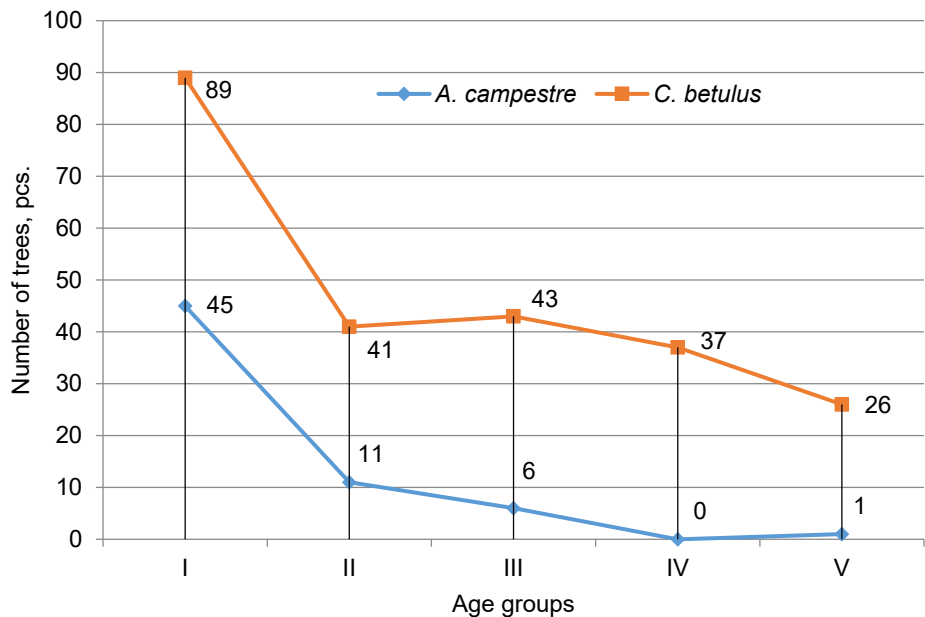


Fig. 5. Comparative characteristics of *A. campestris* and *C. betulus* number in the age structure.

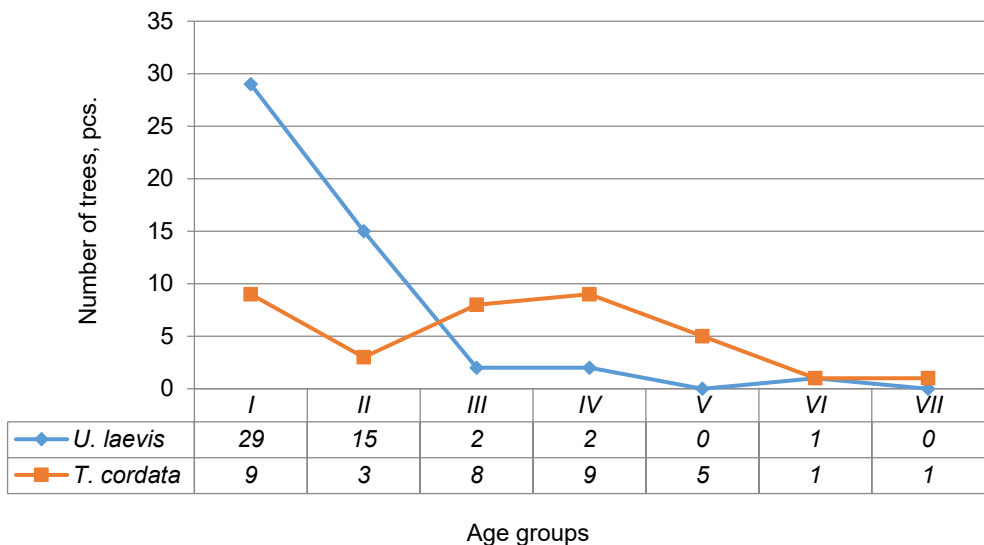


Fig. 6. Comparative characteristics of *U. laevis* and *T. cordata* number in the age structure.

In the age structure 89.7 % of the quantitative potential of elm is concentrated

only in the first two age groups out of the six identified, which indicates the short-

lived nature of *U. laevis* and, accordingly, its low prospects in this coenosis.

The initial self-seeding potential of *T. cordata* in age group I was the lowest among all species (43 pieces) (Table 1). In age group III, 1.3 times less self-seeding linden remained than in I (33 pcs.). This is the lowest rate of natural thinning of self-sowing among all studied species, which indicates the high viability of *T. cordata* in this coenosis (Table 1).

Compared to *U. laevis*, the quantitative indicators of *T. cordata* in age groups I–IV are distributed fairly evenly. However, it should be noted a sharp decrease in the number of linden trees in age group II – 3 pcs., which is 66 % less than in age group I (Fig. 6). In our opinion, the regulation of the quantitative composition of *T. cordata* by anthropogenic factors is unlikely, since is natural regeneration is the least intensive (Table 2). For this reason, a violation of the characteristic stability of quantitative indicators and a decrease in the viability of linden trees occurred due to natural factors.

Analysing the quantitative structure of age groups among the studied species, it was found that the most long-lived in this coenosis are *Q. robur* in the amount of 2 pcs. (Fig. 3) and *F. excelsior* – 3 pcs. (Fig. 4), which belong to age groups XI and IX, respectively. The rest of the studied species were placed in descending order of longevity as follows: *A. platanoides*, *T. cordata*, *U. laevis*, *C. betulus* and *A. campestre* – in the last place.

Conclusions

Currently, the plantation does not correspond to its original composition due to the lack of the quantity of *Q. robur* stipulated by the founders of the park. Through-

out the historical development of the coenosis, *C. betulus* has been the dominant species in the tree stand. The absence of separate age groups of *A. platanoides* and *F. excelsior* was found, which indicates an unbalanced anthropogenic regulation of their number. Considering the high natural self-sowing potential of *F. excelsior* and *A. platanoides*, these two species are candidates for dominance. The high viability and prospects of *T. cordata* and the low prospects of *U. laevis* in the conditions of this park coenosis were revealed. Two long-lived trees of *Q. robur*, aged about 209 and 212 years, corresponding to the status of historical trees, were found on the territory of the plantation.

It was proved that the decay of the primary plantation of *Q. robur* began 100–118 years after its establishment. A steady downward trend in the quantitative structure due mortality and weak natural regeneration over the past 109–127 years was revealed. The loss of the ability to natural recovery of oak on the territory of the planting over the past 54–72 years has been proven. The reason for the lack of natural recovery is probably the non-competitiveness of oak seedlings in age group I.

The inexpediency of using artificial measures to reduce the mass fraction of potentially dominant species *A. platanoides* and *F. excelsior* in the plantations to promote self-regeneration of *Q. robur* was revealed. It was established that the basis of the dominance of *Q. robur* in the territory of the planting was only its quantitative advantage during the creation of the park.

Recommended:

- Regular monitoring of quantitative indicators of self-seeding of competitive species *A. platanoides* and *F. excelsior* to achieve optimal values of the mass frac-

tion of dominant species in the park coenosis up to 20–25 %.

- Restoration of the quantitative structure of *Q. robur* to restore the appropriate status to the historic planting by artificially planting young oak trees in open areas (clearings, gaps, glades). Ensure regular watering of young oak trees and clearing of overgrowth (self-seeding trees, bushes).

- Creation of plantations of *P. sylvestris* in certain areas of the stand as an element of the dendrostructure with a semi-permeable canopy that promotes the natural renewal of *Q. robur*.

- Reducing the mass fraction of *U. laevis* by removing its self-seeding in favour of other promising species such as *F. excelsior*, *A. platanoides* or *T. cordata*.

The provided recommendations for controlling the quantitative and restoration of species structure are the basis of the care strategy for the plantations, which takes into account the coenotic features of development.

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