

<https://doi.org/10.46341/PI2026011>

UDC 581.5 : 630 \* 18 : 581.2 : 621.039.5

## CHRONICLE

# 80 years of the Dendropark “Olexandria” within the National Academy of Sciences of Ukraine: Ecological and coenotic research of old-growth natural oak forest and the main park-forming species of woody plants in the Dendropark “Olexandria”

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**Received:** 23.07.2026 | **Accepted:** 02.10.2026 | **Published:** 10.10.2026

## Abstract

This work is a concise summary of the authors’ scientific research over a 25-year period and launches a series of publications dedicated to the 80th anniversary of the “Olexandria” State Dendrological Park (Dendropark “Olexandria”), part of the Academy of Sciences of Ukraine. The main studies focus on the park’s landscape-forming tree species – Scots pine and pedunculate oak. A number of population studies also concerned other park-forming tree species. In the Dendropark “Olexandria”, Scots pine forms the basis of most decorative compositions, while common oak retains its role as the main species in the arboretum’s natural old-growth oak forest. To date, it possesses strong edifying properties, protects the oak forest’s floristic core, and determines its ecological value. All our research was devoted to previously unexplored issues. For Scots pine, general morphogenetic reactions and their directions during adaptation to urban conditions were examined. For the first time in Ukraine, the impact of radioactive contamination on the morphogenesis of Scots pine outside the 30 km zone of the Chernobyl accident was assessed. For the oak forest, the consequences of long-term anthropogenic interference with its integrity and structure on its viability were studied. Forest pathology monitoring of the old oak forest was initiated. The initial stage included the study of the edificator species. Later, comprehensive population studies of woody plants accompanying the oak and contributing to the oak forest’s floristic core were conducted. Subsequently, similar studies of the main park-forming species were extended to non-oak areas of the Dendropark “Olexandria”. In recent years, studies of succession processes in the old-growth oak forest have been initiated, including the determination of factors, pathways, and models of oak forest degradation; the study of the possibility of its restoration or preservation; and the consequences for phytocenoses of changes in dominant species. A large part of the research was devoted to detailed examinations of the growth conditions, structural organization, and phytosanitary condition of the old-growth oak forest of the Golendernya tract, which joined the Dendropark “Olexandria” in 2008.

**Keywords:** Dendropark “Olexandria”, old-growth oak forests, principal park-forming species, Scots pine, pedunculate oak, morphogenesis, monitoring, succession

**Authors’ contributions:** Conceptualization – N. Dragan, O. Sylenko. Data curation – N. Dragan, N. Doiko, O. Sylenko. Formal analysis – N. Dragan, N. Boiko, N. Doiko, O. Sylenko. Investigation – N. Dragan, N. Boiko, N. Doiko, O. Sylenko, Y. Pydorich, L. Kryvdiuk. Methodology – N. Dragan, O. Sylenko. Project administration – N. Boiko, N. Dragan, N. Doiko. Supervision –

N. Boiko. Writing – original draft – N. Dragan, O. Sylenko. Writing – review & editing – N. Dragan, N. Boiko, N. Doiko, O. Sylenko, Y. Pydorich, L. Kryvdiuk.

**Funding:** This work was carried out as part of the following institutional fundamental research projects: “Conservation and enrichment of plant diversity in the plant communities of the “Olexandria” State Dendrological Park of the National Academy of Sciences of Ukraine under current conditions of climate change” (2018–2022), and “Natural and anthropogenic transformation and issues of conservation of native and introduced flora in the “Olexandria” State Dendrological Park of the National Academy of Sciences of Ukraine” (2023–2025), which is funded under budget program 6541030 (applied research).

**Competing Interests:** The authors declare no conflict of interest.

## Scots pine in the urban environment of the Right-Bank Forest-Steppe of Ukraine

Bioecological features of Scots pine (*Pinus sylvestris* L.) in the urban environment of the Right-Bank Forest-Steppe of Ukraine were studied at the beginning of the 21st century. Comprehensive studies of the vital activity of *P. sylvestris* were conducted in the urban ecosystem of the city of Bila Tserkva (Dragan, 2003; Dragan & Dragan, 2023b). The vital state and limits of *P. sylvestris* vitality in urban conditions were described. The great variability of crown forms, the ability to restructure under existing conditions, and significant potential for the restoration of normal life after the cessation of stress factors have been established (Dragan, 1999).

Adaptive morphogenetic reactions of *P. sylvestris* to living conditions in an urban environment have been identified: inhibition of linear and radial growth and their long-term stabilization, the predominance of sympodial branching, etc. This is reflected in the formation of a specific adaptive ‘urban’ pine ecotype. In extreme environmental conditions, morphogenetic reactions are irreversible and pathological, resulting in the more or less rapid death of plants. Outside extreme ecotopes, *P. sylvestris* showed itself to be a species relatively adapted to urban conditions, as a moderately patient species (Dragan, 2003, 2005a).

At the level of assimilation and generative subsystems, the negative impact of the urban environment was manifested in a decrease in morphometric and weight indicators of assimilating organs, a reduction in the lifespan of needles, increased defoliation, changes in morphometric and morphological indicators of generative organs, increased death of seed primordia and embryos, a decrease in the quantity and quality of seeds, a decrease in pollen germination, and an increase in the number of abnormal pollen grains (Dragan, 2003).

For the first time in Ukraine, outside the 30 km zone of the Chernobyl accident, the features of the influence of radionuclide contamination on the morphogenesis of *P. sylvestris* have been studied, typical modifications of normal organo- and histogenesis have been identified and analyzed, including reserve ways of *P. sylvestris* development in similar conditions, and a quantitative assessment of the destabilization of the morphogenesis of assimilation organs has been carried out (Dragan, 2002).

A number of modified shoot types in *P. sylvestris* have been distinguished according to the features of their structure and genesis. Characteristic disorders of the development of vegetative shoots consisted of incomplete deployment of bud rudiments, atypical budding, inhibition of development or reduction of axillary structures, a sharp change in their structure, violation of the zonality of the distribution of metameris, and death of apical meristems. Under the influence of radiation pollution in *P. sylvestris*, bud formation is stimulated, which consists of an increase in the total number of growth points and the appearance of additional ways of budding. Consequently, eight reserve ways of budding have been described (Dragan, 2002).

At the tissue level, the radiation effect was manifested in serious disturbances in the internal organization of the needles: a decrease or increase in the number of collateral bundles, reversion of conductive elements in collateral bundles, the appearance of two central conductive cylinders in one needle, various disturbances in the shape and structure of resin channels, atypical placement of sclerenchyma in the central conductive cylinder, and a sharp change in the configuration of the needle cross-section (Dragan, 2004, 2005b).

Over ten parameters spanning different levels of biological organization in Scots pine have

been proposed for use in bioindication studies, from the cellular to the organismal level (Dragan, 2005b, 2005c). In 2024, after a long-term stabilization of morphogenetic processes in pine following the Chornobyl disaster, this species and some other pine species were again found to exhibit significant, widespread disturbances in the morphogenesis of vegetative shoots (Dragan et al., 2025). This may become a new research direction related to the environmental consequences of military aggression.

### **The central theme of scientific research at the Dendropark "Olexandria"**

The central theme of scientific research at the arboretum has always been the natural old-growth oak forest. Since 2008, the consequences of long-term anthropogenic interference with the oak forest's integrity and structure have begun to be studied. For this purpose, forest pathology monitoring of the old-growth oak forest was initiated in 2008 (Dragan, 2019; Dragan et al., 2024d). Based on the results of a previous detailed examination of the structure and phytosanitary condition of the oak forest, a monitoring survey program was outlined.

A list of indicators necessary for monitoring the condition of oak stands of the Dendropark "Olexandria" and the frequency of monitoring these indicators were determined – operational control (monitoring the emergence of disease foci and outbreaks of pest reproduction – constantly); regular control (determination of soil moisture in the oak grove – once a month during the growing season; determination of current oak waste – once a year); periodic control (sanitary and phytopathological examination of the oak forest, clarification of its area, number of oaks, density of oak growth, analysis of foci of deterioration and increased oak loss, analysis of the dynamics and structure of current oak loss, determination of the number of oaks with certain pathologies – once every five years) were extended.

As a result of three detailed surveys of the oak forest (2012, 2017 and 2022), changes in the phytocenotic structure of the oak forest were monitored, the dynamics of the phytosanitary state of the oak forest as a whole and in each quarter, and a forecast of the viability of the oak forest was made (Dragan, 2015b; Dragan & Pydorich, 2019; Dragan et al., 2023).

One of the results of monitoring studies was the detection of ecotonization of oak phytocenoses, most pronounced in neighborhoods with anthropogenically changed structure and disrupted integrity (Galkin & Dragan, 2013). Ecotones were places of significant deterioration and major oak loss. Until 2017, 95% of the total oak loss in the oak forest occurred in ecotones; from 2017 to 2022, 92%. In some ecotones, competitive relations arose between the edificator species and its companions (heart-leaved linden), and active processes of structural and functional restructuring of the phytocenosis. As a result of the spatial expansion of the ecotone along the Linden Alley, the oak was pushed out to a distance of 50–90 m into the block (Dragan, 2013).

An important component of monitoring studies was the control of oak decline and the dynamics of current decline, as well as the structure of decline (Galkin et al., 2012; Dragan et al., 2019). Mapping the fallen oaks made it possible to determine the spatial characteristics of litter and the centers of acute and chronic litter. In particular, such centers include the quarters in the central part of the oak forest, most transformed by economic activity.

In quarter No. 14, 92 oak trees fell during the observation period (since 2006), in quarter No. 8, 39 oak trees (41.5%). While in quarter 6, which has preserved the largest number of criteria for old natural forests and has not undergone interference in its integrity and species structure, 33 oak trees fell, only 9.3% of the total number. In total, 571 oak trees fell in the oak forest during the observation period (24.6% of the total number). The indicator of current oak loss was also informative, characterizing not only the quantitative loss for each year but also predicting the loss for the coming years (by considering drying oaks, category IV of vital condition). This indicator began to grow from 1.4% (2017) to 5.1% in 2024.

### **Soil moisture as an indicator of the conditions of old oak stands**

Soil moisture is a critical resource for forest ecosystems; its availability influences tree physiological processes (Bréda et al., 2006; Skiadaresis et al., 2021), and changes in the hydrological regime affect oak growth sensitivity (Sylenko et al., 2026). Although

pedunculate oak (*Quercus robur* L.) is adapted to a wide range of environmental conditions and soil types, and its root system enables it to withstand periods of low soil moisture (Leuschner et al., 2001), substantial changes in soil moisture availability may increase oak mortality (Gričar et al., 2013; Sohar et al., 2014).

In the Dendropark “Olexandria”, soil moisture is systematically monitored in old oak stands in various stand structures: with a preserved vertical structure, park-type stands, and anthropogenically transformed areas. Fieldwork is conducted during the growing season of the pedunculate oak (from April to October). Soil samples were collected monthly from soil horizons at depths of 0–100 cm and processed in the laboratory according to the method described by Lisoval et al. (1984).

The study showed that since 2014, soil moisture in the root zone of old oak stands of the Dendropark “Olexandria” has systematically declined to critical levels during the summer-autumn months (Sylenko & Dragan, 2019). According to the 2019–2022 monitoring data, the most stable water supply indicators were observed in 2021 during most of the oak-growing season, whereas in other years they declined to critical levels during the second half of the growing season or even in May (in 2022). It has been established that a well-preserved vertical forest structure contributes to higher soil moisture (Sylenko, 2020). However, monitoring data show that this pattern is not stable over time and varies from year to year. Although in 2024 there was still a difference in moisture indicators in various phytocenotic structures and their decrease to critical values (Sylenko & Morozova, 2025), the latest studies in 2025 indicate that this trend was no longer evident, as adequate soil moisture levels were maintained in all soil horizons from July to September. It was established that the moisture indicators in the anthropogenically transformed area were slightly lower, especially at the end of the season: the values in the 40–60 horizons approached the critical values, and the 80–100 horizons could not be selected because the soil was extremely dry. Anthropogenic pressure reduces soil water infiltration capacity, reduces biodiversity, and alters the structure and composition of plant communities.

## The studies on the Golendernya tract

In 2008, the Golendernya tract, which had historically formed a single complex with the Dendropark “Olexandria”, was officially joined to the dendropark (Decree of the President of Ukraine No. 538/2008). In the same year, studies on the growth conditions, structure, and phytosanitary conditions of the old oak forest in the Golendernya tract began (Dragan, 2015a).

The boundaries of the old oak forest were established; its area (35.4 ha) was measured; at that time, about 1200 oak trees aged about 100–200 years grew on it, and eight trees aged about 240 years were discovered. It was found that the landscape type within the oak forest is a closed space with vertical crown closure. The site conditions were classified as type C2. The phytocenotic structure of oak plantations is described. According to the level of degradation of the stand and grass cover within the old-growth oak forest, three types of plots were distinguished. The taxonomic indicators of oaks in plots of varying degrees of degradation were determined.

Within the framework of edaphic studies, the type and structure of the soil were studied, a description of the soil profile was made, and the physical (density), water, and agroclimatic (“Holenderna”) are thin, gray forest, sandy loam, with a share of sand fraction of 65–86%, and clay – 6–18%.

Soil degradation was accompanied by compaction, nutrient depletion, and an unsatisfactory hydrological regime (Dragan, 2012). This caused stunted oaks, deterioration of their sanitary and phytopathological condition, and high current waste. The intensity of these processes was directly dependent on the level of anthropogenic load and the magnitude of soil transformation caused by it; in extreme cases, there was a disintegration of stands and their replacement by weed-meadow vegetation, the formation of a mosaic of the aboveground cover in the form of a complex combination of trampled and natural forest areas. Part of the oak plantations was on the verge of stability, while a large part was in a state of degradation (Dragan, 2011).

In 2017 (Dragan et al., 2017) and 2025, repeated surveys of the oak forest of the tract were carried out, and active processes of restoration of the aboveground cover, successful restoration of the edificator

species and its satellites were revealed, which became possible thanks to the organization of protection of the territory of the tract.

### **Development of cenopopulations of woody plants of the main park-forming species of the Dendropark "Olexandria"**

In 2017–2022, the study of the structural organization and developmental patterns of cenopopulations of the main park-forming woody species of the Dendropark "Olexandria" began as part of their conservation in response to the threats posed by climate change and biological invasions by alien dendrophilic insect species and phytopathogenic organisms.

A comprehensive survey of five main park-forming species (sharp-leaved maple, field maple, common ash, heart-leaved linden, common hornbeam) of the Dendropark "Olexandria" was conducted with the determination of the quantitative composition (Boiko et al., 2022), spatial distribution (Boiko et al., 2024), age spectrum (Dragan et al., 2022), vitality structure and phytosanitary condition, main diseases and pests, including invasive organisms, leading to mass loss of woody plants; dynamics and centers of loss of the main park-forming species. Phytosanitary conditions and causes of mass loss were studied not only for five main park-forming species but also for species that form the basis of decorative landscape compositions (Dragan & Pydorich, 2016, 2019; Dragan & Galkin, 2017; Dragan et al., 2020, 2021; Dragan & Dragan, 2023a).

The phytocenotic role of the main park-forming species has been determined (Boiko et al., 2025; Dragan et al., 2024d). It was established that the distribution of the studied species throughout the park exhibits species-specific patterns depending on the ecological conditions of the ecotopes and the direction and intensity of successional processes in the areas. Sharp-leaved and field maples are distributed throughout the Dendropark "Oleksandria". However, their greatest abundance is observed in the old-growth oak forest. The maximum abundance of common ash is observed in the eastern and northeastern parts of the park, with abundance gradually decreasing westward. However, it has formed a large population in the southwestern part of the park. The most numerous mixed-age populations of heart-

leaved linden have formed in the oak-type areas in the central and western parts of the park. In the non-oak-type areas, there are very few natural stands of heart-leaved linden. The distribution of common hornbeam in general resembles that of common ash.

A significant diversity of age spectra was revealed, which was determined by the presence of a reserve for replenishing the population – seedlings, undergrowth, young plants of the pregenerative state, generative individuals of different age groups, senile plants; continuous or discontinuous age spectrum, or discontinuous (absence of certain age groups in the spectrum), dominance of one or another age group.

In most oak forest areas, populations of common maple are in a normal state, have a full-membered structure, and are stable, with a left-sided (dominance of young plants) or 'central' (dominated by the most productive age groups – thorny or middle-aged) maximum. In the field maple, the diversity of age spectra is the highest among all studied species. Stable populations with a left-sided or 'central' maximum with different spectral variants are found in many areas of oak and non-oak forest types.

In common ash, invasive populations are widespread, indicating the spread of this species to areas previously uninhabited by it. In most areas, ash has both complete and incomplete members, with a discontinuous and a non-discontinuous spectrum, and a left-sided or 'central' maximum. There are no populations with a right-sided maximum, which indicates the short-lived nature of ash stands in the park. This species is subject to rapid changes in the age composition of cenopopulations, and there is a threat of its complete disappearance from the park stands. For heart-leaved linden, a complete age spectrum with a "central" maximum is characteristic in many areas of the park. In most cases, the dominant age groups are lindens. In a number of blocks, the age spectra have a right-sided maximum (in artificial stands). In all cases, weak recovery and an extremely small number of young plants in the pregenerative and early generative stages make the populations of this species unstable. In several quarters, the population of heart-leaved linden is represented only by fragments.

The most numerous age group in all species in most ecotopes is young plants. The main pathologies of young plants up to 20 years of age were bark necrosis, young shoot necrosis, stem cancer, crown thinning, dry tops, and, in common ash, halary necrosis. With age, the variety of pathologies, their habitual manifestations, and the number of affected trees increased. The most common were rot, necrotic-cancerous ulcers, bacterial dropsy, dry top, and in common ash, halary necrosis. Criteria for the preservation of old natural forests by the age-old oak arboretum were established (Boiko et al., 2023).

Since 2023, studies of forest successions within the arboretum's phytocenoses have been conducted. When studying forest successions, the dominant population paradigm was used to understand successions as processes of destruction or restoration of population mosaics of edificators, or changes in dominant populations. The population dynamics of woody plants, price-forming plants, and plant groups in the arboretum's ecotopes were studied; the directions of micro-succession of mosaic elements in the arboretum's phytocenoses were also examined. The research aimed to study changes in the floristic composition, spatial, age, and phytosanitary structure of groups, natural renewal, the rate of species change, the decrease in the share of edificators in oak forests, and the successional shift towards shade-tolerant species. Particular importance was given to studying the dynamics of the main price-forming factors in the context of climate change, outbreaks of pest and disease outbreaks, biological invasions, and various anthropogenic influences.

The study of factors determining the level of biodiversity, structural organization, and differentiation of vegetation led to an understanding of the weakening and degradation of the arboretum's oak forest as a complex, multifactorial syndrome. This was followed by the study of the degradation of the oak forest using conceptual models of decline: the chain model of diseases (Houston, 1987); the spiral of diseases, or the spiral of death (Manion, 1991); the conceptual model of the interaction of significant abiotic and biotic factors in the onset of oak decline

in Central Europe (Thomas et al., 2002; Macháčová et al., 2022); cohort aging models of Mueller-Dombois (1992). The polyvariance of successional processes and the diversity of restoration processes in the arboretum's phytocenoses were identified and described (Dragan et al., 2024c).

Research on the restoration of holm oak and the main park-forming species in the light windows of the oak forest (2023–2026). The temporal-spatial mosaic of small areas (light windows) that regularly appear as a result of tree loss, i.e., the mosaic of mini-successions, was studied. An analysis was carried out of microcoenoses that form on the site of 'fallout windows' and transects that form as a result of the loss of woody plants or their groups in stands ('patch dynamics', 'gap dynamics'). The dynamics of the spatial and floristic structure of these microcoenoses were studied, and trends in the formation of groups of dominant species were identified. Factors that limit or make impossible the natural renewal of the edificator species and its satellites were described (Dragan et al., 2024a, 2024b).

Thus, long-term monitoring, succession studies, and analysis of archival data have shown that degradation processes are constantly occurring in the territory of the old-growth oak forest of the Dendropark "Olexandria", with temporal and territorial characteristics and different consequences, explained by different models of forest decline. The specificity of these processes is determined by a complex of negative factors, as well as by the duration and sequence of their action. The most dangerous factor for natural stands, particularly oak forests, is anthropogenic (Dragan, 2013). Under its influence, the degradation of stands is linear and irreversible. With a short-term effect of non-anthropogenic factors, and when their action ceases, the processes of destruction, as a rule, are suspended.

Among the priority areas of future research are the possibility and feasibility of restoring oak forests, the question of whether to preserve or restore oak forests, and the fate that awaits oak forests as a result of the gradual loss of edificatory properties in common oak and the dominance of shade-tolerant species.

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## 80 років дендропарку "Олександрія" у складі Національної академії наук України: Еколого-ценотичні дослідження вікової природної діброви та основних паркоутворюючих видів деревних рослин у дендропарку "Олександрія"

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Ця публікація є підсумком наукових досліджень авторів за 25-річний період і відкриває серію публікацій, присвячених 80-річчю Державного дендрологічного парку "Олександрія" (дендропарку "Олександрія") у складі Академії наук України. Основні дослідження зосереджені на ландшафтоутворюючих породах дерев парку – сосні звичайній та дубі звичайному. Низка популяційних досліджень стосувалася також й інших паркоутворювальних видів дерев. У дендропарку "Олександрія" сосна звичайна становить основу більшості декоративних композицій, тоді як дуб звичайний зберігає свою роль головного виду в природному старовіковому дубовому лісі дендропарку. На сьогодні він має сильні формувальні властивості, захищає флористичне ядро дубового лісу та визначає його екологічну цінність. Усі наші дослідження були присвячені раніше невивченим питанням. Щодо сосни звичайної, вивчалися загальні морфогенетичні реакції та їхні напрямки під час адаптації до міських умов. Вперше в Україні було оцінено вплив радіоактивного забруднення на морфогенез сосни звичайної за межами 30-кілометрової зони Чорнобильської аварії. Щодо дубового лісу було досліджено вплив тривалого антропогенного втручання на його цілісність, структуру та життєздатність. Було розпочато моніторинг лісової патології старого дубового лісу. На початковому етапі було проведено дослідження видів-едификаторів. Згодом було проведено комплексні дослідження популяцій деревних рослин, що супроводжують дуб і входять до флористичного ядра дубового лісу. Згодом аналогічні дослідження основних паркоутворювальних видів було поширено на недібровні ділянки дендропарку "Олександрія". В останні роки розпочато дослідження процесів сукцесії у старовіковому дубовому лісі, зокрема визначення факторів, шляхів та моделей деградації дубового лісу; вивчення можливості його відновлення або збереження; а також наслідків для фітоценозів, пов'язаних зі змінами домінуючих видів. Значна частина досліджень була присвячена детальному вивченню умов росту, структурної організації та фітосанітарного стану старовікового дубового лісу ділянки "Голендерня", яка у 2008 році увійшла до складу дендропарку "Олександрія".

**Ключові слова:** дендропарк "Олександрія", старовікові діброви, основні паркоутворюючі породи, сосна звичайна, дуб звичайний, морфогенез, моніторинг, сукцесія