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The Department of Biology, Ecology, and their Teaching Methods

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“BESSER NATURAL HISTORY STUDIES”

*To mark the 240th anniversary of the birth of the renowned botanist
Willibald Besser and the 215th anniversary of the beginning of his scientific
and pedagogical work in Kremenets*

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A BRIEF INTRODUCTION TO THE DEPARTMENT OF BIOLOGY, ECOLOGY, AND THEIR TEACHING METHODS AT TARAS SHEVCHENKO KREMENETS REGIONAL ACADEMY OF HUMANITIES AND PEDAGOGY

This collection presents the materials of the Second International Scientific Conference *Besser Natural History Studies*, dedicated to the 240th anniversary of the birth of the renowned botanist Willibald Gottlieb von Besser and the 215th anniversary of the beginning of his scientific and pedagogical work in Kremenets.

For many decades, Kremenets has been a significant centre for the emergence, development, and advancement of higher education, not only in the Volyn region but also throughout Ukraine. Taras Shevchenko Kremenets Regional Academy of Humanities and Pedagogy continues the rich, over 200-year-old legacy of the town's academic institutions.

Despite the hardships of war, Ukraine remains committed to advancing scientific research. The Department of Biology, Ecology, and their Teaching Methods continues to develop the botanical research pioneered by the renowned scientist W. G. von Besser in Kremenets. W. G. von Besser dedicated most of his life to Kremenets, where his exceptional talent and scientific achievements transformed the town into one of Europe's leading centres of botanical research. Today, botanists worldwide associate Kremenets with W. G. von Besser, recognizing him as the first researcher of Ukraine's flora. His legacy endures, with both his former residence and burial site preserved in the town.

The conference was held to promote scientific communication among researchers working on the development of biological science.

The Department of Biology, Ecology, and their Teaching Methods is part of the Faculty of Physical Education, Biology, and Psychology. Its primary mission is to develop professional competence



in future specialists, equipping them with the knowledge, skills, and personal qualities necessary for success in their fields.

The department is dedicated to providing high-quality training for future teachers of biology, health studies, and geography in secondary education, as well as for ecologists and conservation specialists. Graduates are prepared to be competitive in the labour market, proficient in their professions, and adaptable to related fields of activity.

From 2004 to 2015, the department was led by the distinguished botanist, Professor and Academician V. I. Chopyk. Under his leadership, the department initiated the creation of a herbarium of Western Podillia's flora — a scientific treasure trove and an invaluable resource for further research.

To enhance practical training for future specialists, the department established several research laboratories, including *"Human Problems and the Philosophy of Health," "Ecological Monitoring and Experimental Biology,"* and *"Innovations in Biological and Ecological Education."*

The department's key research areas include studying the impact of urban environments and climatic factors on human health, analysing the biotic diversity of Northern Podillia — its current state and anthropogenic transformation — and exploring modern approaches to implementing innovative practices in education. A vital component of the department's educational and practical base is its greenhouse, which plays a crucial role in the comprehensive training of future biology and ecology specialists.

Strong professional ties between the department and regional scientific institutions have fostered close collaboration with the Kremenets Botanical Garden, the *Kremenets Mountains*, and the *Podilski Tovtry* National Natural Parks. These partnerships have resulted in the organization of international conferences such as *"Besser Natural Science Studies"* (2014) and *"Podilski Readings"* (2017, 2018). Additionally, within this framework of cooperation, the department arranges student educational practices, conducts large-scale environmental and educational events for schoolchildren and students, and engages in practical activities focused on environmental protection and conservation.



The department established the “*ECOHUB KREMENETS*” centre in 2021 as a hub for education, training, and the promotion of the *Zero Waste* concept. This initiative aims to raise awareness and encourage sustainable practices within the community.

Additionally, the department operates an air quality monitoring station equipped with wind direction and speed sensors from *SaveEcoBot*. This is the only ecological system in Ukraine that integrates real-time environmental data, including air pollution levels, pollutant concentrations, and environmental protection measures.



The department serves as a hub for biodiversity conservation initiatives and a key centre for both formal and informal environmental education in the region. Its members played a pivotal role in establishing the Kremenets district branch of the *International Association of University Ecologists*, which engages in organizational, scientific, educational, and publishing activities in accordance with its charter. To enhance environmental education, the department’s educators actively integrate modern tools such as *i-Tree* software for ecological analysis, *DOCU/CLUB* network documentaries, and interactive eco-board games into their teaching and outreach efforts.

The department offers comprehensive training for students pursuing bachelor’s and master’s degrees in *Secondary Education (Biology and Human Health)* and *Ecology*.

Graduates of the department receive rigorous preparation, enabling them to work in educational institutions as well as in biological, medical, environmental, and agricultural sectors. Many alumni have gone on to become school directors, researchers, and scholars, earning degrees in biological, agricultural, and historical sciences.

Committed to excellence, the department upholds its strong educational, scientific, and methodological traditions while continuously developing innovative approaches to enhance the training of highly qualified teachers for modern Ukrainian schools.

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THE BOTANICAL GARDEN — THOUGHTS ABOUT THE FUTURE

Andreas Wenninger, MA, born in Vienna in 1968, has served as the Head of the OeAD Cooperation Office in Lviv and Attaché for Science and Education at the Austrian Embassy in Kyiv since October 2000. In February 2022, he also assumed the role of Head of the Ukraine Section in Austria within the Department for International Cultural Affairs of the Austrian Foreign Ministry. He studied Eastern European history, painting and graphics, and cultural management in Vienna.

Ten years ago, on the occasion of the 230th anniversary of the birth of botanist Willibald Besser, we met here in Kremenets with botanists, gardeners and the director of the Austrian Federal Gardens and Parks, Professor Brigitte Mang, and honoured our common Austrian-Ukrainian history and the botanist Willibald Besser. Willibald Besser was born in Innsbruck, but his life path brought him to Kremenets. Professor Mang now works in a different position, but nevertheless sends her warmest greetings and wishes on the occasion of this anniversary.

Willibald Besser is one example of a scientist in the very broad and interconnected cultural and scientific environment of the 19th century within the former Austro-Hungarian monarchy. During the Napoleonic Wars, he was forced to leave his native Innsbruck in Alpine Tyrol as an orphan. His journey took him through Lviv and Kraków before he eventually settled in Kremenets and later in Kyiv. Besser studied in Lviv and Kraków, conducted research, travelled across Volhynia, Galicia, and the vast steppe expanses to the Caucasus and Crimea, and facilitated the exchange of botanical material with colleagues throughout Europe. Today, many young botanists learn about him in their studies, and several plant species bear his name. Thank you for preserving this shared historical heritage!

As a lover of gardens and parks, I would like to share a few thoughts on the future of the Botanical Garden and the invaluable importance of your work. Today, a garden or vegetable plot is typically a place where people grow vegetables, pick fruit, hang a hammock, or grill sausages. Such spaces are usually private property, enclosed by boundaries, hedges, fences, or walls that

separate them from neighbouring plots. Access to these gardens is limited, and not everyone is welcome there.

The idea of a garden or park as a living space is rarely considered. A prime example of this concept is the Christian Paradise, or Garden of Eden, where two humans, God, animals, and plants coexisted. The term “paradise” originally referred to an “enclosed space,” and in ancient Greek, παράδεισος (*parádeisos*) also denoted a fenced garden or park for animals. Even in the earliest known epic, *The Epic of Gilgamesh*, there is evidence of gardens in Uruk that served representational and recreational purposes. Such “paradises” are believed to have spread from the Near East to the Mediterranean.

Throughout human history, the meaning and use of gardens have evolved. The monastery garden, the Baroque public park, the English park, Japanese garden art, the alpine garden, the integrative public garden, the art garden (such as the one created by Austrian artist André Heller in Marrakech), and urban greening are just a few examples of the many garden and park styles that have emerged over the past 2,000 years. And the development continues.

In recent years, gardeners in the English-speaking world have begun implementing a cutting-edge concept known as the “intelligent garden network.” These “Cognitive Gardens” integrate artificial intelligence technologies to enhance the productivity of living systems. Technicians install a series of sensors in the garden beds, which transmit data to a computer, enabling gardeners to monitor and respond to the plants’ needs with unprecedented precision.

In a new study published in *New Phytologist*, a team of scientists from the Royal Botanic Gardens, Kew, the UK, has used advanced software and artificial intelligence to predict, for the first time, the risk of extinction for all 328,565 known species of flowering plants.

This ground-breaking research enables anyone — from a private individual selecting their first houseplant to a professional biodiversity researcher — to search for any species online and instantly determine whether it is threatened with extinction in the wild. Revolutionary artificial intelligence may help protect the world’s plants from extinction amid the growing threats of climate change. Tomorrow’s gardens rely on today’s technology.

Plants, in turn, offer natural solutions to the challenges of climate change, such as absorbing carbon from the air and protecting coastlines from erosion. Understanding their extinction status helps us assess the resources still available and recognize when a vital natural asset is at risk of disappearing.

Plants have developed adaptation mechanisms that differ significantly from those of animals and humans. In the 21st century, humanity can learn a great deal from botany. Because plants are sedentary, barely moving, and do not seek contact with us, we often perceive them as mere green decorations rather than living beings. We value them as vegetables or fruits, admire their flowers, or protect them as the foundation of ecology. However, unlike animals, plants do not flee or attack when faced with danger; instead, they remain in place and respond at an extremely slow pace. It rarely occurs to us that the surrounding plants may possess some form of intelligence.

Plants often discover solutions that humans would never have imagined. They play a crucial role in maintaining healthy, resilient ecosystems and can provide natural solutions to combat climate change while supporting efforts to restore degraded environments. To achieve the global goals of the Convention on Biological Diversity, it is essential to understand which plants exist, where they are found, and the conditions in which they thrive.

We deeply appreciate your invaluable botanical research and contributions to the Botanical Garden. Many new and exciting challenges lie ahead, especially with modern technological advancements and the evolving nature of research, which continually reshape the botanists' work.

THE SCIENTIFIC HERITAGE OF WILLIBALD BESSER AND THE KREMENETS PERIOD OF HIS ACTIVITY

Svitlana Pyda, Candidate of Biological Sciences (Ph.D. in Biology), Doctor of Agricultural Sciences, Professor, and Head of the Department of Botany and Zoology at Ternopil Volodymyr Hnatyuk National Pedagogical University. Born in 1959. In 1994, she defended her candidate's thesis on "Allelopathic and Symbiotic Features of Lupine at Different Levels of Nitrogen Nutrition." In 2007, she earned her doctoral degree with a dissertation titled "Physiology of Symbiosis in *Bradyrhizobium* sp. (*Lupinus*) — *Lupinus* L. Systems: An Allelopathic Analysis." In 2011, she was awarded the academic title of Professor in the Department of Botany. Her research focuses on the mechanisms of legume-rhizobial symbiosis under the influence of bacterial preparations and plant growth regulators of natural origin. She also studies the effects of nodule bacteria strains, biologically active substances, organo-mineral fertilizers, and pesticides on the physiological parameters and productivity of agricultural crops, as well as the historical development of biological science. Email: pyda@chem-bio.com.ua

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This year, the scientific community commemorates the 240th anniversary of the birth and the 215th anniversary of the commencement of the scientific

and pedagogical career of Willibald Gotlibovich Besser (1784–1842), a renowned botanist and entomologist, and Doctor of Medicine in the first half of the 19th century. W.G. Besser was the first to study the flora of western and southwestern Ukraine, gaining recognition as a distinguished morphosystematist of vascular plants and a prominent introducer of species. He is also celebrated for founding the Kremenets Botanical Garden (now the Kremenets Botanical Garden under the Ministry of Ecology and Natural Resources of Ukraine), the Botanical Garden of the Saint Volodymyr Imperial University of Kyiv (now the Academician Oleksandr Fomin Botanical Garden of Taras Shevchenko National University of Kyiv), and the Department of Botany at the same university.

Willibald Swibert Joseph Gottlieb von Besser (also known as Vilibald Gotlibovich Besser) was born on July 18, 1784 (July 7, Old Style), in Innsbruck, in western Austria. He began his education in his hometown but was orphaned at the age of 13. From 1797, he was raised and educated in Lviv by his mother's relative, S. B. Schivereck, a professor of botany and chemistry at Lviv University. In Lviv, he completed the gymnasium and enrolled at the university. However, in 1805, he moved to Kraków, where he graduated from the local university in 1807 with a doctoral degree in medicine. He subsequently began working as an assistant in a clinic while simultaneously studying the local flora [4, pp. 38–39; 6].

Willibald Besser's work in Ukraine began in 1809 and was associated with two institutions. From 1809 to 1834, he served as a teacher of natural history and director of the botanical garden at the Higher Volyn Gymnasium, which became the Kremenets Lyceum in 1818. Later, from 1834 to 1838, he became the first professor of botany at the Saint Volodymyr Imperial University of Kyiv (now Taras Shevchenko National University of Kyiv) [3, pp. 120–121; 7, pp. 98–99; 10].

Willibald Besser moved to Kremenets at the invitation of Tadeusz Czacki, the director of the Higher Volyn Gymnasium. Botany was one of the academic disciplines that T. Czacki actively supported and promoted in the institutions under his supervision as the inspector of education for the Volyn Governorate. To secure a professor of botany for the gymnasium, T. Czacki corresponded with professors at the University of Kraków (now the Jagiellonian University in Kraków, Poland), including Professor Jackiewicz, who recommended Doctor of Medicine Willibald Besser for the position. Although Besser was

a foreigner, he had lived in Poland for an extended period and was well-acquainted with the flora of Galicia, much of which he had already studied [3, p. 120; 11, pp. 342–347]. Willibald Besser accepted Tadeusz Czacki's invitation to become a teacher of zoology, botany, and natural history, as well as to assume the role of director of the botanical garden. On July 1, 1808, he signed an agreement in Kraków, which included a provision for a one-year trip to Vienna at the gymnasium's expense to further his knowledge in these fields [4, p. 38; 11, pp. 342–347].

After completing his internship, Willibald Besser moved to Kremenets in June 1809, marking the beginning of his long-standing association with Ukraine. The rich and largely unexplored flora of Volyn and Podillia became the foundation for his scientific research, which ultimately earned him international recognition in the field of botany [4, p. 38].

At the Higher Volyn Gymnasium, and later at the Volyn Lyceum, Willibald Besser taught natural sciences, actively reorganized the Kremenets Botanical Garden, and expanded its botanical and zoological collections. The botanical garden, originally established in 1806 by the Irish botanist Dionysius Mickler on approximately 4.5 hectares adjacent to the Volyn Gymnasium estate, underwent significant changes under Besser's leadership, both in its appearance and operational structure. Through his relentless efforts and extensive network of scientific contacts, Willibald Besser transformed the Kremenets Botanical Garden into a renowned European scientific institution. He established connections with numerous botanical gardens, including those in Kraków, Vienna, Göttingen, Vilnius, and Paris [2, pp. 85–88; 5, pp. 31–39].

As director of the botanical garden, Willibald Besser actively worked to expand and improve its territory. Under his leadership, an innovative irrigation system was constructed to prevent the destructive effects of water runoff from the surrounding mountain slopes. Besser's efforts led to an increase in the number of greenhouses and hothouses in the garden. He expanded the botanical garden to 20 hectares and built the first residential buildings for gardeners, significantly improving plant care. During Besser's tenure in Kremenets, experienced specialists served as gardeners: I. Grabowski (1809–1818) and K. Winzel (1818–1827). The longest-serving gardener was V. Hoffmann (1827–1845), who, in 1834, collaborated with Besser on the transportation of plants from the Kremenets Botanical Garden to Kyiv [1, p. 370; 3, p. 121; 9, pp. 317–320]. At that time, the Kremenets Botanical Garden became one of the key centers

for introducing new plant species in Ukraine. Around 100 plant species were first cultivated within its territory [5, pp. 31–39]. By 1823, the number of plant species grown in the garden had reached 9,000, and by 1832, it had increased to 12,000 [1, p. 370; 4, p. 39]. This expansion allowed Willibald Besser to observe plant development dynamics, analyze their morphological structure and phenology, and more precisely determine the boundaries of phenotypic variability, contributing to a deeper understanding of these species. He also sought to engage the local intelligentsia in the study of nature. In 1826, Besser wrote and published a brochure in Vilnius for teachers of powiat schools (county schools), outlining methods for studying flora. It included descriptions of powiats, techniques for collecting and drying plants, examples of herbarium sheets, and guidelines for arranging plants for shipment. Teachers were encouraged to conduct biological research, and between 1826 and 1830, each collected and sent between 100 and 500 herbarium sheets to the Kremenets Botanical Garden, often adding descriptions and noting growth locations. These collections came from Right-Bank Ukraine, Belarus, and Lithuania. Besser not only received herbarium sheets but also returned identified plants to the schools, keeping one copy for himself [10; 12, pp. 145–151].

Thanks to Willibald Besser's efforts, a large collection of herbaceous ornamental plants was assembled in the Kremenets Botanical Garden. These plants were described in the work *Spis roślin ozdobnych znajdujących się w ogrodzie botanicznym liceum Wołyńskiego w Krzemieńcu*, published in Kremenets in 1821 [2, pp. 85–88].

Professor Besser continuously enriched the botanical garden's herbarium with plants not only from Ukraine but also from Europe and other regions of the world. For example, he received part of the herbarium from Professor S. B. Schivereck, who had collected numerous plant specimens in Austria, Tyrol, Galicia, and other parts of Europe. When relocated to Kyiv, the herbarium contained specimens of 18,000 plant species [9, pp. 317–321].

To enhance the species composition of the botanical garden, Willibald Besser corresponded with and exchanged plants, seeds, and herbarium materials with botanical gardens across Europe, including those in Warsaw, Vienna, Hamburg, Heidelberg, Göttingen, Dresden, Copenhagen, Leipzig, London, Madrid, Paris, and Prague. His active efforts enabled the Kremenets Botanical Garden to be recognized in the global nomenclature of botanical gardens [9, pp. 317–321].

The popularization and development of the botanical garden in Kremenets were further supported by the publication of plant catalogues. In 1810, Willibald Besser compiled and published the first catalogue of the botanical garden's plants in French, detailing the scope and nature of plant introduction and acclimatization from France, Switzerland, Germany, Belgium, America, and other countries. For example, species such as the *Amorpha fruticosa*, the *Corylus colurna* (the Turkish hazel), the *Gleditsia triacanthos* (the honey locust), the *Cotinus coggygria* (the European smoketree), the *Rhus typhina* (the staghorn sumac), the *Symphoricarpos rivularis*, and the *Ptelea trifoliata* (the common hoptree) were first acclimatized in the botanical garden and later spread throughout Ukraine [3, p. 122; 5, pp. 31–39].

During his work in Kremenets until 1830, Willibald Besser published eleven catalogues of the botanical garden's plants, which are now considered bibliographic rarities. He meticulously prepared these catalogues, attracting the attention of botanists and specialists in botanical gardens and parks, thereby enhancing the garden's reputation. According to E. Yanchevska [9, pp. 317–321], two catalogues have been preserved in the Lviv Library of the NAS of Ukraine: one from 1810, published in French, and another from 1816, published in Latin. In 1819, 1820, 1821, 1823, and 1830, Besser also published catalogues of plant seeds from the Kremenets Botanical Garden, along with descriptions of newly discovered plant species collected in Volyn and Podillia.

In addition to his teaching activities and work in the botanical garden, Willibald Besser devoted a significant part of his time to studying the flora of Right-Bank Ukraine, particularly in Volyn and Podillia. He organized and led scientific expeditions in which his students A. L. Andrzejowski and P. S. Rogovych participated. Between 1809 and 1845, Willibald Besser published 43 works focused on floristics; the systematics of certain genera, such as *Artemisia*, *Rosa*, and *Veronica*; introductions (catalogues of plants and seeds from the Kremenets Botanical Garden and their appendices); the history of botanical science; and methodologies for creating scientific herbaria. His most significant and well-known contribution to the study of flora is the two-volume edition *Primitiae florae Galiciae Austriacae utriusque*, published in 1809 in Vienna. This work is dedicated to the study of the flora of former Galicia and includes descriptions of 1,212 species of vascular plants according to the system of C. Linnaeus [2, pp. 85–88].

No less important for botanists is the compilation of the flora of Volyn, Podillia, Kyiv Governorate, the Odessa region, and parts of Moldova, titled *Enumeratio plantarum hujusque in Volhynia, Podolia, Gub. Kijoviensi, Bessarabia Cis-Tyraica et circa Odessam collectarum simul cum observationibus in Primitias Florae Galiciae Austriacae*, published in 1822 in Vilnius. This was the first scientific compilation of the flora of Right-Bank Ukraine, including information on 1,632 plant species, more than 70 of which were new to science [7, pp. 98–100]. Among the new species described by the author were *Aster amelloides* Bess., *Carlina onopordifolia* Bess., *Centaurea stereophylla* Bess., *Medicago procumbens* Bess., *Pulsatilla vulgaris* Bess., *Viola alba* Bess., *V. uliginosa* Bess., *Salvia cremenecensis* Bess., *Rosa czackiana* Bess., and others — 37 of which have retained their names in modern plant taxonomy in Ukraine [8].

It is also worth noting that Willibald Besser was the first among domestic botanists to attempt an analysis of the flora of Volyn and Podillia from a geographical perspective. He sought to investigate the chorological characteristics of the region's flora and its connections with the flora of neighboring and more distant territories. In his work *Aperçu de la géographie botanique de la Volhynie et de la Podolie*, published in 1823 and reprinted in Polish in 1828 in Vilnius (*Rzut oka na geografję fizyczną Wołynia i Podola*), Besser examined the flora of Volyn and Podillia in terms of areal features — specifically, its similarities and differences with the floras of regions to the east and north, as well as Siberia, the Tauride, the Caucasus, Austria, Germany, and Italy.

Although from a modern perspective the ideas of this early 19th-century scientist about geographical range groups were somewhat simplified, and his attempt to conduct a geographical analysis based on them was not entirely successful, it is important to recognize that at the time, a developed theory of plant ranges did not yet exist, and the accumulation of reliable chorological data was only beginning. Besser's undeniable contribution was that he was significantly ahead of his time in his efforts to generalize and understand the patterns of species distribution based on geography. It was only half a century later that the first fundamental principles of botanical-geographical analysis were formulated [7, pp. 98–100].

In Kremenets, in addition to teaching at the lyceum and conducting scientific research in the botanical garden, Willibald Besser also provided medical treatment to local residents. In 1831, during a cholera epidemic, he worked in an infectious disease hospital and offered free assistance to the sick in

Kremenets. After moving to Kyiv, he continued to practice medicine [4, p. 41; 9, pp. 317–321].

On January 31, 1834, Willibald Besser was appointed ordinary professor of botany at the Saint Volodymyr Imperial University of Kyiv, where he headed the Department of Botany. He delivered his lectures in Latin, as he did not know Russian. For first-year students, he taught organography and plant terminology; for second-year students, plant systematics and physiology; and for senior students, courses on plant geography and the history of botany. Besser's contemporaries noted his deep knowledge of the subject, as well as his ability to support theoretical generalizations and conclusions with rich botanical material [4, pp. 38–40; 5, pp. 31–39].

In 1836, a decision was made to establish a botanical garden at the Saint Volodymyr Imperial University of Kyiv, which today is known as the Academician Oleksandr Fomin Botanical Garden of Taras Shevchenko National University of Kyiv. Professor of Botany Willibald Besser was appointed director of the garden. The herbarium of the Saint Volodymyr Imperial University of Kyiv at the time of its founding was based on several collections: the herbarium of greenhouse and garden plants from the Kremenets Lyceum, comprising 6,000 species; the herbarium of A. L. Andrzejowski, containing 10,000 species; and the herbarium of the Vilnius Medical and Surgical Academy. These herbaria are currently housed at the M. G. Kholodny Institute of Botany of the NAS of Ukraine and hold significant scientific and historical value.

In 1837, Professor Willibald Besser retired, and in 1841 he returned from Kyiv to Kremenets, where he died on October 23 (11), 1842, and was buried in the monastery cemetery [4, p. 39; 7, pp. 98–100].

The scientist's achievements were highly regarded by both the scientific community and the public of his time. He was an honorary and active member of more than ten scientific societies, including the Warsaw Society of Friends of Science, the Kraków Scientific Society, the Society of Gardeners in London, as well as scientific societies in Bonn, Leipzig (Lipsk), Berlin, and others. The people of Kremenets held Willibald Besser in deep respect as an outstanding figure who brought recognition to the Kremenets Botanical Garden, the Kremenets Lyceum, and the town of Kremenets on the international stage [3, p. 124; 4, p. 41].

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ATTRIBUTES OF THE FLORA ACROSS ZONES IN CARGO RAILWAY STATIONS: EASTERN POLAND AS A CASE STUDY

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In Europe, railway transport has been under development since the Industrial Revolution of the 18th century. Railways serve important economic and social functions, e.g., supporting links between countryside and urban areas, encouraging tourism, and ensuring the accessibility of various goods. On the other hand, the construction of railway lines represents a form of natural landscape transformation. Railway networks pass through various land-use types (e.g., agricultural, urban, or high-nature-value areas, i.e., compact forest complexes) and contribute to unprecedented changes in abiotic conditions, e.g., temperature, moisture, light availability, and wind speed. The exceptional mosaic of habitats within railway areas and the proximity of different surrounding ecosystems exposes organisms to diverse abiotic and biotic conditions.

The system of railway stations (cargo stations, passenger stations, transshipment stations) may play a distinctive role in altering railway flora and plant community composition. Most studies on the effect of distinctive railway habitats refer to railway flora *sensu lato* [1, pp. 229–248; 2, pp. 121–130], the formation of plant communities [11, pp. 659–666; 15, pp. 96–101; 9, pp. 126–133], or population dynamics [5, pp. 323–331]. Several papers have

considered railway areas as valuable reservoirs of biological diversity, e.g., habitats for rare and endangered species [12, pp. 545–553; 7, pp. 75–85; 3, pp. 19–24], or bee-forage species, which support pollinators [8, pp. e101297; 13, pp. 1666; 4, pp. 156551]. Railway areas with special characteristics of habitats, e.g., straight, open-space corridors and turbulent or vortex flows of air, have been regarded as habitats that might accelerate the dispersal of propagules and the migration of non-native plant species [10, pp. 721–729; 6, pp. 40–47; 14, pp. 1275–1284].

The study aimed to determine whether the species richness and composition correlate with characteristic zones (microhabitats) of cargo railway stations and to assess whether species in particular microhabitats differ in terms of key biological traits (life strategy, lifespan, pollination mode, crown height, dispersal type, and seed bank).

Floristic surveys of railway cargo stations were conducted in six cargo railway stations located in southeastern Poland. The stations were selected based on (i) location, (ii) the size of the station area, (iii) the station handling capacity, and (iv) the population density in the surrounding areas. Four distinctive zones (microhabitat types) were identified in each station: (i) railway track (area close to high-speed running tracks), (ii) railway siding (area used to ‘set aside’ trains, parts of trains, and to store rolling stock), (iii) cargo yard (area beside a siding area for loading/unloading goods), and (iv) railway embankment (a construction to support track stability). The flora was sampled in 15 transects randomly selected in each zone, resulting in 90 transects per zone and 360 in total (6 stations $\times$ 4 zones). Each transect was approximately 300 m long and 2–3 m wide.

Species richness was associated with specific anthropogenic disturbance across the distinctive zones within the railway cargo stations. Among the 602 plant taxa recorded in the entire dataset, there were 393 native species (65%) and 209 (35%) alien species, including 78 (13%) archaeophytes (i.e., aliens that arrived prior to 1500) and 131 (22%) neophytes (i.e., aliens that arrived after 1500). Most of the alien species were of European and western Asian origin (57%). The remaining 21% originated from North America (e.g., *Asclepias syriaca*, *Amaranthus albus*, *Echinocystis lobata*). The lowest number of species was observed in the cargo yard zone (mean = 21.3 ± 6.3 SD), and the highest number was found in the railway siding zone (mean = 74.7 ± 21.2 SD). The significant area-species relationship was observed only for native species.

The number of alien species, including invasive species, was linked to the cargo handling capacity of the stations.

The flora composition was affected by geographical location (altitude) and climatic variables (mean annual temperature and precipitation). However, approximately 30% of species were common across all cargo stations. When comparing biological traits, lifespan, canopy height, and seed bank differed among zones. Annual species predominated in the railway track zone (approximately 45%). Perennial species predominated in the railway siding, cargo yard, and railway embankment zones, accounting for approximately 44%. Tiny, rosette plants were common in the railway track and cargo yard zones (approximately 45%). Species taller than 30 cm were mainly found on the railway embankments.

The plants in the railway track formed a short-term persistent seed bank (approximately 36%). The species forming a transient seed bank were found mainly in the railway siding (approximately 44%) and railway embankment zones (approximately 54%). A long-term persistent seed bank was characteristic of the species in the cargo yards (approximately 52%).

Irrespective of the zone, the flora in the cargo railway areas was dominated by small-to-medium leaf area plants, C- or CR strategists, reproducing both by seeds and vegetatively, and insect- or wind-pollinated, anemochorous species. A high proportion of alien species was observed (35%, on average). Species with a slightly larger leaf area, representing an annual life cycle (approximately 56%) and C- or CR life strategies with sexual reproduction, were frequent among the alien species.

The mean ecological indicator values showed significant differences in the habitat conditions among the cargo station zones. No difference was found for continentality, temperature requirements, or soil organic matter content. The values of light tolerance, soil moisture, soil/water pH (R), trophic level, and soil salinity differed among the zones. The flora in the railway track, railway siding, and cargo yard zones prefers moderate to full light, whereas the flora in the railway embankment requires partial shade. The species in the railway track and railway siding zones are adapted to dry soils, while the species in the cargo yards and railway embankments require moister soils. In general, the soil pH ranged from 6 to 7 within the cargo station zones.

In terms of trophic level, mesotrophic (in the railway sidings and embankments) or nutrient-poor (in the railway track and cargo yard) soils are

characteristic of the cargo stations. The most salt-tolerant species were found in the railway tracks and cargo yards; halophytes were rare in embankments.

In the study, the species richness was associated with specific anthropogenic disturbance across the distinctive zones (microhabitat types) within the railway cargo stations, e.g., variations in land use (urbanization, agroforestry, agriculture) and diversity in land use and plant cover (natural, semi-natural, man-made) in adjacent areas. Spontaneous flora in intra-urban railway areas exhibits distinct adaptations to unique urban-industrial ecosystems with different degrees of anthropogenic disturbance.

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TEN RARE BIOTOPES OF THE KREMENETS MOUNTAINS

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Biodiversity assessment involves analyzing it at different organizational levels, including the ecosystem level, which is based on topological units — biotopes. Rare biotopes, particularly those that reflect regional specifics or require specific conservation measures, deserve special attention.

In the geobotanical zoning system, the Kremenets Mountains are classified as part of the Opillia-Kremenets geobotanical district of beech and hornbeam-oak forests, real meadows, and steppe meadows, which represent typical vegetation [3]. The mountains consist of isolated high-altitude remnants and elongated ridges with branching spurs, whose slopes vary in steepness and exposure. This determines the presence of forests, meadow and petrophyte steppes, meadows, swamps, petrophyte outcrops of carbonate type, i.e., high biotopic diversity. We identify ten of the rarest biotopes that warrant special attention and require targeted conservation measures.

G1231 (UkrBiotop) Ash forests. National Catalogue of Biotopes (NCB) Д1.2.1¹; EUNIS: G1.A; Resolution No. 4 of the Bern Convention (RBC) G1.A2; *Annex I of the Habitats Directive (AHD)* 9180 [2,4]. Syntaxonomy: *Carpino-Fagetea sylvaticae* Jakucs ex Passarge 1968, *Carpinetalia betuli* P. Fukarek 1968, *Carpinion betuli* Issler 1931. *Alno glutinosae-Populetea albae* P. Fukarek et Febijani C 1968, *Alno-Fraxinetalia excelsioris* Passarge 1968, *Fraxino-Quercion roboris* Passarge 1928 (*Alnion incanae* Pawlowski et al. 1928).

The plant communities are confined to the broad bottoms of gullies, where rich, well-developed soils with sufficient moisture form [2]. The primary dominant species in these forests is *Fraxinus excelsior*, with co-dominants including *Carpinus betulus*, *Acer platanoides*, *A. pseudoplatanus*, and *Ulmus glabra*. The herbaceous layer is notably dense, with forests dominated by *Allium ursinum* being of particular value. Among the species that deserve attention are *Arum besseranum*, *Galanthus nivalis* occur here.

Threats: clear-cutting, creation of non-typical forest crops after felling, ash diseases. Based on the developed methodology [1], an assessment of the stability (resistance) of biotopes to external threats (S-III class), sociological significance (V-II class) and risks of losses (R-II class) was carried out.

G:1.232 Linden-sycamore forests. NCB Д1.3.1; EUNIS G1.4; RBC G1A4; *AHD* 9180. Syntaxonomy: *Carpino-Fagetea sylvaticae* Jakucs ex Passarge 1968, *Aceretalia pseudoplatani* Moor 1976, *Tilio-Acerion* Klika 1955.

The communities here are known from an isolated locality of the mountain range located north of the town of Kremenets (Bilokrynysia Nature Conservation Research Department, block 29). A characteristic feature of this

¹ Here and throughout the text, Ukrainian classification codes are given in their original form to ensure consistency with the National Catalogue of Biotopes of Ukraine and relevant Ukrainian regulatory documents.

location is that ash and sycamore are rare and occur singly, while hornbeam and sharp-leaved maple dominate, but in the grass cover, *Lunaria rediviva* forms a continuous cover. *Scopolia carniolica* *Allium ursinum* and the rare fern *Polystichum lonchitis* are noted.

Threats: clear-cutting, creation of non-typical forest crops after felling, ash diseases, windthrow. S-III, V-I, R-II classes.

G:2.217 Pine forests growing on carbonates. NCB D2.3.1a; EUNIS G3.4; RBC G3.4. Syntaxonomy: *Erico-Pinetea* Horvat 1959, *Pinetalia pallasianae-kochianae* Korzenevskiy 1998; *Libanotido intermediae-Pinion sylvestris* Didukh 2003.

They are confined to the upper part of the southern slopes of the Maslyatyn mountain massif. The tree layer is dominated by *Pinus sylvestris* with the participation of *Betula klokovii*. The floristically rich grass cover is formed by meadow-steppe calciphilic species *Carex humilis*, *Bupleurum falcatum*, *Teucrium chamaedrys*, *Anthericum ramosum*.

Threats: successional changes, transformation into deciduous forests, logging, fires. Requires monitoring and care to prevent the penetration of broadleaf tree species, under whose canopy pine and birch will not be able to recover. S-I, V-I, R-I classes.

E2. 112 Meadow steppes (*Carex humilis*) of the Central European type on dry carbonate-enriched soils (rendzins). NCB T1.3.1; EUNIS E1.23; EUNIS-21 R1A; RBC E12; AHD 6210. Syntaxonomy: *Festuco-Brometea* Br.-Bl. et Tx. ex Soo 1947, *Brachypodietalia pinnati* Korneck 1974, *Cirsio-Brachypodion pinnati* Hadač et Klika in Klika et Hadač 1944.

They are noted on the southern slopes of the spurs of the Kremenets Mountains near the villages of Pidlisne, Krutniv and Mala Goryanka. The *Cirsio-Brachypodion pinnati* alliance with the dominance of *Carex humilis*, *Brachypodium pinnatum* are located on the northeastern border of the exclave of the Central European meadow steppes. Due to the cessation of grazing, mesophytization and sylvatization are observed, as well as the expansion of *Solidago canadensis*. To ensure effective monitoring of successional changes, these valuable areas should be incorporated into the Kremenets Mountains National Nature Park. S-II, V-II, R-II classes.

E 2.124 Steppes dominated by *Stipa capillata* on leached chernozems. NCB T1.4; EUNIS E1.2 D; EUNIS-21 R1A; RBC E1.2; AHD 62C0. Syntaxonomy: *Festuco-Brometea* Br.-Bl. et Tx. ex Soó 1947, *Festucetalia valesiacae* Soó 1947,

Stipetum capillatae Dziubaltowski 1925, (*Potentillo arenariae-Stipetum capillatae* LIBB. 1933 em Krausch 1960).

Groups dominated by *Stipa capillata* in the form of small localities are noted on the southern slopes of the spurs of the Kremenets Mountains near the villages of Pidlisne and Viliia. They are confined to the top of the convex southern slopes. The base is loess rocks, on which poorly developed leached chernozems are formed. Overgrowth with shrubs is observed. These valuable territories should be attached to the Kremenets Mountains National Nature Park, which will ensure monitoring of successional changes. S-II, V-II, R-II classes.

E2.211 Forb-dominated plant communities on carbonate deposits. NCB T1.2.2.a; EUNIS E1.23; EUNIS-21 R1A; RBC E12; AHD 6210. Syntaxonomy: *Cirsio-Brachypodium pinnati* Hadać et Klika 1944 em Krausch 1961: *Asteri-Linetum flavae* Giaczek 1968, *Inuletum ensifoliae* Kozłowska 1925, *Antherico ramosi-Trifolietum montani* Kukovitza, Didukh, Shelyag-Sosonko, Abduloeva 1998.

They are noted on the southern slopes of the spurs of the Kremenets Mountains near the villages of Pidlisne, Borshchivka, Krutniv and Mala Goryanka. They are confined to the middle part of the steep southern slopes, where chalk and marl come to the surface, so soils are practically not formed. The dominant are the various herbaceous meadow-steppe species *Anthericum ramosum*, *Teucrium montanum*, *T. polium*, *Linum flavum*, *Thymus podolicus*, *Carlina onopordifolia*, *Festuca pallens*, with a minor participation of the typical *Inula ensifolia* for such groups. The main threat is sylvatization (artificial planting with pine), intensive formation of *Rhamno-Prunetea* groups. They require monitoring, measures to counteract the appearance of shrubs and trees. S-II, V-II, R-II classes.

E2.213 + H:2.11 Herbaceous and shrubby biotopes in combination with succulent communities on basiphytic carbonate substrates. NCB T1.2.2a; EUNIS E1.29+E1.11; EUNIS-21 R1A; RBC E12; AHD 6190+6110. Syntaxonomy: *Festuco-Brometea* Br.-Bl. et Tüxen ex Br.-Bl. 1949, *Stipo pulcherrimae-Festucetalia pallentis* Pop 1968, *Galio campanulati-Poion versicoloris* Kukovytsia et al. 1997 ex Didukh Vasheniak 2017. *Minuartio auctae-Festucetum palentis* Onyshchenko 2001; *Sedo-Scleranthetea* Br.-Bl. 1955, *Alysso-Sedetalia* Moravec 1967, *Alysso alyssoidis-Sedion* Oberd. et T. Müller in T. Müller 1961.

The groups are confined to the outcrops of Tertiary limestones, on the top of the mountain Maiden Rocks (Ukr. *Divochi Skeli*), which have a table-like shape or in the form of shelves and ledges, abruptly break off downwards.

The basis is made up of chamephytic subshrubs of the tomilary type, among which *Helianthemum canum*, *Minuartia aucta*, *Teucrium montanum*, *Thymus podolicus*, *Sedum acre*, *S. ruprechtii* dominate. Such groups are unique and characteristic only for the Kremenets Mountains. The threat is excessive recreation, eutrophication. S-III, V-II, R-II classes.

H:2.12 Biotopes of steep slopes on outcrops of dense carbonate rocks from the Paleozoic to Cenozoic eras. NCB K2.1.3.a; EUNIS E1.11; EUNIS-21 R1A; RBC E111; *AHD* 6110. Syntaxonomy: *Asplenietea trichomanis* (Br.-Bl. in Meier et Br.-Bl. 1934) Oberd. 1977, *Potentilletalia caulescentis* Br.-Bl. in Br.-Bl. et Jenny 1926, *Asplenion rutae-murariae* Oberd. et al. 1967, *Potentillion caulescentis* Br.-Bl. in Br.-Bl. et Jenny 1926.

The groups are characteristic of open, steep cliffs composed of Tertiary limestones [2, 4]. The cliffs, reaching up to 5 m in height, have a porous structure with cracks inhabited by chasmophyte ferns such as *Asplenium ruta-muraria*, *A. trichomanes*, *Cystopteris fragilis*, and others. A lichen-moss cover is also present. Threats: rock collapse, quarry development, artificial afforestation, and littering. They require monitoring. S-III, V-II, R-II classes.

H:2.114 Shaded chasmophyte communities in association with lichens and bryophytes. NCB K5.2; EUNIS H3.25; RBC H 32. *AHD* 8210. Syntaxonomy: *Polypodietea* Jurko et Peciar ex Boşcaiu, Gergely et Codoreanu in Raţiu et al. 1966; *Ctenidio-Polypodietalia* Jurko et Peciar ex Boşcaiu, Gergely et Codoreanu in Raţiu et al. 1966; *Ctenidio-Polypodion vulgare* S. Brullo et al. 2001.

These communities, characteristic of Transnistria, Precarpathia, and the Carpathians [8], are recorded here from an isolated locality in a mountain range north of the town of Kremenets (Bilokrynysia Nature Conservation Research Department, block 29). They are confined to steep, north-facing cliffs shaded by a tree layer, composed of porous Tertiary limestones.

Characteristic species include *Phyllitis scolopendrium*, *Asplenium trichomanes*, *Cystopteris fragilis*, as well as *Geranium robertianum*, *Chrysosplenium alternifolium*, *Galeobdolon luteum*, *Chelidonium majus*, and *Cardaminopsis arenosa*, which inhabit the rock fissures. The moss cover is fairly dense, with species such as *Pseudanomodon attenuatus*, *Conocephalum salebrosum*, and others.

Threats: deforestation, rock exposure, excessive recreational activity. S-III, V-I, R-II classes.

D:2.2 Alkalotrophic bogs on carbonate soils. NCB B2.1.1; EUNIS D4.1; EUNIS-21 Q41; RBC D4.1; *AHD* 7210. Syntaxonomy: *Scheuchzerio*

palustris–*Caricetea fuscae* Tx. 1937; *Caricetalia davallianae* Br.-Bl. 1950; *Caricion davallianae* Klika 1934.

The bog is preserved near the village of Bilokrynytsia, situated among the drainage channels of the Ikva River floodplain. Threats: land reclamation, drainage of bogs and floodplains, afforestation, grazing.

Due to land reclamation, the groundwater level has decreased across most of the area; however, a small site still retains the structure and floristic composition of *Caricion davallianae* communities. *Schoenus ferrugineus* dominates, with rare species such as *Pinguicula vulgaris* and *Epipactis palustris* also present. Invasion by *Molinia caerulea*, as well as overgrowth with birch and various *Salix* species, has been observed.

To ensure conservation, restoration of the hydrological regime to the appropriate level and regular monitoring of successional changes are necessary. S-I, V-I, R-I classes.

Therefore, the most vulnerable and valuable among the above are the alkalotrophic bogs on carbonate soils (D:2.2) and pine forests on carbonates (G:2.217), classified as Class I. These are characterized by the highest risk of loss and require special conservation measures. The other biotopes, classified as Class II, also require specific targeted actions to ensure their preservation.

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PARTICIPATION OF THE UMCS BOTANICAL GARDEN IN LUBLIN IN ACTIVITIES FOR THE PROTECTION OF ENDANGERED SPECIES

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The Botanical Garden of Maria Curie-Skłodowska University (UMCS) was officially established in 1965 and opened to the public in 1974, although efforts to establish it had been ongoing since the University's early days. The Garden is located on the slope of the Czechówka River valley, in Stawinek, now part of Lublin, formerly a suburban manor and, at the turn of the 19th and 20th centuries, a health resort. It covers an area of 21.25 ha. It is a university-wide organizational unit of UMCS and a botanical garden as defined by the Nature Conservation Act of April 16, 2004. According to this act, it is a site for *ex situ* conservation, cultivation of plants from various climate zones and habitats, scientific research, and education. Therefore, the Garden's primary task is *ex situ* conservation, i.e., protecting plant species outside their natural habitats.

The Botanical Garden in Lublin holds a collection of about 7,500 taxa (species and varieties) of plants. These include plants native to Poland and Europe as well as from other continents, often endangered species listed under the Bern Convention or CITES. A significant part of the collection, comprising nearly 1,000 taxa, consists of native flora species, of which 266 are legally protected, endangered, or extinct in the wild within Poland. Among them are 173 protected species, 113 listed in the Polish Red Data Book of Plants [2,

pp. 1–895], and 202 on the Polish Red List of Pteridophytes and Flowering Plants [1, pp. 1–44]. Collections often include specimens from different populations (sites) to preserve genetic diversity within a species. For example, conservation cultivation includes *Veratrum nigrum* from all six known sites in Poland and *Arctostaphylos uva-ursi* from six natural sites: Rebiznaty, Borowe, Sobibór, Orle, Gnizado, and Osowa.

Ex situ conservation activities involve cultivating plants within the Garden, as well as participating in seed bank and gene bank initiatives. As part of the FlorNaturROBiA (2013–2014) and FlorIntegral (2019) projects, seeds from 15 endangered plant species were collected for long-term storage in a gene bank. Seeds were secured from: *Muscari comosum* (Machnowska Góra, Borowa Góra, Liwiec, Kozia Góra, Chomęciska), *Achillea setacea* (Gródek, Dobużek), *Senecio umbrosus* (Stawska Góra near Chełm, Biała Góra near Tomaszów Lubelski), *Allium rotundum* (Chodywańce), *Drosera anglica* (Plebanka), *Veronica paniculata* (Tarnogóra), *Carlina onopordifolia* (Stawska Góra, Rogów), *Isolepis supina* (near Werbkowice), *Ligularia sibirica* (Zawadówka), *Veratrum nigrum* (Kąty, Serwitut Forest, Niedzieliski Forest, Łabunie, Teresin, Strzeleckie Forests), *Hypericum elegans* (Niedzieliska), *Caldesia parnassifolia* (Lake Uściwierz), *Stipa joannis* (Tarnogóra), *Primula vulgaris* (Ciechanki Łańcuchowskie), *Echium russicum* (Czumów).

Based on the Garden's collections, for over 30 years, efforts have been undertaken to strengthen weak populations or reintroduce species to their historical sites. From 1996 to 2023, reinforcement efforts targeted populations of: *Polemonium coeruleum* (Wola Niemiecka), *Iris aphylla* at six sites (Broczówka near Skierbieszów, Ciechanki near Łęczna, Kazimierz Dolny, Opoka Duża near Annopol, Szczecyn near Gościeradów, Tarnogóra near Izbica), *Echium russicum* and *Chamaecytisus albus* (Czumów), *Veratrum nigrum* (Łabunie and Strzeleckie Forests), and *Ligularia sibirica* (Sobowice and Kozia Gotówka). Reinforcement of *Ligularia sibirica* populations used seeds previously collected in the seed bank because natural populations were so weak that they did not produce viable seeds.

Endangered species were protected by relocating *Lycopodiella inundata* from a sand mine to the shores of Lake Kleszczów, or by transferring 13 individuals of *Primula vulgaris* from Dębówka to Łańcuchów. The replacement site for *Primula vulgaris* in Łańcuchów is currently the only known site of this species in Poland. In cooperation with the Regional Directorate for Environmental Protection in

Lublin, effective measures were taken to prevent the destruction of the largest *Adonis vernalis* site in the Lublin region. The most threatened individuals were transplanted several hundred meters to a “safer” replacement site.

Plants from the Garden’s collections have been used to improve not only populations but also entire habitats. During habitat restoration along the Pivonia River, *Betula humilis*, *Iris sibirica*, and *Salix lapponum* were introduced to natural sites. From 1996 to 1999, as part of the “Renaturalization of Ecological Conditions in the Piskory Lake Region” program, 67 species were introduced to natural sites, including about 20 protected and endangered at that time: *Aconitum variegatum*, *Arctostaphylos uva-ursi*, *Betula humilis*, *Daphne mezereum*, *Drosera rotundifolia*, *Frangula alnus*, *Galanthus nivalis*, *Helichrysum arenarium*, *Hepatica nobilis*, *Iris sibirica*, *Jovibarba sobolifera*, *Lilium martagon*, *Marsilea quadrifolia*, *Menyanthes trifoliata*, *Nymphaea alba*, *Nymphoides peltata*, *Polemonium caeruleum*, *Ribes nigrum*, *Salix lapponum*, *Salvinia natans*, *Trollius europaeus*, *Viburnum opulus*.

As part of the project “Conservation and Educational Development of Xerothermic Grasslands in the Kazimierz Landscape Park,” natural sites were planted with: on Góra Trzech Krzyży — *Linosyris vulgaris*, *Linum hirsutum*, *Linum flavum*; in Janowiec — *Ornithogalum collinum*, *Linum hirsutum*, *Linum flavum*; in Międzyrzec — *Iris aphylla*, *Ornithogalum collinum*, *Linosyris vulgaris*; on Skarpa Dobrska — *Iris aphylla*, *Carex supina*, *Festuca makutrensis*, *Festuca pseudovina*, *Prunus fruticosa*, and *Ornithogalum collinum*. *In situ* activities also included habitat protection for rare species. To improve light conditions, shrubs and tree undergrowth were removed at *Veratrum nigrum* sites in Łabunie and *Orchis purpurea* in Kornelówka. Under the project “Conservation of Biodiversity in Grassland Habitats of Eastern Lublin Region,” attempts were made to restore xerothermic grassland in the Natura 2000 area of Drewniki by relocating entire patches of grassland with valuable plant species to areas where they had previously been destroyed.

Ex situ and *in situ* activities are complemented by ecological education conducted by the Botanical Garden. The Garden hosts thematic walks, workshops, and outdoor games aimed at familiarizing participants with rare and protected plant species. An educational trail titled “See, Learn, and Help Protect Them: Polish Protected, Rare, and Endangered Plants” allows visitors to get to know 40 rare and protected plant species in Poland. Garden staff participated in preparing textbooks on CITES-listed species and are involved in developing the Red List and Red Data Book of Plants of the Lublin Region.

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2. Kaźmierczakowa R, Zarzycki K, Mirek Z, editors. *Polish Red Data Book of Plants. Ferns and flowering plants*: 3rd ed. Kraków: Institute of Nature Conservation, Polish Academy of Sciences; 2014. 895 p. *(in Polish)*

THE MOST SIGNIFICANT SCIENTIFIC WORKS OF PROFESSOR VOLODYMYR I. CHOPYK

Oksana Halahan, born in 1983 (Ternopil), Candidate of Biological Sciences (Ph.D. in Biology), Associate Professor at the Department of Biology, Ecology, and their Teaching Methods at Taras Shevchenko Kremenets Regional Academy of Humanities and Pedagogy. She has studied the phytobiota of Kremenets and its environs, phytoinvasions, mapping the areas of adventitious plant species, comparing urban flora, has researched the biographies of botanists W. Besser and V. Chopyk. She is also interested in modern educational technologies of the New Ukrainian School. She initiated the creation of the regional ecological and educational center “ECO HUB KREMENETS”, leads the problem group “Kremenets Ecological Region”, and promotes an ecological lifestyle.

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Volodymyr Ivanovych Chopyk (1929–2015) was an outstanding Ukrainian botanist, ecologist, phytosozologist, phytogeographer, Professor at Taras Shevchenko National University of Kyiv, Doctor of Biological Sciences, and Academician of the Academy of Sciences of the Higher School. He is recognized as a seminal figure in Ukrainian botanical science and is regarded as a classic authority in domestic floristics and systematics.

V. I. Chopyk authored more than 200 scientific works, including 16 monographs, textbooks, and scientific reference books. He was the author of the first edition of the *Red Data Book of the Ukrainian SSR* (1980) and co-author

of both the first (1978) and second (1984) editions of the *Red Data Book of the USSR*.

Over the course of his career, he supervised the research of 3 Doctors of Sciences and 19 Candidates of Sciences. His total scientific and pedagogical experience spanned 60 years. Throughout his professional life, V. I. Chopyk played an active role in both public and academic spheres — as a member of editorial boards for numerous scientific journals and collections in Ukraine and the former USSR, and as a participant in scientific societies and specialized academic councils [2].

For his personal contributions to the advancement of science and education in Ukraine, he received numerous awards and honors. From 2004, he actively served as Chief Scientific Secretary of the Academy of Sciences of Higher Education of Ukraine and as an advisor to the Presidium of the Academy.

His life can be conventionally divided into three periods: the Transcarpathian period (1929–1954), the Kyiv period (1955–2007), and the Kremenets period (2007–2015). His scientific legacy encompasses works on the flora of the Ukrainian Carpathians, species conservation, plant taxonomy, and other related fields.

V. I. Chopyk was a native of Transcarpathia, born on June 4, 1929, in the village of Tereblya, Tyachiv Raion (Tyachiv District), Zakarpattia Oblast (Transcarpathian Region).

His first scientific work was a diploma thesis devoted to fungal diseases of cereals in Zakarpattia Oblast, which he defended in 1953 upon graduating from the Faculty of Biology at Uzhhorod University with a degree in Botany and the qualification of “Biologist-Botanist.” In the thesis, he described diseases such as brown leaf rust of wheat, yellow rust of wheat, stem rust of cereals, brown stem rust of rye, ergot of rye, wheat blight, oat loose smut, and barley blight. The scientific supervisor of the work was Associate Professor Kh. Yu. Rudenko.

Chopyk, V. I. The Main Fungal Diseases of Cereals in Zakarpattia Oblast and Measures for Their Control. Uzhhorod, 1953. 90 p. (in Ukrainian)

Works Dedicated to the Flora of the Ukrainian Carpathians

V. I. Chopyk’s second scientific work was his Candidate’s thesis on the topic “Flora and Vegetation of the Western Part of the Ukrainian Carpathians,”

completed under the supervision of Doctor of Biological Sciences, Professor M. I. Kotov. It was Professor Kotov who proposed replacing the term “Soviet Carpathians” with “Ukrainian Carpathians.” Notably, nearly all of Chopyk’s subsequent research would be devoted to the flora of this region of Ukraine.

Chopyk, V. I. *Flora and Vegetation of the Western Part of the Ukrainian Carpathians*: Dissertation ... Candidate of Biological Sciences: 03.00.05. Kyiv: Publishing House of the Academy of Sciences of the Ukrainian SSR, 1958. (in Ukrainian)

His next significant work — a doctoral dissertation titled *Analysis of the High-Mountain Flora of the Ukrainian Carpathians* — was defended in 1973. It was written while V. I. Chopyk served as Deputy Director for Scientific Work at the Institute of Botany of the Academy of Sciences of Ukraine and was later appointed Head of the Department of Higher Plants [3].

Chopyk, V. I. *High-Mountain Flora of the Ukrainian Carpathians and Its Analysis*: Dissertation ... Doctor of Biological Sciences: 03.00.05. Kyiv, 1973. (in Ukrainian)

In 1976, a monograph was published based on the study of the flora and the analysis of endemics and relicts, in which V. I. Chopyk proposed a new hypothesis regarding the origin and formation pathways of the high-mountain flora of the Carpathians, as well as its florogenetic connections with the floras of other European mountain systems.

Chopyk, V. I. *High-Mountain Flora of the Ukrainian Carpathians*. Kyiv: Naukova Dumka, 1976. 320 p. (in Ukrainian)

In 1977, the *Plant Identification Guide of the Ukrainian Carpathians* was published under the editorship of V. I. Chopyk and other authors.

***Plant Determinant of the Ukrainian Carpathians*. V. I. Chopyk, M. I. Kotov, V. V. Protopopova, et al.; ed. V. I. Chopyk. Kyiv: Naukova Dumka, 1977. 432 p. (in Ukrainian)**

At the Central Botanical Garden of the Academy of Sciences of Ukraine, V. I. Chopyk completed the construction of the botanical and geographical section “Carpathians,” which had been initiated by Professor O. I. Sokolovsky.

Works Dedicated to the Protection of Plant Species

V. I. Chopyk was the founder and pioneer of scientific research in the field of protecting the species diversity of Ukraine's plant world, as reflected in numerous publications from 1959 to 2010. In these works, he proposed and substantiated two new areas of research in phytosoziology: autophytosoziology — the protection of individual plant species, and symphytosoziology — the protection of phytocenoses.

Chopyk, V. I. *Rare Plants of Ukraine*. Kyiv: Naukova Dumka, 1970. 188 p. (in Ukrainian)

Chopyk, V. I. *Rare and Disappearing Plants of Ukraine: Reference Book*. Kyiv: Naukova Dumka, 1978. 216 p. (in Russian)

As a result of these studies, the first *Red Data Book of Ukraine* was published in 1980, co-authored with zoologist A. Fedorenko.

Chopyk, V. I., Fedorenko, A. P. *Red Data Book of the Ukrainian SSR*. Kyiv: Naukova Dumka, 1980. 505 p. (in Ukrainian)

He was a co-author from Ukraine in both the first and second editions of the *Red Data Book of the USSR*. In collaboration with Academician A.L. Takhtadzhyan, he contributed to the compilation of rare and endemic plant species of the flora of Europe for the USSR territory (first and second editions — London, 1976, 1984).

Works Devoted to Plant Taxonomy and Other Directions

***Determinant of Higher Plants of Ukraine*. D.N. Dobrochaeva, M.I. Kotov, V.I. Chopyk, et al. Kyiv: Naukova Dumka, 1987. 548 p. (in Russian)**

He also stood at the origins of phytogeography in Ukraine. From 1972, V. I. Chopyk was part of the team of Soviet phytogeographers who, together with scientists from 36 European countries, began work on the multi-volume pan-European publication *Atlas of the Flora of Europe*. Until the end of his life, he represented Ukraine as a member of the Main Editorial Board of this edition and was a co-author of all 16 volumes. All volumes are now housed in Kremenets, in the auditorium named after Prof. V.I. Chopyk.

***Atlas Florae Europaeae*. V. Chopyk [et al.]. Helsinki. Vol. I (1972) — Vol. XVI (2013). *Horology of the Flora of Ukraine*. Kyiv: Naukova Dumka, 1986. 272 p. (in Russian)**

From 1975, he worked at Taras Shevchenko National University of Kyiv as Head of the Department of Higher Plants, later serving as Dean of the Faculty of Biology and Professor at the Department of Botany.

During his leadership, the department focused on studying the flora of the Middle Dnieper region, resulting in the first complete and detailed edition of the *Compendium of the Flora of the Middle Dnieper Region* (1998).

***Compendium of the Flora of the Middle Dnieper Region: A Teaching Aid*. V. I. Chopyk, Yu. O. Voytyuk, M. M. Bortnyak, et al. Kyiv: Phytosociocenter, 1998. 139 p. (in Ukrainian)**

The manual *Latin Botanical Nomenclature* was co-authored for students, postgraduates, teachers, and researchers in botanical disciplines of biological faculties. It presents the basic principles of the formation and functioning of Latin botanical nomenclature, elements of the Latin language, and the rules for writing and pronouncing Latin botanical names and terms.

Chopyk, V. I., Yena, A.V. *Latin Botanical Nomenclature: A Teaching Aid*. Kyiv: EPC “Kyiv University”, 1997. 57 p. (in Ukrainian)

Another publication for biology students and botanists was issued under the title *Herbarium: History, Creation, and Functioning*, which explores the history of the origin and development of the herbarium, its role in the advancement of botany, and its current and future significance in biodiversity studies. The history of herbarium work in Ukraine is presented for the first time, along with the technology of collecting, systematizing, and storing herbarium collections.

Chopyk, V.I., Myakushko, T.Ya., Solomakha, T.D. *Herbarium: History of Creation and Functioning*. Kyiv: Phytosociocenter, 1999. 130 p. (in Ukrainian)

After working for twenty years at Taras Shevchenko National University of Kyiv in various positions (Dean, Head of Department, Leading Researcher), V. I. Chopyk wrote essays on the history of the Faculty of Biology at this institution. For him, historical facts were no less important than botanical ones.

After all, many renowned botanists worked at the university: W. Besser, E. R. von Trautvetter, O. Rogovych, I. Shmalhausen, S. Navashin, K. Purievych, O. Fomin, Y. Baranetsky, M. Kholodny, N. Korniyushenko, D. Zerov, O. Lypa, and others. Notably, the university's first rector was Professor of Botany, historian, and scholar-encyclopedist Mykhailo Maksymovych.

Chopyk, V. I., Berdyshev, G. D., Golda, D. M. *Essays on the History of the Faculty of Biology of Taras Shevchenko National University of Kyiv*. Kyiv: Phytosociocenter, 2004. 168 p. (in Ukrainian)

In 2007, he became Head of the Department of Ecology and Plant Physiology at the Faculty of Biology of Taras Shevchenko Kremenets Regional Institute of Humanities and Pedagogy (now Taras Shevchenko Kremenets Regional Academy of Humanities and Pedagogy). Under his leadership, the All-Ukrainian Conference with international participation "Besser Studies" was held in 2014. He founded the research laboratory "Ecological Monitoring and Experimental Biology" and initiated the Herbarium of Plants of Western Podillia.

It was especially meaningful to him that he worked as Head of the Department of Botany both in Kyiv and in Kremenets — just as Willibald Besser once had.

Chopyk, V., Halahan, O. *Professor of Saint Volodymyr University Willibald Besser and His Students — the First Researchers of the Flora of Ukraine (on the 225th Anniversary of His Birth)*. Kremenets, 2010. 48 p. (in Ukrainian)

Summarizing the results of recent research on biodiversity conservation, V. I. Chopyk concludes that all efforts to date have not only failed to prevent but also to halt the inevitable degradation of the environment and the destruction of plant and animal species. This, he argues, is because these approaches are rooted in a technocratic paradigm of thinking. New approaches are needed — new biological thinking, a new paradigm that entails a shift from anthropocentrism (the primacy of human interests) to biocentrism (the primacy of protecting all forms of life on Earth).

He proposes supplementing the modern definition of biology: "Biology is the science of living nature and the preservation of all living things." Biocentrism, he asserts, should and can become a transnational world religion, which provides a framework for new biological thinking, fostering a new mentality among people of all faiths and nations, and establishing new ethical norms for human behavior and interaction with nature. He viewed biocentrism as

a unifying idea for the community, a factor of social, scientific, and moral-ethical progress. Like the national idea, it is a passionate embodiment of the philosophy of life, intellect, and human morality in the 21st century. He noted that just as Latin once signified culture and education, and the civilization of society, so too will biological thinking and ecological ethics and culture become the measure of civilization in the 21st century [4].

A number of articles have been published on this concept of biocentrism, including one co-authored with K. M. Sytnyk.

Chopyk, V. I. *The Concept of Biocentrism in the Context of Globalization. Collection of Scientific Papers of the Academy of Sciences of Ukraine*. Kyiv, 2009. Issue VII. (in Ukrainian)

Chopyk, V. I., Sytnyk, K. M. *Biocentrism and Globalization. Bulletin of the National Academy of Sciences of Ukraine*. Kyiv, 2009. No. 12. (in Ukrainian)

In 2015, V. I. Chopyk completed and published the fundamental work *Flora of the Ukrainian Carpathians* in co-authorship with Mykola Fedoronchuk, Doctor of Biological Sciences of the M.G. Kholodny Institute of Botany of the National Academy of Sciences of Ukraine, through the Ternopil publishing house "Terno-graf."

Chopyk V.I., Fedoronchuk M.M. *Flora of the Ukrainian Carpathians*. Ternopil: LLC "Terno-graf," 2015. 712 p.

The *Flora of the Ukrainian Carpathians* includes 2,532 species of native and adventive vascular plants. This work is of great importance for the preservation of the phytogenofund of the mountain region. In the preface, the author notes that in the countries where the Carpathian Mountain system is located, the inventory of flora has already been completed. Therefore, it would be appropriate to publish a *Chorological Flora of the Carpathians*. V. I. Chopyk intended to contribute to such a collective work [3]. The epigraph to the preface — "*I did what I could; let whoever can do better*" — is in Latin. This was the work of his entire life, as he studied the flora of the Carpathians throughout his career.

V. I. Chopyk died on December 4, 2015, in Kyiv, likely from chronic ischemic heart disease, at the age of 87. His ashes are buried in Kyiv next to his wife.

After the death of V. I. Chopyk, his daughter Maryana donated her father's library (325 volumes), diplomas, medals, and awards to Taras Shevchenko

Kremenets Regional Academy of Humanities and Pedagogy. In honor of his anniversary, the academy opened a named auditorium after Professor V. I. Chopyk, based in the botany office, where some of his books and personal belongings are preserved.

V. I. Chopyk always promoted Ukrainian culture among students. He advocated for the purity of the Ukrainian language. V. I. Chopyk was not only a scientist but also a true patriot of Ukraine. His knowledge in various areas of Ukrainian culture consistently inspired respect and elevated his authority among students as a university educator.

On his desk, in a frame, stood a herbarium specimen of edelweiss, which he had brought from the Carpathians. It was his favorite flower and the symbol of his work. He resembled this plant — growing high in the mountains, where strong winds blow, with a unique star-shaped inflorescence. He too was born in the mountains, was physically resilient, had a sharp mind, and held far-sighted views.

The earthly journey of V. I. Chopyk has ended, but his thoughts and views remain in books, articles, and monographs. His ideas will be carried forward by students and followers.

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WILLIBALD BESSER'S WORK AT SAINT VOLODYMYR UNIVERSITY IN KYIV

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When speaking of 19th-century botanists, one cannot overlook the remarkable figure of Willibald Gottlieb Besser. He entered the history of biological science as a botanist, entomologist, and naturalist of Ukraine, earning great respect from both the public and the scientific community during his lifetime. His name is closely associated with the Kremenets Lyceum, its botanical garden, and the Saint Volodymyr Imperial University of Kyiv (now Taras Shevchenko National University of Kyiv).

Willibald Besser was born on July 7, 1784, in Innsbruck, Austria. After receiving his medical education at the universities of Lviv and Kraków, he worked at the Kraków clinic in 1808. Soon after, he became the head of the Kremenets Botanical Garden and taught botany, zoology, and natural history at the Higher Volyn Gymnasium, later renamed the Lyceum (1809–1831). He concluded his scientific and teaching career at the Saint Volodymyr Imperial University of Kyiv in 1838 with the title of Honored Professor of Botany.

According to the university charter, the title of professor could be conferred upon a Doctor of Sciences. Professors were elected for five-year terms, and after 25 years of full-time teaching at the university, one could be awarded the title of Honored Professor [1, p. 94].

W. G. Besser was the first renowned figure of the Kremenets Lyceum, and the Kremenets Botanical Garden owed its development to his efforts [2]. Despite a meager budget, he managed to expand the garden's collection to 12,000 species of native and exotic plants. The Volyn nobility, proud of the accomplishments of the scientist who had brought fame to their Lyceum, accepted Besser into their circle in 1828.

As a scientist, W. G. Besser stood on equal footing with the leading botanists and entomologists of his time, and international scientific societies awarded him honorary membership. He devoted special attention to floristic research in Volyn-Podillia, Right-Bank Ukraine, Bessarabia, and other regions of modern Ukraine.

A significant period in Besser's life was his time in Kyiv, associated with the Saint Volodymyr Imperial University of Kyiv. The university's history dates back to November 8, 1833, when Minister of Education S. S. Uvarov's proposal to establish the Imperial University of Saint Volodymyr, based on the Volyn Lyceum relocated from Kremenets to Kyiv, was approved. On March 8, 1834, the teachers of the Kremenets Lyceum were invited to a meeting of the University Council. The order establishing the university was read aloud, and the

Lyceum's teachers were appointed as university professors — despite the fact that almost none of them spoke Russian fluently enough to teach in it.

To the timid objections of the Kremenets professors, the response was: "Teach in whatever language you want, just not in Polish, and we will see later." As a result, with the commencement of classes, Latin, French, and a peculiar mix of local dialects and Polish were heard from the lecterns. No one was particularly concerned about whether the students understood these languages [1]. After all, as time would show, Russian was not always the language of instruction — even later, when Polish teachers were replaced by Germans.

On July 15, 1834, the grand opening of the university took place on the feast day of Saint Volodymyr, Equal-to-the-Apostles. By that time, most of the property had been transported from Kremenets, including the lyceum's archive and treasury, church utensils, library, zoological, mineralogical, physical, mechanical, painting, and surveying instruments, as well as the botanical garden collection [1].

The educational process began on August 28, 1834. During the 1834–1835 academic year, the university had only one faculty — the Faculty of Philosophy — which consisted of two departments: Historical and Philological, and Physical and Mathematical. The latter included the Department of Botany, headed by Ordinary Professor W. Besser (a position equivalent to the modern-day head of department).

Most academic positions were occupied by Polish instructors from the former Volyn Lyceum. Nearly every professor lectured from his "own book" or from notes compiled according to his personal methodology.

The pages of the *History of the University of Saint Vladimir* (1860) note that lectures on botany during this period of the university's history were delivered by four instructors, but the guiding figure who set the tone and direction of student work was Ordinary Professor Willibald Gottlieb Besser.

In the first half of the 1834–1835 academic year, plant organology was taught by Adjunct A. Andrzejowski (a student of W. Besser) for three hours per week. Beginning in late January 1835 and continuing until March 5, 1838, W. Besser himself began lecturing, delivering his course in Latin for six hours per week. He taught organology and terminology in the first year, plant physiology and systematics in the second year, and plant geography and the history of botany in the senior years.

W. Besser's lectures on "Organology, Terminology, and Physiology of Plants" followed the work of Bartholomew, while his taxonomy course was

based on the writings of C. S. Kunth and A. Richard, supplemented by the contributions of A. P. de Candolle, J. Lindley, F. G. Bartling, and C. von Martius. In the second semester, teaching responsibilities were shared with Doctor of Philosophy P. Kornukh-Trotsky, who lectured on plant organology following the work of M. Maksymovych, and on physiology using his personal notes.

High standards were set for teaching biological disciplines. Candidates for associate professorships or professorships were required to deliver a public lecture in their field of specialization, attended not only by university faculty but also by interested members of the academic community, including those from lyceums and gymnasiums.

Although W. Besser was not an outstanding speaker during lectures, he was rightfully regarded as a profound expert in his field. In his relationships with colleagues, he displayed friendly affection and was respected as a decent and kind person. W. Besser valued accuracy and precision in all matters and had a deep love for order. To some extent, this made him somewhat burdensome for his peers, and even more so for young students who struggled to understand the teacher's Latin. According to contemporaries, Professor Besser viewed students as a teacher views his pupils, maintaining a certain distance. The way students approached the professor and their subsequent recognition was seen as a reflection of their talent or competence. Students were expected to adhere to proper etiquette and were not permitted to express approval or dissatisfaction during lectures. His high level of professionalism, recognition, and achievements created a distance between Professor Besser and students who were novices in the field. The more the professor remained distant from the university's youth, the more his attention was valued. Despite his apparent inaccessibility, Besser played a crucial role in the educational process — educating and supporting students while training qualified specialists, including Opanas Rogovych, a member of his first group of students, who later became the director of the university botanical garden and head of the botany department. Besser acknowledged the achievements of his colleagues, never claimed credit for others' work, but at the same time, he attached great importance to his own scientific contributions and took pleasure in receiving positive feedback.

The diligence, patience, and hard work of W. Besser were remarkable: he conscientiously delivered lectures in languages foreign to him, cared for educational collections, processed the materials he collected, and maintained

constant correspondence with renowned botanists and entomologists. Beginning in 1834, following expeditions to southwestern Ukraine, his notable works were published, including *Dracunculi — Wormwoods* (1834), *Classification of Representatives of the Genus Artemisia Illarum (Wormwoods), Not Seen with One's Own Eyes* (1835), additions to the *Register of Absynthiorum* (Bitter Wormwoods), and an attempt to describe *De Abrotanis* (High Wormwood), among others. W. Besser's work on the genus *Artemisia* was included almost unchanged in the fundamental compilation by the Geneva botanist A. P. de Candolle.

In addition to teaching, Professor W. Besser was responsible for the organization and management of the university's botanical garden, which was established based on the collection of the botanical garden at the Volyn Lyceum. In this regard, in August 1833, the Kyiv Educational District decided to transport the plants from the Volyn Lyceum's botanical garden in Kremenets to Kyiv. According to reports from 1834, the collection contained 5,024 species and varieties of plants from open and closed ground, along with 3,920 names of seeds, totaling 8,944 units. However, in Kyiv, a suitable site for the garden had not yet been selected, so the collection was temporarily placed at the Kyiv State Garden and on plots rented from private individuals. According to the 1834 register, 513 plants from 34 species were accepted, with 329 plants designated for the university, while 184 plants were to remain in the Palace Garden, as botanists hoped it could later be transformed into the university's botanical garden. These hopes were not realized. The issue of land for the future botanical garden was resolved when construction of the university's main building began, and no applicants came forward for the undeveloped, somewhat neglected land next to the university. In 1838, after Besser's resignation, the collections of the future botanical garden were placed under the care of Ernst Rudolf von Trautvetter, who had moved to Kyiv from St. Petersburg. In 2024, the 240th anniversary of Willibald Besser's birth will be celebrated, Taras Shevchenko National University of Kyiv will mark its 190th anniversary, and the Academician Oleksandr Fomin Botanical Garden of Taras Shevchenko National University of Kyiv, will celebrate its 185th anniversary. Willibald Besser was instrumental in the creation of the Faculty of Biology, one of the university's oldest natural science faculties. Its history began with the Department of Botany and Zoology, whose initial scientific focus areas were floristics, systematics, and plant introduction. Furthermore, thanks to

Professor Willibald Besser's efforts, the herbarium collection and the future University Botanical Garden began to develop.

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THE ROLE OF W. G. BESSER AND HIS STUDENTS IN ADVANCING SCIENTIFIC RESEARCH ON THE SPECIES DIVERSITY OF DOG ROSES IN UKRAINE'S NATURAL FLORA

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At the beginning of the 19th century, active research into the species diversity of dog roses began in the territories that now comprise modern Ukraine. This work is primarily associated with the outstanding researcher W. G. Besser, who was the first to study the flora of Podillia, Volyn, and Bes-sarabia using a scientific approach to describe vegetation cover and address taxonomic issues.

After moving to Kremenets in 1809, Besser began his floristic research in the Kremenets Mountains; his work later expanded to cover the entire territory from Polissia to the Black Sea, and from Volyn and Podillia to the Dnipro region [9]. As a result, he and his students compiled a herbarium consisting of 60,000 sheets, including 845 sheets representing 66 species and 97 forms of dog roses. During Besser's time, the Kremenets Botanical Garden became one of the first centers for the introduction of dog roses in Ukraine [8, p. 33–34]. Between 1809 and 1822, a number of his works were published, sparking significant interest among botanists and initiating a new stage of floristic research — particularly of the genus *Rosa* L. — in the territory of Ukraine. These

publications marked the beginning of scientific florology in the region. Of particular importance for the development of dog roses research in Ukraine's natural flora are three of his works.

In his publication *Primitiae Florae Galiciae Austriacae Utriusque*, published in 1809, W. G. Besser described a species new to the territory he studied — *Rosa solstitialis* Besser [13, p. 324]. In subsequent editions of *Catalogue des Plantes du Jardin Botanique du Gymnase de Volhynie à Krzemieniec* (1811, 1814–1816), W. G. Besser published for the first time ten species of *Rosa* he had described from Ukrainian territory: *Rosa balsamica* Besser (1815), *R. dimorpha* Besser (1814), *Rosa floribunda* Besser (1815), *R. frutetorum* Besser (1814), *R. glandulosa* Besser (1814), *R. humulis* Besser (1811), *R. klukii* Besser (1816), *R. livescens* Besser (1815), *R. microcarpa* Besser (1811), and *Rosa uncinella* Besser (1811). In addition, he included *Rosa andrzeiowskii* Steven ex Besser for the studied territories, officially publishing the name in 1815 [10, p. 21; 11, p. 118; 14, pp. 18–20; 15, pp. 18–19].

In his work *Enumeratio plantarum Volhyniae, Podoliae etc.* (Vilnius, 1822), V. G. Besser described thirteen more new species of dog roses: *R. boreykiana* Besser, *R. caryophyllacea* Besser, *R. ciliatopetala* Besser, *R. czackiana* Besser, *R. friedlaenderiana* Besser, *R. glaucescens* Besser, *R. gorenkensis* Besser, *R. kosinskiana* Besser, *R. nitidula* Besser, *R. poteriifolia* Besser, *Rosa ratomsciana* Besser, *R. terebinthinacea* Besser, and *R. wolfgangiana* Besser. He also formally published the names of three species: *R. armata* Steven ex Besser, *R. floribunda* Steven ex Besser, and *R. glauca* Schott ex Besser [12, pp. 59–68, 99].

It should be noted that the most thorough treatment of the genus *Rosa* of that time was the work *Enumeratio plantarum Volhyniae, Podoliae, etc.* (Vilnius). It was W. G. Besser who carried out a critical analysis of the data obtained during many years of research and, summarizing the results, organized the system of the genus *Rosa*, listing 33 species and 2 forms of wild dog roses for the territory of Volyn-Podillia: *R. andrzeiowskii*, *R. armata*, *R. boreykiana*, *R. canina* L., *R. caryophyllacea*, *R. ciliatopetala*, *R. cinnamomea* L., *R. czackiana*, *R. dimorpha*, *R. floribunda*, *R. friedlaenderiana*, *R. frutetorum*, *R. glauca*, *R. glaucescens*, *R. jundzillii*, *R. klukii*, *R. kosinskiana*, *R. livescens*, *R. microcarpa*, *R. montana*, *R. nitidula*, *R. pygmaea* M. Bieb., *R. pumila* Jacq., *Rosa ratomsciana*, *R. saxatilis* Steven ex M. Bieb., *R. solstitialis*, *R. spinosissima* L., *R. spinosissima* α. *pimpinellifolia*, *R. spinosissima* φ *spinosissima*,

R. terebinthinacea, *R. tomentosa* Smith, *R. uncinella*, *R. venosa* Sw., *R. villosa* L., and *R. wolfgangiana*.

In this work, W. G. Besser introduced several taxonomic revisions to species he had previously described. For instance, he renamed *R. glandulosa* to *R. jundzillii*, as the former was a later homonym. The previously described *R. ratomsciana* and *R. balsamica* were reduced to synonyms of *R. humulis* (later transferred to synonymy with *R. kosinskiana*) and *R. klukii*, respectively. *R. gorinkensis* was not included in the final list.

Additionally, the author noted that *R. microcarpa*, when cultivated in the Kremenets Botanical Garden, was practically indistinguishable from *R. spinosissima*, while *R. poteriifolia* stood out among the forms closely related to *R. spinosissima* [12, pp. 59–68, 99]. Today, these species are considered synonyms of one of the forms of the latter [16, 17].

Faithful students and followers of W. G. Besser included A. L. Andrzejowski and O. S. Rogovych. A. L. Andrzejowski worked closely with his mentor and actively participated in collecting herbarium specimens, which were later used by W. G. Besser in developing the system of the genus *Rosa*.

In his publications *Calculation of Plants of the Podolsk Province and Adjacent Areas* (in Russian; 1860, 1862), A. L. Andrzejowski listed 31 species of dog roses for the territory of the Podolsk province: *R. andrzejowskii*, *R. armata*, *R. boreykiana*, *R. canina*, *R. caryophyllacea*, *R. cinnamomea*, *R. czackiana*, *R. dimorpha*, *R. floribunda*, *R. friedlaenderiana*, *R. frutetorum*, *R. glauca*, *R. glaucescens*, *R. jundzillii*, *R. klukii*, *R. kosinskiana*, *R. livescens*, *R. montana*, *R. nitidula*, *R. poteriifolia*, *R. pygmaea*, *R. pumila*, *Rosa ratomsciana*, *R. saxatilis*, *R. spinosissima*, *R. terebinthinacea*, *R. tomentosa*, *R. uncinella*, *R. venosa*, *R. villosa*, and *R. wolfgangiana* [1, pp. 1–51; 2, pp. 94–142].

According to the author, almost all species of dog roses published by W. G. Besser in 1822 were recorded in the Podolia Governorate, with the exception of *R. ciliatopetala*, *R. solstitialis*, and *R. microcarpa*. Instead, he added *R. poteriifolia*, which was absent from the final list presented by W. G. Besser in his 1822 work *Enumeratio plantarum Volhyniae, Podoliae, etc.* (Vilnius) [12, p. 99].

O. S. Rogovych conducted floristic research in the Volyn, Podolia, Kyiv, Chernihiv, and Poltava Governorates of the Kyiv educational district for nearly 20 years. The herbarium he compiled consists of 12,260 sheets, 119 of which represent 10 species and 1 form of dog roses, the vast majority collected in the Kyiv province during 1850–1851 [8, pp. 34–35].

In 1855, O. S. Rogovych published the article *Review of Vascular and Semi-Vascular Plants that are Part of the Flora of the Kyiv, Chernihiv, and Poltava Governorates* (in Russian), where he listed the species and forms of dog roses found in the specified territory (6 species and 2 forms): *R. pimpinellifolia* Dec., *R. pimpinellifolia* ε . *lejustyla* Led., *R. cinnamomea*, *R. canina*, *R. canina* α . *vulgaris* Koch., *R. canina* β . *dumetorum* Koch., *R. canina* γ . *collina* Koch., *R. tomentosa*, *R. pomifera* Herrm., and *R. gallica* L. [6, pp. 1–147].

In the 1868 edition *Overview of Seed and Higher Spore Plants that are Part of the Flora of the Kyiv Educational District: Volyn, Podolia, Kyiv, Chernihiv, and Poltava Governorates* (in Russian), he provides an expanded list of dog roses (7 species and 8 forms): *R. pimpinellifolia*, *R. pimpinellifolia* α . *spinosissima* Led., *R. pimpinellifolia* ε . *lejustyla*, *R. cinnamomea*, *R. canina*, *R. canina* α . *vulgaris*, *R. canina* β . *dumetorum*, *R. canina* γ . *collina*, *R. canina* δ . *sepium* Koch., *R. rubiginosa* L., *R. rubiginosa* α . *pedunculis* Led., *R. rubiginosa* β . *pedunculis glabris subglabris* Led., *R. tomentosa*, *R. pomifera*, and *R. gallica*. At the same time, the author reduces the species *R. spinosissima* and *R. villosa* to synonyms of *R. pimpinellifolia* and *R. pomifera*, respectively [7, pp. 87–88].

The status of the species described by W. G. Besser has been repeatedly revised by taxonomists. For example, *R. balsamica* was reinstated in 1987 by O. M. Dubovik [4, pp. 8–13], and *R. frutetorum*, *R. solstitialis*, and *R. atomsciana* were reinstated by I. O. Buzunova in 2001 [3, pp. 329–361].

Today, most of the species described by W. G. Besser are considered synonyms [16, 17]. According to modern taxonomic compilations, only seven of the twenty-four dog rose species he described have retained species status: *R. balsamica* (with *R. friedlaenderiana* recognized as its synonym), *R. caryophyllacea*, *R. gorenkensis*, *R. livescens*, *R. andrzejowskii*, *R. $\times$ nitidula*, and *R. kosinskiana*, the latter three of hybrid origin. The species of hybrid origin *R. andrzejowskii* was published by W. G. Besser in 1815.

Despite the fact that only seven species described by W. G. Besser have retained their status today, the vast amount of factual material collected by him and his students, as well as the critical and systematic works developed on the basis of their herbarium collections, generated significant interest among researchers and stimulated the creation of new comprehensive studies over the next 200 years, in which considerable attention was devoted to the genus *Rosa*. Notable among these are the works of such recognized botanical researchers as F. A. Marschall von Bieberstein, J. Th. Schmalhausen, O. O. Lonachevsky,

A. M. Krasnov, V. V. Montresor, E. I. Lindeman, Y. K. Pachosky, B. A. Fedchenko, A. F. Flerov, M. I. Kotov, A. Margittai, S. V. Yuzepchuk, V. H. Khrzhanovsky, E. V. Wulff, S. S. Fodor, O. M. Dubovyk, M. M. Fedoronchuk, I. O. Buzunova, et al. [5; 8, pp. 33–57].

Thus, W. G. Besser described 24 new species from the territories that are now part of modern Ukraine and published the names of four additional species. In total, the aforementioned authors, between 1809 and 1869, recorded 36 species and eight forms of dog roses for the regions they studied. The works of W. G. Besser and his students attracted the attention of researchers to representatives of the genus *Rosa* and laid a solid foundation for the further study of dog rose species diversity in the natural flora of Ukraine.

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CONSERVATION OF *EX SITU* PHYTODIVERSITY IN THE COLLECTION “RARE PLANTS OF THE FLORA OF UKRAINE”

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Mykola Haponenko, born in Kyiv in 1965. In 1987, he graduated from the Ukrainian Agricultural Academy with a degree in Agrochemistry and Soil Science. In 1990, he completed postgraduate studies at the M. M. Hryshko National Botanical Garden of the NAS of Ukraine (NBG), and since 1992 has held a degree of Candidate of Biological Sciences in Botany (a PhD in Biological Sciences with a specialization in Botany). In 1999, he was awarded the title of Senior Research Fellow. He worked in the Department of Natural Flora and served as Scientific Secretary of the NBG. He has served as Deputy Director for Scientific Work since 2006. His scientific interests include the geography, ecology, and protection of rare and endangered plant species, technologies for propagation and cultivation, biodiversity conservation, and research methodology.
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One of the main areas of activity of botanical gardens is the introduction and preservation of plant diversity. Human interest in growing, caring for, and decorating homes with plants can play a significant role in conserving species that are disappearing in natural habitats due to various factors [3]. Studying

the principles of population formation and the current state of introduced species, as well as the prospects for their further development in cultivated phytocenoses, is an important and urgent task for the theory and practice of plant introduction. This applies both to the conservation, cultivation, breeding, and enhancement of phytodiversity, and to the adventitization of flora [2].

The site “Rare Plants of the Flora of Ukraine,” established in 1970 with the participation of Dr. B. S. and Prof. V. G. Sobko at the M. M. Hryshko National Botanical Garden of the NAS of Ukraine (Kyiv), serves as an exhibition and collection area primarily showcasing the phytorarity of Ukraine’s flora [1]. Between 2020 and 2024, a study of the plants and a new inventory of the site’s collection were conducted. According to the results, more than 150 plant taxa were recorded within an area of 1.05 hectares, including 106 species listed in the third edition of the Red Data Book of Ukraine. Among them, 52 species have the protection status of “vulnerable,” 16 are “rare,” 12 are “endangered,” 23 are classified as “insufficiently known,” and 2 are “extinct in the wild.” Additionally, 7 species are protected under the Bern Convention, 13 are included in the European Red List, 17 are listed in CITES, and 19 species are regionally rare for the city of Kyiv and the surrounding region.

The main part of the collection consists of herbaceous plants. The collection of rare trees and shrubs includes only 17 species: *Cerasus klokovii* Sobko, *Chamaecytisus graniticus* (Rehmann) Rothm., *Ch. podolicus* (Błocki) Klask., *Ch. rochelii* (Wierzb.) Rothm., *Daphne cneorum* L., *Daphne taurica* Kotov, *Daphne sophia* Kalen., *Euonymus nana* M. Bieb., *Fraxinus ornus* L., *Larix polonica* (Raciborski & Wóycicki) Domin, *Pinus cembra* L., *Juniperus excelsa* M. Bieb., *Rhamnus tinctoria* Waldst. et Kit., *Sorbus torminalis* Crantz, *Spiraea polonica* Błocki, *Staphylea pinnata* L., *Syringa josikaea* J. Jacq. ex Rchb., and *Taxus baccata* L.

It should be noted that over the past five years, the introduced populations of *Cerasus klokovii*, *Daphne cneorum*, *D. taurica*, *D. sophia*, and *Euonymus nana* have been gradually degrading due to a decline or cessation of vegetative reproduction and a complete absence of seed formation. We associate these trends with both the aging of clones and climate change. *Chamaecytisus rochelii* and *Fraxinus ornus*, introduced between 2016 and 2020, have reached the generative stage; *Ch. rochelii* forms self-seeding. The formation of viable seeds and the ability of plants to reproduce under cultivation conditions are crucial for the *ex situ* conservation of these species. An assessment of the status of 23 rare steppe plants in the “Rare Plants of the

Flora of Ukraine” section showed that most adapted well to the conditions of introduction and successfully produced fruit with seeds [4]. Among them, 16 species have formed stable, homeostatic introduced cenopopulations. Five species have developed numerous and well-reproducing introduced cenopopulations: *Crocus angustifolius* Weston, *Delphinium sergii* Wissjul, *Gymnospermium odessanum* DC. (Takht.), *Paeonia tenuifolia* L., and *Silene sytnikii* Krytzka, Novosad & Protop [5].

Currently, the collection cultivates and protects 57 phytore species from the Chernihiv region, of which 29 are listed in the *Red Data Book of Ukraine* (3rd edition), and 28 are included in the list of regionally rare plant species of the Chernihiv region. Most of these plants are successfully restored *ex situ* with moderate care or without additional human intervention. It has been established that cryptophytes (50.88%) and hemicryptophytes (42.11%) dominate the biomorphological spectrum of these introduced plants, while the proportions of phanerophytes, chamaephytes, and therophytes are minimal. Seventeen phytore species have formed stable, homeostatic populations. Of these, five species are protected and listed in the *Red Data Book of Ukraine*: *Allium ursinum* L., *Crocus reticulatus*, *Epipactis helleborine* (L.) Crantz, *Galanthus nivalis* L., and *Pulsatilla pratensis* (L.) Mill.

Among the rare plants of the Crimean flora, *Crocus speciosus* M. Vieb. has formed a large introduced cenopopulation, while from the Carpathians, *Colchicum autumnale* L. has been successfully introduced.

The successful cultivation of several Ukrainian phytore species in the collection of the M. M. Hryshko National Botanical Garden of the NAS of Ukraine demonstrates the effectiveness of their *ex situ* conservation.

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INFLUENCE OF THE COMPOSITE TREVITAN® RECVLVANT ON THE YIELD INDICATORS OF LUPINUS ALBUS L. UNDER THE CONDITIONS OF THE WESTERN FOREST-STEPPE OF UKRAINE

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Legumes are valuable food crops that contain bioactive compounds in the grain, including proteins with essential amino acids, unsaturated lipids, complex carbohydrates, dietary fiber, vitamins, and minerals. Among legumes, white lupine (*Lupinus albus* L.) holds a special place in human nutrition, as its consumption improves health by lowering blood glucose levels, reducing cholesterol, and enhancing intestinal function. It is also cultivated as a honey plant, and its seeds are used as a protein supplement in animal feed [5]. The protein content in lupine seeds ranges from 30% to 55% [3, p. 13].

The varietal policy for *Lupinus albus* L. is currently based on domestic varieties. The 2024 catalog of plant varieties suitable for distribution in Ukraine includes 11 white lupine varieties: Barvinok, Veresnevy, Volodymyr, Diyeta, Lybid, Makarivsky, Rapsodiya, Serpnevy, Snigur, Chabansky, and Shchedry 50 [2]. The main research institution involved in crop selection is the National Scientific Center “Institute of Agriculture of the NAAS of Ukraine”. The varieties developed there are successfully introduced into production both in Ukraine and abroad.

Among the varieties developed by the National Scientific Center “Institute of Agriculture of the NAAS of Ukraine,” the high-protein, early-ripening variety Diyeta is particularly noteworthy. It has a universal application and is used in both human nutrition and animal feed. According to the UPOV database (International Union for the Protection of New Varieties of Plants), the *Lupinus albus* L. variety Diyeta is registered in the UK for inclusion in the national catalog [4].

The aim of the study was to determine the effect of pre-sowing treatment of white lupine seeds of the Dieta variety with the composite recultivator TRE-VITAN® (CRT) on seed productivity and crop yield structure indicators.

The research was conducted in 2023–2024 at the experimental sites of Taras Shevchenko Kremenets Regional Academy of Humanities and Pedagogy on gray forest soil. The study material was white lupine (*Lupinus albus* L.) of the Dieta variety, developed by the National Scientific Center “Institute of Agriculture of the National Academy of Sciences of Ukraine.” The

experiments followed this scheme: Option 1 — control: seeds not treated with the preparation, moistened with tap water at a rate of 2% by weight; Option 2 — experimental: seeds treated before sowing with a 0.5% CRT solution at a rate of 2% by weight.

White lupine seeds were sown using the wide-row method with 45 cm row spacing, at a depth of 4–5 cm, in the second decade of April, under optimal soil temperature and adequate moisture conditions. The sowing rate was 125 kg/ha (0.7 million seeds/ha).

The CRT was developed by the Limited Liability Company “TREVITAN UKRAINE” in accordance with TU 20.1-44141048-002:2021. It contains organic substances, with a mass fraction of 55.0–75.0%, fulvic and humic acids, potassium, nitrogen, phosphorus, and water-soluble salts (Mg, Ca, Mn, Fe, Cu, Zn, Co), with a mass fraction of 0.5–1.0% [1].

Upon ripening, white lupine seeds were harvested manually. Microsoft Excel was used for the statistical processing of the research results.

An important aspect of modern agricultural production involves research aimed at improving crop cultivation technologies through the introduction of new elements that enable the management of productivity processes — specifically, the creation of optimal conditions for plant growth and development under which yield indicators reach their maximum potential.

The research results showed that CRT, used for pre-sowing treatment of seeds and planting material, increased seed productivity and contributed to improved formation of white lupine yield structure indicators.

High productivity of white lupine is achievable in crops with an optimally dense stem stand. Therefore, one of the key indicators influencing crop yield is the number of plants per 1 m². It was found that in the experimental variant, this indicator was 17.2% higher compared to the control (control — 26.7 ± 0.9 pcs; experimental — 31.3 ± 0.9 pcs). The CRT improved the field germination of plants in the experimental variant and enhanced their survival during ontogenesis.

Important indicators characterizing crop structure include the number of beans per plant, bean length, and the number of seeds per bean. It was found that pre-sowing treatment of seeds with CRT increased bean length by 21.7% (control — 6.0 ± 0.6 cm; experiment — 7.3 ± 0.3 cm); the number of beans per plant by 43.2% (control — 3.7 ± 0.3 pcs; experiment — 5.3 ± 0.3 pcs); and the number of seeds per bean by 32.5% (control — 4.3 ± 0.3 pcs; experiment — 5.7 ± 0.3 pcs).

One of the main elements influencing crop yield is the mass of 1000 seeds. The study showed that in the experimental variant, the mass of 1000 seeds of *Lupinus albus* L. variety Dieta was 23.5 g higher compared to the control (experiment — 280.8 ± 5.1 g; control — 257.3 ± 3.6 g). The composite recultivant TREVITAN® had a positive effect on yield structure indicators, which in turn contributed to increased crop productivity. The mass of white lupine seeds per 1 m² in the experimental variant was 10.8% higher than in the control (experiment — 55.4 ± 0.9 g; control — 50.0 ± 0.4 g).

Thus, pre-sowing treatment of white lupine seeds of the Dieta variety with the composite recultivant TREVITAN® under the soil and climatic conditions of the Western Forest-Steppe of Ukraine contributed to the formation of taller plants, increased bean length, seed number per bean, and the mass of 1000 seeds, thereby statistically significantly increasing plant productivity. The use of this preparation as an element in the cultivation technology of *Lupinus albus* L. represents a promising direction for further field research under the conditions of the Western Forest-Steppe of Ukraine.

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USE OF HIGHER AQUATIC PLANTS IN LANDSCAPING

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To create highly aesthetic and decorative compositions, it is important to select appropriate plants. In urban environments, however, the diversity of wetland plants decreases, and species sensitive to anthropogenic impact are often eliminated from their communities. Therefore, not all such species can be used in landscaping [2]. The decorative qualities of plants, particularly their ability to bloom, are of great significance.

In recent years, the creation of water features on private plots, dachas, in parks, and winter gardens, as well as their integration into the architectural planning of settlements, has become increasingly popular. Consequently, a current priority is the study and introduction of aquatic species into cultivation, along with the development of scientific principles for forming decorative compositions using higher aquatic and emergent aquatic species.

When designing a water landscape, it is essential to follow principles that enable more effective use of hydrophilic species and mitigate negative anthropogenic impacts.

1. Ecological principle. This principle involves aligning artificial conditions with natural ones. According to this principle, aquatic species are classified into three groups based on ecological amplitude: wide, medium, and narrow. As noted by V. Golub, 95% of decorative macrophytes in the Right-Bank Forest-Steppe possess a wide ecological amplitude and are suitable for cultivation in both natural and artificial reservoirs [1]. I propose forming compositions using the following species: *Butomus umbellatus*, *Iris pseudacorus*, *Typha angustifolia*, *Rumex hydrolapathum*, *Salvinia*

natans, and *Nymphaea alba*. These species are well-suited for creating green spaces with artificial reservoirs in cities, towns, schoolyards, and private estates.

2. Biological principle. This principle involves considering the growth and development characteristics of species to achieve maximum decorative effect [1]. The flowering period of selected species is particularly important. For example, *Nuphar lutea* and *Nymphaea alba* bloom the longest — from May to September. To enhance decorative appeal, I recommend combining these species with *Salvinia natans*, *Potamogeton natans*, and *Iris pseudacorus*.

3. Cenodynamic principle. This principle involves considering the edificatory properties of species. To form stable decorative biogroups, it is necessary to account for the ability of edificators to create cohesive plant communities [4]. The application of this principle is important when combining species that are mutually tolerant in natural and artificial environments. In particular, the following combinations are recommended for decorative biogroups: Dominant *Trapa natans* with co-dominants *Salvinia natans* and *Nymphoides peltata*; Dominant *Nymphaea candida* with co-dominants *Trapa natans*, *Salvinia natans*, and *Nymphoides peltata*.

4. Aesthetic principle. This principle involves creating compositions that are visually appealing and meet aesthetic criteria.

5. Landscape principle. This principle involves taking into account the landscape features of the area where the composition is being developed.

6. Architectural principle. This principle involves incorporating small architectural elements to enhance the decorative effect of the compositions [1]. Depending on the size of the pond, it can be adorned with small stones or a single large stone that mimics a geyser. In the center of a large lake, a decorative fountain with various special effects or a plaster sculpture may be placed.

7. Resource principle. This principle involves utilization of the phytomass of aquatic and semi-aquatic species for economic purposes (e.g., livestock feed and the production of “green” energy from *Phragmites australis* biomass for heating buildings), as many semi-aquatic species have high productivity. Based on this principle, I recommend the following species for landscaping: *Carex acuta*, *Potamogeton natans*, *Sagittaria sagittifolia*, *Typha angustifolia*, *Phragmites australis*.

8. Nature conservation principle. This principle involves preservation of the gene pool of rare, endangered, and relict species. This principle is essential for the conservation and restoration of vulnerable species with decorative qualities such as *Acorus calamus*, *Nymphoides peltata*, *Nymphaea alba*, *N. candida*, and *Trapa natans*. It is more appropriate to use introduced species for landscaping artificial reservoirs in botanical gardens.

9. Phytoremediation principle. This principle involves cultivation in reservoirs of species with water-purifying properties [1]. These should primarily be species that are highly resistant to pollution from various runoff sources, possess well-developed root systems, can form tall, dense stands, recover easily after mowing, and produce a large biomass. In particular, plants with aquatic roots are of great importance for water purification, such as *Typha angustifolia*, *T. latifolia*, and *Iris pseudacorus*.

When selecting species for landscaping, the following characteristics should be considered: appearance, duration and intensity of flowering, decorative value, and substrate requirements. In this context, species with valuable ornamental morphological features — such as broad or dissected leaves (*Trapa*, *Potamogeton*, *Utricularia*) and attractive flowers (*Batrachium*, *Butomus*, *Nymphaea*, *Nuphar*, *Nymphoides*) — are promising for reservoir landscaping.

Considering the biological, ecological, and decorative properties of higher aquatic and semi-aquatic species, the following plants are recommended for landscaping natural aquatic ecosystems in Northern Podillia: *Batrachium aquatile*, *Hydrocharis morsus-ranae*, *Nuphar lutea*, *Nymphaea alba*, *N. candida*, *Salvinia natans*, *Potamogeton natans*, *Trapa natans*, and *Utricularia vulgaris*. Among these, *Nymphaea alba* is the most widespread and is notable for its wide range of cultivated varieties and hybrids [3].

Coastal aquatic vegetation also plays an important role in aquatic ecosystems, as it occupies transitional zones between aquatic and terrestrial environments and facilitates their interaction. The following species of higher aquatic plants are promising for landscaping natural ecotopes: *Alisma lanceolatum*, *Butomus umbellatus*, *Caltha palustris*, *Carex acuta*, *C. riparia*, *C. pseudocyperus*, *Sparganium erectum*, *Typha angustifolia*, *T. latifolia*, and others.

For small backyard ponds, I recommend using plants that are more resistant to artificially created conditions. These may include the following species: *Alisma plantago-aquatica*, *Caltha palustris*, *Carex acuta*, *Nymphaea alba*, *N. candida*, *Nuphar lutea*, *Trapa natans*, *Hippuris vulgaris*, *Iris pseudacorus*, and

Sagittaria sagittifolia. It is also advisable to plant varieties specifically bred for cultivation in artificial water bodies and acclimatized to the temperate zone [4].

For reservoir landscaping, it is advisable to use species that can be conditionally divided into the following groups: swamp, coastal, and surface-floating (rooted and unrooted).

Swamp species require a moist substrate rich in organic matter and a water flow. The most popular representatives of this group are *Iris pseudacorus* and *Polygonum amphibium*.

Coastal species provide a strong aesthetic effect, especially when combined with floating species. Representatives of this group help blur the boundary between water and shore — *Alisma plantago-aquatica*, *Caltha palustris*, *Carex acuta*, *C. pseudocyperus*, *Sagittaria sagittifolia*, *Sparganium erectum*, *Typha angustifolia*, and *T. latifolia*.

Plants that float on the water's surface provide shading, preventing the water from overheating. These species are best placed on the sunny side of the reservoir. Their submerged parts absorb minerals and carbon dioxide from the water, helping to suppress algae growth — *Trapa*, *Polygonum*, *Nuphar*, *Nymphaea*.

Thus, despite the fairly wide range of higher aquatic and emergent aquatic species with decorative qualities, they are rarely used in landscaping ponds on homestead plots, in parks, and public squares. One reason for this is the complexity of their cultivation and the need to ensure optimal growth conditions. I believe that increasing the use of ornamental aquatic species in the landscaping of settlements, particularly in cities, will enhance the aesthetic value of the urban landscape.

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**COLLECTION FUNDS OF THE PHYTOSOZOLOGY
DEPARTMENT OF THE KREMENETS BOTANICAL
GARDEN (MOBILIZATION, DYNAMICS, MAINTENANCE)**

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As stated in Article 2 of the 1992 Convention on Biological Diversity, “biological diversity” refers to the variety of living organisms from all sources, including, inter alia, terrestrial, marine, and other aquatic ecosystems, as well as the ecological complexes of which they are a part; this concept encompasses diversity within species, between species, and diversity of ecosystems. The objectives and provisions of the Convention regarding the conservation of biological diversity and the use of genetic resources remain relevant today [1].



Photo 1. General view of the collection of natural flora plants of the Department of Phytosoology (June 2020).

Plant diversity is protected and maintained primarily through *in situ* and *ex situ* methods. The former focuses on preserving natural centers of plant populations, while the latter is an active protection method involving the preservation of phytodiversity in cultivation, with attention to the origin of specimens.

Botanical gardens play a leading role in the preservation of plant diversity through the maintenance of living collections. After the resumption of the institution's activities in 2001, the primary task of the Kremenets Botanical Garden was the formation of plant collections (Photo 1). As of 2024, the collection fund of the Department of Phytosoology occupies an area of 0.08 hectares and consists of several sections: "Natural Flora," "Rare Species," "Regionally Rare Species," and a nursery of rare plants. In addition, some specimens contribute to the exhibition area of the botanical garden, showcasing the diversity of natural plant species and their potential for ornamental use. The collection funds of the Kremenets Botanical Garden also serve as a subject for comprehensive study and analysis, the introduction and reintroduction of species, and the formation of a seed bank to ensure the further preservation of the gene pool of collection plants.

The origin of plant material is important in the formation of collections. All acquisitions are recorded in the register of receipts, which includes: serial number, registration number, Latin name of the species, date of receipt, stage

of development (vegetating, budding, flowering, fruiting, seeds, bulbs, tubers), quantity, source and donor, origin, planting location, and recipient (signature). Since 2014, this register has been maintained in electronic format.

Mobilization and replenishment of plants in the collection are carried out in various ways [3, p. 18], the most significant of which is the collection of seeds or live specimens during expeditions. According to the register, material for replenishing collections also came from specialized institutions and private collections, as well as through purchases from specialized stores. From 2001 to the first half of 2024, samples for the formation of collections were obtained from 17 botanical gardens, including 8 foreign ones, 5 arboretums of Ukraine, 8 national nature parks, the research station of medicinal plants of the Institute of Agroecology and Environmental Management of the National Academy of Agrarian Sciences of Ukraine, and other sources [3, p. 18]. It should be noted that during the years of quarantine restrictions and the full-scale Russo-Ukrainian war, when expeditionary trips became infrequent, the share of acquisitions from private collections increased significantly, reaching 67% in 2021 and 93% in 2022. In total, 965 specimens were received over the past decade. Collection material by origin was obtained from 14 regions of Ukraine [3, p. 18], covering the western, southern, eastern, and central parts of the country, Crimea, as well as 10 foreign countries. By the 20th anniversary of the department's operation, all information about the current plant collection was compiled into a catalog illustrated with photographs.

As of 01.08.2024, the collection fund of the Department of Phytosozology of the Kremenets Botanical Garden represents more than 28% of the regional flora [2, pp. 167–192], which constitutes almost 6% of the flora of Ukraine and includes 527 species.

The collection is organized according to a random principle and includes species, subspecies, forms, varieties, and hybrids. The core of the collection consists of herbaceous meadow-steppe and forest species. The families Asteraceae, Lamiaceae, and Ranunculaceae are most widely represented. A significant number of species from the small genera *Vinca*, *Polygonatum*, *Lunaria*, *Leucojum*, *Fritillaria*, and *Eryngium* have been collected. Some species are also represented by natural white-flowered forms.

In addition to species of the Ukrainian flora, the collection successfully cultivates interesting and little-known introduced plants, such as *Morina*

longifolia Wall., *Teucrium hircanicum* L., *Caryopteris incana* Miq., *Hypericum calycinum* L., *Lippia dulcis* Trevir., *Origanum heracleoticum* L., and *Nauclea orientalis* (L.) L.

Collections of living plants are dynamic entities. The fund of collection plant species of natural flora continues to grow steadily, also contributing to the mobilization and preservation of the phyto gene pool in the botanical garden. The dynamics of the collection fund's development over the past decade demonstrate a trend of gradual growth (Fig. 1).



Figure 1. Dynamics of the formation of the collection fund of the Department of Phytosozology from 2014 to 2023.

It should be noted that since 2001, the collections have been relocated four times, which negatively affected the dynamics of species numbers. The most recent relocation took place in 2016, to the Bilya Zuba tract, where the department's collection fund remains to this day (Fig. 1).

The most important factors for the successful maintenance of species in the collection are soil condition and composition, soil moisture, and protection from pests and fungal diseases such as rust, leaf spot, and powdery mildew. Given the ongoing climate changes — including decreased precipitation and an increase in the number of high-temperature days — preserving the

collection fund requires increased efforts to maintain soil moisture. This issue is addressed through additional watering and mulching with organic materials (green mass, straw). Biological products are primarily used to combat diseases and pests.

The collection funds of the Department of Phytosozology play a crucial role in preserving the gene pool, as well as in the introduction and reintroduction of valuable species. They also serve as a source of botanical knowledge. Scientific research, educational practices, natural science lessons for school-children and students, excursions, and outreach activities aimed at addressing biodiversity conservation and fostering environmental awareness are all conducted based on these collections.

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STRUCTURE OF THE NATURE RESERVE FUND OF RIVNE OBLAST

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Introduction. The Nature Reserve Fund (NRF) sites play a vital role in conserving biodiversity, supporting ecological processes, and promoting the sustainable development of natural systems. They serve as key tools for environmental protection and natural resource management, ensuring the preservation of rare and unique species of flora and fauna that may be threatened by human activities or natural factors [1].

The NRF sites provide essential environmental services such as water purification, climate regulation, and soil erosion prevention. Forests and other natural habitats within the NRFs [2] contribute to carbon absorption, helping to mitigate the effects of greenhouse gases on the climate. These areas also function as natural laboratories for scientific research and sources of environmental education. They facilitate the study of natural processes, ecosystems, and species in their natural habitats while raising public awareness about the importance of nature conservation and environmental issues.

Additionally, the NRF sites offer opportunities for ecotourism and recreation, allowing people to enjoy nature without compromising the ecological integrity of the areas [4]. They also possess cultural and historical significance, preserving indigenous traditions and archaeological sites. The effective management and maintenance of these areas are crucial for ensuring ecological stability and the sustainable development of society.

The object of the study is the structure of the Nature Reserve Fund of Rivne Oblast (Rivne Region). This includes all categories of nature reserves, such as reserves, national nature parks, nature reserves, regional landscape parks, natural monuments, and other types of nature reserves with varying protection statuses and purposes.

The subject of the study is the distribution and characteristics of the sites within the NRF of Rivne Oblast in terms of their quantitative and territorial distribution. This encompasses an analysis of the area and number of different categories of nature reserves, their role and functions in preserving biodiversity, supporting ecological processes, as well as their socio-economic aspects, such as opportunities for ecological tourism and recreation.

The purpose of the study is to analyze the structure of the NRF in the Rivne Oblast in order to assess the distribution and characteristics of sites across different protection categories. This includes evaluating the quantitative and territorial distribution of nature reserves, analyzing their role in preserving

biodiversity and ecological processes, and exploring their socio-economic impact, particularly on ecological tourism and recreation.

For this analysis, materials [3] from the Department of Ecology and Natural Resources of the Rivne Regional Military State Administration, as well as a regional report on the state of the environment in Rivne Oblast, were utilized.

Research Results. There are 29 sites of national importance within the NRF in Rivne Oblast, covering a total area of 119,299.517 hectares. The largest share in terms of area is occupied by national natural parks (3 sites), which cover 55,032.417 hectares, approximately 46.1% of the total area of the NRF of national importance. Nature reserves, of which there is one object, cover 47,046.8 hectares (39.4%). Reserves, of which there are 13 in the region, occupy an area of 16,720 hectares (14%). Other categories, including dendrological parks, zoological parks, natural monuments, and parks-monuments of garden and park art, cover minimal areas, accounting for less than 0.5% of the total area of the NRF.

Table 1. *Distribution of the Number and Areas of Categories of National and Local Importance in Rivne Oblast*

NRF Category	Number		NRF Category	Number	
	Qty	Area (ha)		Qty	Area (ha)
National Significance			Local Significance		
Dendrological Park	1	29.5	Zakaznyk (Nature Reserve)	114	50,789.0
Zakaznyk (Nature Reserve)	13	16,720.0	Protected Tract	96	3,328.6
Zoological Park	1	11.6	Natural Monument	76	1,603.6234
National Nature Park	3	55,032.417	Park-Monument of Landscape Art	13	137.1962
Natural Monument	8	420.2	Regional Landscape Park	3	58,708.0

NRF Category	Number		NRF Category	Number	
	Qty	Area (ha)		Qty	Area (ha)
Park-Monument of Landscape Art	2	39.0			
Nature Reserve	1	47,046.8			
Total	29	119,299.517	Total	302	114,566.42

Nature conservation areas of local importance significantly prevail in terms of the number of sites, with 302 sites in Rivne Oblast, covering a total area of 114,566.42 hectares. The largest areas among them are occupied by regional landscape parks (3 sites), with a combined area of 58,708 hectares, accounting for approximately 51.2% of the total area of the NRF of local significance. The most numerous are zakaznyks (nature reserves) (114 sites), covering 50,789 hectares (44.3%). Other categories, such as protected tracts, natural monuments, and parks-monuments of landscape art, occupy smaller areas but make a significant contribution to the preservation of biodiversity at the local level.

Conclusion. The analysis of the nature reserve fund shows that the Rivne region has a well-developed system of nature conservation areas, represented by various categories of NRFs at both national and local levels. At the national level, the main emphasis is placed on national nature parks and nature reserves, while at the local level, regional landscape parks and reserves predominate. Despite the greater number of sites of local importance, their areas are smaller compared to those of national importance, indicating a difference in approaches to nature conservation at different administrative levels.

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A NEW ALIEN SPECIES OF APHID *APHIS VITALBAE* (HEMIPTERA: APHIDOIDEA: APHIDIDAE) IN UKRAINE

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During the examination of meadow areas near Kharkiv and near the village of Dokuchayevske, close to Ryazanova Balka, between May 23 and 28, 2024, several colonies of *Aphis* (*Aphis*) *vitalbae* Ferrari, 1872 were collected from the shoots, stems, and petioles of *Clematis integrifolia* L. (a plant included in the List of Protected Plants in Kharkiv Oblast) and ornamental *Clematis* spp. This aphid species had not previously been recorded in Ukraine.

Clematis species are affected by 27 species of aphids (Blackman & Eastop 2014), nine of which belong to the genus *Aphis*, with around 600 species known within this genus. In contrast, a total of 757 aphid species are recorded in Ukraine, two-thirds of which belong to the subfamily Aphidinae, with approximately half of the species belonging to the genus *Aphis*.

A. vitalbae is known from southern and central Europe. Since around the 1960s, the species has expanded its range northward. It is monoecious, anholocyclic in the southern part of its range, and holocyclic further north. It may also be attended by ants.

Part of the material is preserved as slides and in alcohol with the label:
- NE UKRAINE, Kharkiv Obl., Kharkiv Raion, h=124m, 49.99788° / 36.14863°,

2024.V.28 leg. Zhebina T. det., Bengus Y. All findings have been recorded on the “iNaturalist” website and partially on the “GBIF” website.

Table 1. *Findings of the Aphid Aphis vitalbae (HEMIPTERA: APHIDOIDEA: APHIDIDAE) in Ukraine*

Species	Location of finding	Coordinates in decimal system		Date of finding	Author-ship of finding
		Latitude	Longitude		
<i>Aphis vitalbae</i>	Near Ryazanova Balka, vicinity of Dokuchayevske village, Kharkiv Raion, Kharkiv Oblast, Ukraine	49.99788°, 49.88891°	36.14863°, 36.44429°	2024-05-28 2024-05-23	T. Zhebina, Y. Bengus

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KREMENETS BOTANICAL GARDEN AS A CENTER FOR ENVIRONMENTAL EDUCATION AND OUTREACH AMONG YOUTH

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The processes of globalization and social transformation have increased the priority of environmental protection, requiring Ukraine to take urgent action. According to the Law of Ukraine "On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the Period Until 2030" dated February 28, 2019, No. 2697-VIII, the goal of state environmental policy is to achieve a good environmental status by introducing an ecosystem approach to all areas of Ukraine's socio-economic development. This aims to ensure the constitutional right of every citizen to a clean and safe environment, promote balanced nature management, and preserve and restore natural ecosystems.

Decisions and resolutions addressing environmental issues are reflected in key documents adopted by the international community. Much attention is devoted both to environmental culture in general and to its individual components. Studying human interactions with the environment is essential not only for understanding the natural factors necessary for human life and society but also for analyzing human impact on nature. A progressive ecological culture can serve as a vital motivation for sustainable social development, as it reflects the values of the present in the relationship between humans and nature [1, p. 122].

Environmental education plays an important role in this context and consists of both formal and informal components. Elements of formal environmental education are present across educational institutions at all levels. Informal environmental education refers to the formation of environmental awareness through the activities of various environmental, scientific, research, and cultural institutions and organizations [2, p. 279].

The educational work and outreach activities of botanical gardens have significant potential for fostering ecological culture. According to the Law "On the Nature Reserve Fund of Ukraine," botanical gardens, in addition to scientific and educational activities, are tasked with promoting ecological awareness and encouraging public involvement in the preservation of natural heritage.

The Kremenets Botanical Garden collaborates with all segments of the population, enterprises, institutions, and organizations of all forms of ownership, as well as with state executive authorities, local self-government bodies, public and international organizations. Particular attention is given to cooperation with preschool, general education, extracurricular, vocational, technical, and higher educational institutions, as well as with the media.

The work on cultivating ecological culture is carried out in three interrelated areas: ecological and educational activities, educational and research activities, and environmental protection activities. These are expressed through a variety of forms, methods, and techniques.

The development of ecological culture among the population is closely linked to the aesthetic and moral development of the individual. Aesthetic education holds paramount importance and can only be achieved through constant interaction with unspoiled nature. To feel part of a larger whole, a person must engage regularly, not episodically, with the natural world [3, p. 339].

The exhibition areas of the Kremenets Botanical Garden, combined with natural landscapes, create unique ensembles that form an important component of the educational environment and serve as a model of ecological education. Staff at the Kremenets Botanical Garden foster a love for nature and teach an appreciation of its beauty. Aesthetic experiences gained from observing the diversity and remarkable beauty of nature inspire a genuine appreciation for surrounding phenomena, objects, and landscapes, and encourage concrete actions to improve the state of the environment.

The most effective means of reaching a wide audience is through environmental education and information campaigns via the media. For individual campaigns, original videos and slide films highlighting biodiversity conservation issues are prepared and shared on social media, and close cooperation is maintained with local publications. Specialists of the Kremenets Botanical Garden organize drawing competitions as part of various environmental campaigns, deliver talks during class hours, engage visitors in conversations, and host flash mobs, quizzes, and quests, distributing promotional materials, thematic leaflets, and booklets.

An important direction in the formation of ecological culture is educational and research activity. This includes participation in seminars, conferences, and round tables, as well as conducting student field practices, outdoor lessons (eco-art workshops, practical classes), and various types of excursions (overview, thematic, interpretive, individual, and group). The ecological knowledge gained allows individuals to form the best possible relationships with nature and make informed decisions to protect and preserve the environment.

To facilitate familiarity with nature, plant diversity, and notable features within the garden, ecological trails and excursion routes have been developed, providing both educational and cognitive value. During excursions, visitors to the botanical garden have the opportunity to explore typical representatives of natural autochthonous flora, expositions of decorative dendroflora, flower gardens and ornamental species, rare plant collections, and gardens featuring magnolias, lianas, rhododendrons, and shaped fruit crops, all while admiring the beautiful landscapes.

The most effective forms of environmental education involve observations and experiments conducted during walks or excursions, allowing visitors direct contact with nature. An important aspect of environmental protection activities is the organization of various environmental campaigns ("Primrose," "Clean Environment," "Plant a Tree," "Instead of a Christmas Tree, a Winter Bouquet," "Greening the Planet," etc.), which play a key role in developing ecological knowledge and skills by directly involving children and youth in practical activities. Tree planting, the making and hanging of artificial nesting boxes for birds, landscaping efforts, and other actions are carried out with broad public participation, primarily involving schoolchildren and students, and are aimed at protecting nature and improving the environment.

The study of a phenomenon from different perspectives provides a more comprehensive understanding of it. An eco-cultural project, the open-air gallery *Open Portal*, is currently being successfully implemented within the territory of the botanical garden. Unique and original art objects, created from natural materials and carrying deep philosophical meaning, decorate plant expositions, integrate harmoniously into the landscapes, and inspire environmentally focused reflection.

Thus, in order to foster ecological culture and consciousness, the specialists of the botanical garden integrate environmental education with educational, research, and conservation activities. Diverse efforts in these areas

elevate the level of ecological culture, cultivate a respectful attitude toward nature, and encourage a commitment to environmental protection through practical actions.

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MONITORING OF OAK AND BEECH FORESTS, THEIR CONSERVATION AND REPRODUCTION IN THE TERRITORY OF THE KREMENETS MOUNTAINS NATIONAL NATURE PARK

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The total area of the Kremenets Mountains National Nature Park (herein-after referred to as the Park) is 6,951.2 ha, with 6,730.3 ha covered by forest vegetation, accounting for 96.8% of the Park's total territory. The most valuable areas include native and regenerated oak-hornbeam, oak-maple-ash, oak-hornbeam-ash, and beech plantations, as well as centuries-old trees of common oak, holm oak, forest beech, Scots pine, sharp-leaved maple, common ash, and

others [1]. The main forest-forming species in the Park are common oak and forest beech. Oak plantations are most commonly found with admixtures of common hornbeam, sharp-leaved maple, common ash, and other species.

The purpose of our research is to examine and assess the current state of oak and beech forests and analyze their natural regeneration within the Park. We studied the representation of common oak, red oak, sycamore oak, and forest beech, as well as their proportions in the composition of existing stands. This was done across six subformations of the common oak formation, one subformation of the sycamore oak formation, five subformations of the red oak formation, and one subformation of the forest beech formation (Table 1).

To conduct this research, we applied widely accepted methods in forestry and comparative ecology to analyze the dynamics and condition of the stands. Areas of forest types were selected based on taxonomic descriptions by allotments. This allowed for the clarification of the distribution limits of common, red, and sycamore oaks, as well as forest beech, and the determination of the proportions of the main species in the existing stands. Forest types and vegetation conditions were classified according to the principles of Ukrainian forestry typology. Natural regeneration was studied by establishing trial plots following the method of M. M. Gorshenin [2].

Table 1. *Areas of forest types and shares of common oak, sessile oak, northern red oak, and European beech in the territory of the Park*

Share of common oak in the composition of stands, ha, %						
Subformation	100-80	79.9-60	59.9-30	9.9-0	+Additional units Total	
Oak	428.5/ 18.1	573.1/ 24.2	1361.5 57.5	5.9/ 0.2		2369.0/ 100
Hornbeam-oak				6/ 4.25.1	54.8/ 24.9	219.0/ 100
Pine-oak				2.1/ 1.5	44.3/ 58.5	86.4/ 100
Ash-oak			20.1/ 11.0	31.3	132.7/ 72.0	184.1/ 100
				7.0		

Sycamore-oak				19.2/ 100		19.2/ 100
Maple-oak				9.1/100		9.1/100
Share of sessile oak in the composition of stands, ha, %						
Oak			2.4/100			2.4/100
Pine-oak					10.1/100	10.1/100
Share of northern red oak in the composition of stands, ha, %						
Pure oak	35.7/ 13.9	66.8 / 25.9	155.7/ 60.2			258.2/ 100
Ash-oak				3.4/100		13.4/100
Sycamore-oak				20.5/ 100		20.5/100
Maple-oak				5.8/100		5.8/100

Oak stands in the park cover 40.2% of the forested area. These stands are primarily artificially created, following the native type. The most common forest type is fresh hornbeam-oak (D2GD), making up 50.6%. In these stands, the first tier is formed by common oak, with occasional admixtures of common ash and common hornbeam. The second tier is occupied by species such as sharp-leaved maple, sycamore, and heart-leaved linden. Dry forest stands (D1) are rare in elevated areas, comprising 2% of the Bilokrynytsia Nature Conservation Research Department, and 1% of the Maslyatyn Nature Conservation Research Department. These are represented by dry hornbeam forests. Nearly half of these stands have low density (0.65 and below), with well-developed undergrowth. Fresh forest stands (S2) are represented by fresh hornbeam-pine forests (S2GDS), which make up a maximum of 28.6% of the Maslyatyn Nature Conservation Research Department, and fresh hornbeam forest stands (S2GD), which make up up to 15.5% of the Stizhok Forestry, now part of the park without land withdrawal. Moist forest stands (S3) are represented by moist hornbeam forests (S3GD) and moist hornbeam-pine forests (S3GSD) on the territory of Stizhok Forestry (Table 2).

Today, the predominant age classes of oak stands in the Park consist of young and middle-aged trees, primarily of artificial origin. Sessile oak covers an area of 2.4 hectares and is also present sporadically as part of a pine plantation over 130 years old, occupying an additional 10.1 hectares. This species, characteristic of moderately mild climates, is typically found on hilly terrain

and sunny slopes. It is less demanding in terms of soil and moisture conditions than common oak.

Table 2. *Distribution of areas of oak and beech plantations by forest types in the Park*

Forest Type Index	Forest Type	Uhorsk Nature Conservation Research Department	Bilokrynytsia Nature Conservation Research Department	Maslyatyn Nature Conservation Research Department	Stizhok Forestry (territory without land withdrawal)
S1D	Dry forest stands		<1%	2.6%	
S2GDS	Fresh hornbeam-pine forest stands	21%	11%	28.6%	
S2GD	Fresh hornbeam forest stands		3%	10.8%	15.5%
S3GD	Moist hornbeam forest stands	<1%	<1%	<1%	22.1%
S3GSD	Moist hornbeam-pine forest stands		<1%	1%	45.2%
S4GD	Wet hornbeam forest stands			<1%	

Prior to the Park's establishment in 2009, intensive forestry activities were conducted on its territory by the former land user (State Enterprise "Kremenets Forestry"), including clear-cutting, regeneration felling, and sanitary logging. As a result, monocultures were established in the 1960s, often including invasive and non-native species — particularly red oak, which now occupies 252.2 hectares (3.9% of the Park's forested area).

In contrast to oak stands, beech forests within the Park cover only 89.9 hectares. These are primarily located in areas characterized by the D2 forest site type, as well as in wet hornbeam-beech forest conditions (D3GBk) within the Bilokrynytsia and Maslyatyn Nature Conservation Research Departments

(Table 2). In lowland growth conditions, beech stands are typically confined to hilly landscapes at elevations of 300 meters or more above sea level. Within the Park, these beech forests are situated at the northeastern edge of the species' range, where some individual trees up to 200 years old have survived. These specimens exhibit structural features typical of primeval forests.

A classic beech-oak stand of site quality class I has been preserved within the territory of the Uhorsk Nature Conservation Research Department and is part of the local botanical natural monument *Bilokrynytska Buchyna* No. 1 and No. 2, covering an area of 17.3 hectares. This site serves as a gene pool reserve for European beech. The area contains 10-year-old natural regeneration of European beech, 1.5–2 meters high, with a density of 4,200 individuals per hectare.

The oldest beech stand in the Park is located in Compartment 46, Plot 12, and Compartment 47, Plot 7 of the Maslyatyn Nature Conservation Research Department. It is 123 years old and occupies the highest part of the forest massif. This stand is part of the local botanical natural monument *Kremenetska Buchyna* No. 1 and No. 2, which protects highly productive beech-oak-hornbeam and beech-pine stands of site quality class I. The soil is dark gray, light loam, weakly gleyed, on loess-like loams, with a forest site type of D2GD.

The stand is uneven-aged and pure in species composition, with a minor admixture of Scots pine, common hornbeam, and Norway maple. The average diameter is 36.3 cm, and the average height is 27.1 m. The beech timber volume amounts to 665.74 m³ per hectare.

Adjacent to the old-growth beech forest, in Compartment 47, Subplot 1 of the Maslyatyn Nature Conservation Research Department, a two-layered Scots pine-hornbeam-beech stand has formed. Its composition is 8PAb1Hc1B-m+By+Fe, covering 6.0 hectares. The stand is 120 years old, with an average diameter of 48 cm, an average height of 32 m, and a density of 0.7.

Among the monocultures of beech forests, one can also distinguish a 119-year-old plantation with an area of 5.2 ha in square 12, type 9 of the Maslyatyn Nature Conservation Research Department with a density of 0.75 and high productivity (I bonitet), growing in a fresh hornbeam-beech forest stand [4]. In order to study the natural regeneration of common oak and beech forests, we established trial plots in areas where excellent regeneration of the main forest-forming species is observed. Beech forests, sycamores and sharp-leaved maples are intensively naturally regenerated. Common hornbeam is

widely distributed, and to a lesser extent, common oak and common ash (Table 3-7). Common oak in the conditions of the Park bears fruit annually, but abundant harvests occur depending on weather conditions once every 2-4 years. The determining ecological factor influencing the preservation, growth and development of self-seeding and undergrowth of oak is low light, which under the canopy of high-density oak-hornbeam forest stands reaches 0.5-3.0% of total light, which leads to the gradual death of self-seeding in the second or third year of life.

Table 3. *Natural regeneration under the canopy of a 120-year-old stand on Permanent Sample Plot LPP-11, Compartment 46, Subplot 12 of the Maslyatyn Nature Conservation Research Department with a composition of 9Bm1PSc (in the undergrowth: Bm1Sy + TI + PSc)*

Tree Species	Distribution of the Number of Natural Regeneration Individuals by Age and per 1 ha, units			Total
	2-3 years	4-7 years	8 i <	
Bm (<i>Fagus sylvatica</i>)	8,964	10,782	3,636	23,382
Sy (<i>Acer pseudoplatanus</i>)	9,454	45,327	8,236	63,017
Fm (<i>Acer platanoides</i>)	6,654	17,454	16,727	40,836
Hc (<i>Carpinus betulus</i>)		473		473
Cv (<i>Prunus avium</i>)	236			236

Table 4. *Natural regeneration under the canopy of a 100-year-old stand at Permanent Sample Plot LPP-12, Compartment 47, Subplot 1 of the Maslyatyn Nature Conservation Research Department with a composition of 8PAb1Hc1Bm+By+Fe (in the undergrowth layer: 5PAb4Hc1Bm+By+Am+Sy)*

Tree Species	Distribution of the Number of Natural Regeneration Individuals by Age and per 1 ha, units			Total
	2-3 years	4-7 years	8 i <	
Bm (<i>Fagus sylvatica</i>)	17,029	17,597	9,179	43,805
Sy (<i>Acer pseudo-platanus</i>)	26,776	40,373	9,179	76,328
Fm (<i>Acer platanoides</i>)	8,418	8,985	5,925	23,328
Hc (<i>Carpinus betulus</i>)	955	10,825	5,731	17,582
Fe (<i>Fraxinus excelsior</i>)	179			179
Bp (<i>Betula pendula</i>)	179	567		746
Cv (<i>Prunus avium</i>)	1,134	179		1,313

Table 5. *Natural regeneration under the canopy of a 120-year-old stand at Permanent Sample Plot LPP-9, Compartment 41, Subplot 9 of the Uhorsk Nature Conservation Research Department with a composition of 6Qr1Fe3Hc+Tl (in the regeneration layer: 5Bm2Qr2Hc1Fe+Tl+Fm+Bv+By)*

Tree Species	Distribution of the Number of Natural Regeneration Individuals by Age and per 1 ha, units			Total
	2-3 years	4-7 years	8 i <	
Bm (<i>Fagus sylvatica</i>)	17,600	21,770	3,220	42,590
Hc (<i>Carpinus betulus</i>)	6,767	4,581	2,907	14,255
Fe (<i>Fraxinus excelsior</i>)	12,584	953		13,534
Sy (<i>Acer pseudo-platanus</i>)	20,349	13,069	232	33,650
Fm (<i>Acer platanoides</i>)	2,418	232		2,650

Table 6. *Natural regeneration under the canopy of a 107-year-old stand at Permanent Sample Plot LPP-13, Compartment 6, Subplots 10 and 13 of the Maslyatyn Nature Conservation Research Department with a composition of 4Qr1Fe5Hc+Fm+Tl (in the regeneration layer: 4Qr3Fe3Hc+Tl+Sy+By+Fm)*

Tree Species	Distribution of the Number of Natural Regeneration Individuals by Age and per 1 ha, units			Total
	2-3 years	4-7 years	8 i <	
Fm (<i>Acer platanoides</i>)	2,000	2,285		4,285
Tl (<i>Tilia cordata</i>)	570			570
Sy (<i>Acer pseudo-platanus</i>)	280			280
Fe (<i>Fraxinus excelsior</i>)	1,420	280		1,700
Hc (<i>Carpinus betulus</i>)	2,850	1,000		3,850

Table 7. *Natural regeneration under the canopy of a 90-year-old stand at Permanent Sample Plot LPP-14, Compartment 59, Subplot 3 of the Uhorsk Nature Conservation Research Department with a composition of 4Fe1Qr1Sy5Hc (in the regeneration layer: 3Fe1Qr1Sy5Hc+Tl+Fm)*

Tree Species	Distribution of the Number of Natural Regeneration Individuals by Age and per 1 ha, units			Total
	2-3 years	4-7 years	8 i <	
Fe (<i>Fraxinus excelsior</i>)	3,580	760		4,340
Fm (<i>Acer platanoides</i>)	1,5120	80	170	15,370
Sy (<i>Acer pseudo-platanus</i>)	9,910	6,920	1,530	18,360
Tl (<i>Tilia cordata</i>)	340			340
Qu (<i>Quercus robur</i>)	760			760
Ro (<i>Quercus rubra</i>)	80			80
Hc (<i>Carpinus betulus</i>)	2,470	250	80	2,800
Bm (<i>Fagus sylvatica</i>)	1,190	1,280	170	2,640

The soil conditions of the Park allow for the cultivation of forests featuring common and sycamore oaks, as well as forest beech. Since the Park's inception, sycamore oak forests have been established on plots of land abandoned for agricultural use and on degraded biomeadows, covering an area of 17.8 hectares. Additional sycamore oak forests have been planted on 0.1 hectares, and forest beech forests on 2.6 hectares. The average survival rate of these forest crops is 92.2%. The crops are maintained throughout the growing season.

To gradually replace non-native and derivative, low-quality, even-aged, structurally simple, and low-productivity plantations with native species, we have developed and implemented the "Program for the Preservation and Restoration of Native Tree Stands" [3]. Since 2019, work has been carried out to reproduce and preserve native stands in the Park by introducing the main forest-forming species — Scots beech and common oak — at a planting density of 500 seedlings per hectare (10x2 m spacing) in pure, overmature hornbeam, spruce, and birch-derived stands. During this period, 234.2 hectares have been covered, with 83,550 Scots beech and 1,290 common oak seedlings planted. The average survival rate is 72.3%.

The introduction of Scots beech and common oak is carried out using seedlings from ecologically related ecosystems in the region, sourced from areas adjacent to the Park. This approach maximizes the preservation of the local gene pool of valuable tree species and enables the rapid and cost-effective establishment of plantations resistant to adverse environmental conditions.

Overall, the condition of plantations featuring common oak, holm oak, and forest beech in the Park is satisfactory. The implementation of measures to restore indigenous plantations contributes to the preservation of forest genetic resources — an essential component in the broader effort to protect and regenerate biodiversity on our planet.

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HYDROLOGICAL RESERVE SITES IN THE STRUCTURE OF THE NATURE RESERVE FUND OF KREMENETS RAION: THEIR ECOLOGICAL ROLE

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Volodymyr Chernyak, born in 1948, earned his doctoral degree in 2005 with a dissertation titled "Cultivated Dendroflora of Volyn-Podillia: Prospects for Its Use and Enrichment." Since 2011, he has been Professor of the Department of Horticulture and Forestry. His scientific interests include the phytodiversity of the Kremenets Uplands and the dendroflora of silvicultural landscapes of Ukraine.

Contemporary trends in global and regional climate change, the reduction of freshwater reserves, and the decline in groundwater levels necessitate the intensification of all forms and methods of water resource conservation. A key role in addressing this task is assigned to the territories and sites of the nature reserve fund. The most representative approach to the protection and preservation of water resources is the conservation of existing and the creation of new hydrological reserve sites [1].

Kremenets Raion (Kremenets District) is located in the northern part of Ternopil Oblast (Ternopil Region), within the zone of the western forest-steppe of the Volyn-Polissia Plateau. Its area is 263,520 hectares, which constitutes 19.0% of the total area of Ternopil Oblast (1,383,600 hectares). The district comprises eight territorial hromadas (communities): Borsuky rural hromada, Velyki Dederkaly rural hromada, Vyshnivets settlement hromada, Kremenets

urban hromada, Lanivtsi urban hromada, Lopushne rural hromada, Pochayiv urban hromada, and Shumsk urban hromada. The current area of the nature reserve fund of national and local significance in the Kremenets District (excluding the areas of those sites that are part of the territories of other reserve objects) is 23,285.14 hectares, which accounts for 8.84% of the district's area (reserve index) [5].

The nature reserve fund (NRF) sites in Kremenets Raion are represented by the following categories: national nature park (NNP), nature reserve (zakaznyk), nature monument, protected tract, botanical garden, dendrological park, zoo-logical park, and landscape art park (park-monument of landscape art).

The distribution of the territories and objects of the nature reserve fund in Kremenets Raion by communities and categories is presented in Table 1.

Table 1. Distribution of Nature Reserve Fund Territories and Sites in Kremenets Raion, Ternopil Oblast, by Community (Hromada) and Category

No.	Name of Territorial Community (Hromada)	National Nature Park	Nature Reserve (Zakaznyk)	Nature Monument	Protected Tract	Botanical Garden	Zoo	Dendrological Park	Park-Monument of Landscape Art
1	Borsuky Rural Hromada								-
2	Velyki Dederkaly Rural Hromada								-
3	Vyshnivets Settlement Hromada								1
4	Kremenets Urban Hromada			0					-
5	Lanivtsi Urban Hromada								1
6	Lopushne Rural Hromada								-

No.	Name of Territorial Community (Hromada)	National Nature Park	Nature Reserve (Zakaznyk)	Nature Monument	Protected Tract	Botanical Garden	Zoo	Dendrological Park	Park-Monument of Landscape Art
7	Pochayiv Urban Hromada								-
8	Shumsk Urban Hromada		3	0					-
Total Number of NRF Territories and Sites in the Hromadas			6	2					2
Actual Number of NRF Territories and Sites		*	2	2					2

Note. The Kremenets Mountains National Nature Park is located within the territories of Kremenets and Shumsk urban hromadas; the Gorynsky Hydrological Zakaznyk is located within the territories of Vyshnivets settlement, Lopushne rural, and Pochayiv urban hromadas; the Vacantsy Botanical Zakaznyk is located within the territories of Kremenets and Shumsk urban hromadas; the Kipykha Botanical Zakaznyk is located within the territories of Borsuky rural and Lanivtsi urban communities.

Thus, there are 104 nature reserve units and sites within the territory of Kremenets Raion. Among them are 9 hydrological reserve sites with a total area of 233.55 hectares, including 3 hydrological nature reserves covering 232 hectares and 6 hydrological natural monuments covering 1.55 hectares. The distribution of hydrological reserve sites is presented in Table 2.

Table 2. *Distribution of Hydrological Protected Areas in Kremenets Raion, Ternopil Oblast, by Community (Hromada), Category, and Area*

Name of Territorial Community (Hromada)	Name	Category	Area (ha)	Date of Establishment
Borsuky	Peredmirske Spring	Nature Monument	0.02	18.03.1994
Kremenets	Maloberezhetskyi	Nature Reserve (Zakaznyk)	59.50	30.08.1990
	St. Anna's Spring	Nature Monument	0.25	21.08.2000
	Koryto Spring	Nature Monument	0.25	15.10.2015
Lanivtsi	Zelena Krynytsia No. 1 Tract	Nature Monument	1.00	26.12.1983
	Vyshhorodotske Spring	Nature Monument	0.02	15.10.2015
Lopushne	Horynskyi	Nature Reserve (Zakaznyk)	18.10	26.12.1983
	Source of the Horyn River	Nature Monument	0.01	21.08.2000
Vyshnivets	Horynskyi	Nature Reserve (Zakaznyk)	41.60	26.12.1983
Pochayiv	Horynskyi	Nature Reserve (Zakaznyk)	46.30	26.12.1983
Shumsk	Kutyanskyi Lug (Kutyanskyi Meadow)	Nature Reserve (Zakaznyk)	66.50	30.08.1990

A hydrological zakaznyk is a nature reserve established to preserve water bodies, swamps, waterfalls, and springs that have particularly important water protection, water regulation, or aesthetic value. Reserves of this type are valuable as climate stabilizers, regulators of the hydrological regime, and for the conservation of flora and fauna [2].

The “Horynskyi” Hydrological Nature Reserve is a wetland area that plays a significant role in the formation of the source of the Horyn River. The flora of the reserve is primarily represented by aquatic and meadow-marsh vegetation. Particularly valuable species include trifoliate buckbean (*Menyanthes trifoliata* L.), Shiverack’s kidney vetch (*Anthyllis schiwereckii* (DC.) Blocki), and hybrid butterbur (*Petasites hybridus* L.) — all of which are listed among the rare and endangered plant species of Ternopil Oblast.

The “Maloberezhetskyi” Hydrological Nature Reserve is a wetland massif located in a floodplain that helps regulate the water regime of the Ikva River. Its flora consists mainly of aquatic, riparian, and meadow-marsh vegetation. Particularly valuable species include the Red Data Book-listed broad-leaved marsh orchid (*Dactylorhiza majalis* (Rchb.)), early marsh orchid (*Dactylorhiza incarnata* (L.) Soo), and yellow water-lily (*Nuphar lutea* (L.) Smith), all included in the List of Rare and Endangered Plant Species in Ternopil Oblast.

The “Kutyanskyi Lug” Hydrological Nature Reserve is a wetland massif that regulates the water regime of the Kutyanka River. It is home to typical meadow-marsh vegetation of the Western Forest-Steppe. Noteworthy species include the Red Data Book-listed broad-leaved marsh orchid, blueberry willow (*Salix myrtilloides* L.), and trifoliate buckbean (*Menyanthes trifoliata* L.), all of which are included in the List of Rare and Endangered Plant Species in Ternopil Oblast.

Natural monuments are unique natural formations of particular environmental, scientific, aesthetic, educational, and cultural significance, preserved in their natural state [2].

The hydrological natural monuments of the studied region include both natural and artificially created sites. These comprise a natural groundwater spring with crystal-clear water (“St. Anna’s Spring”), sources of drinking water (“Peredmirsk Spring,” “Koryto Spring,” “Vyshhorodotske Spring”), a basin with an artificially created pond considered the birthplace of the Zbruch River (“Zelena Krynytsia No. 1 Tract”), and a powerful groundwater spring regarded as the source of the Horyn River (“Source of the Horyn River”). These sites play a vital role in maintaining the region’s hydrological regime, serve important water protection functions, and serve health, aesthetic, historical, ecological, educational, and economic roles [3, 4].

Thus, within Kremenets Raion of Ternopil Oblast, water resource conservation is carried out through nature reserves covering a total area of 233.55 hectares. A significant portion of this area is occupied by hydrological nature

reserves (232 hectares), while a much smaller area is designated as hydrological natural monuments (1.55 hectares). These protected areas play an important role in nature conservation and environmental management. In addition to their ecological value, they hold cultural significance, serve as key elements in the development of recreational and tourism activities, and function as important educational sites and bases for environmental and educational initiatives.

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USE OF CITIZEN SCIENCE IN DEVELOPING ENVIRONMENTAL COMPETENCE AMONG YOUTH STUDENTS

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Citizen science initiatives are recognized as one of the promising approaches to engaging citizens in research and addressing various socio-ecological challenges. The use of accessible and user-friendly digital tools, combined with public involvement in environmental initiatives, contributes to the development of environmentally aware and active individuals [6–7].

The prospects and practical application of citizen science in the fields of ecology and environmental protection in Ukraine are reflected in the works of O. Boldyriev, O. Kozak, I. Sviezhentseva, V. Serebryakov, L. Skuybida, and K. Shavanova [2, 4–5].

Key features of citizen science include: the opportunity for interested parties to join projects; the use of a unified, pre-developed protocol to enable the integration and comparison of collected data; the gathering of indicators for forming scientifically valid conclusions; and collaboration between scientists and volunteers, with open data sharing available equally to all participants [2].

In Ukraine, the first attempts to apply citizen science to the study of biodiversity were carried out without the use of digital tools. For example, during the “Grak-84” monitoring campaign, ornithologists distributed 20,000 questionnaires [4]. Today, citizen science is considered one of the promising approaches for disseminating scientific knowledge and involving citizens in scientific and technical activities [1]. It is gaining popularity and is now employed

by individual scientists, public organizations, and school and university students to collect scientific data.

According to the results of the project survey “*Use of Citizen Science in Times of War, Crisis, and Catastrophe*,” it was noted that not all Ukrainian scientists have a clear understanding of the concept of “citizen science.” Researchers do not always distinguish this term from the “popularization of science,” and some, despite using citizen science tools, have never encountered the term itself [2].

Despite the relevance of citizen science in disseminating knowledge and supporting volunteer engagement, its potential use in working with students has not been sufficiently explored. Therefore, the purpose of this publication is to examine the features of applying citizen science tools in the development of students’ environmental competence.

As part of the educational process under the Bachelor’s degree programs *Secondary Education (Biology and Human Health. Geography)* and *Ecology* at Taras Shevchenko Kremenets Regional Academy of Humanities and Pedagogy, students are trained to use digital citizen science tools. In particular, during the instruction in practice-oriented core educational components — *General Ecological Practice, Landscape and Ecological Practice*, and *Educational Field Practice on Biodiversity* — students actively use the iNaturalist mobile application and i-Tree software.

To collect data on the species diversity of plants and animals, students use the iNaturalist mobile application (<https://www.inaturalist.org>), which assists in identifying species and provides additional information about them. A key feature of the platform is that many of its users are professionals who regularly review new data, cross-verify identifications, and ensure the quality of the information [3].

Students use the i-Tree software (<https://www.itreetools.org/about>) to collect data on trees. This tool allows them to explore the ecosystem services provided by green spaces and to assess the monetary value of those services.

While studying the educational components *Human Ecology and Socioecology, Sustainable Development*, and *Environmental Education and Culture*, students become familiar with digital tools for documenting the consequences of environmental pollution and ecological disasters, including:

- EcoZagroza — <https://ecozagroza.gov.ua/help>
- SaveEcoBot — <https://www.saveecobot.com/features/environmental-crimes>

The EcoZagroza application is an official resource of the Ministry of Environmental Protection and Natural Resources of Ukraine, which enables users to report environmental threats and violations they have witnessed. The SaveEcoBot platform consolidates information about pollution, pollutants, and environmental protection tools. The use of these applications enables students to access reliable information on environmental quality and to demonstrate civic engagement.

It should be noted that students who participate in citizen science demonstrate initiative and interest in scientific research and are capable of motivating their peers to adopt an active environmental stance. We are convinced that engaging Ukrainian society — particularly students — in scientific activity through citizen science tools will enable research institutions to broaden their scientific efforts.

Conclusion. Citizen science holds significant potential for shaping the environmental consciousness of Ukrainian society. In particular, the use of digital applications such as iNaturalist, i-Tree, EcoThreat, and SaveEcoBot in the educational process contributes to the development of environmental competence and an active civic stance among students.

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IMMERSIVE TECHNOLOGIES IN BIOLOGICAL, ECOLOGICAL, AND GEOGRAPHICAL EDUCATION

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Information and communication technologies (ICT), which are rapidly being integrated into education, are shifting the educational paradigm from the accumulation of information to continuous access to it in various forms. Online classes, mobile applications, alternative information sources, and the use of cloud technologies are becoming increasingly popular in both everyday life and the educational process. In education, this enables an individualized approach, differentiation of cognitive activity, interactive engagement among participants in the educational environment, and encourages students to pursue independent inquiry and creative work.

The modern generation of youth is naturally inclined toward advanced technologies, embracing both new methods of acquiring knowledge and interactive forms of communication. One of the latest examples of ICT tools is immersive technologies, which allow the creation of an effective, immersive educational environment that fosters learning motivation, intellectual and practical development, emotional engagement, and creative self-realization among students [5].

Immersive technologies in education, by combining passive and active learning, enhance information retention and make classes more effective. Everything — from a tiny molecule to the vast Universe — can be brought to life through visualization.

Immersive technologies refer to tools that enable full or partial immersion in a virtual environment, blending real and virtual environments [1]. They are also known as augmented reality technologies because they allow for presence in entirely different domains. Immersive technologies include:

- VR — virtual reality, where the environment is entirely simulated using modern technologies;
- AR — augmented reality, in which elements of simulated reality are added to real-world reality (RR).

These immersive technologies have distinct characteristics: augmented reality (AR) is considered more promising and easier to implement in education than virtual reality (VR), as it helps broaden students' worldviews [1]. AR engages students in the learning process (e.g., animating images), stimulates the acquisition of new knowledge, and supports the development of new competencies, making it particularly suitable for studying biology.

Virtual reality, on the other hand, makes lessons unusual and highly engaging by enabling audiovisual and sensory interaction within a virtual environment. It is often used for video-based experiences, supporting the development of subject-specific competencies in fields like ecology and geography.

The use of immersive technologies offers several advantages:

- Clarity — enables the visualization of objects and phenomena that are nearly impossible to observe in reality, especially with ongoing development, updates, and dynamic transformations;
- Concentration — helps maintain focus and minimizes distractions during the learning process;
- Efficiency — captures interest through novelty and modernity;
- Safety — in a virtual environment, damage can be simulated without real-world consequences;
- Motivation — captures learners' attention, provides an interactive and engaging experience, and encourages the pursuit of knowledge and discovery.

Immersion in the virtual world through immersive technologies should be integrated and balanced with the real environment. It allows the simultaneous provision and reception of information from multiple sources, enhancing the quality and speed of educational activities.

It is well known that visualization enhances perception, as people tend to remember best what they see. AR technologies enable the effective use of visually obtained information [6].

VR technologies enable the visualization of complex processes or unusual phenomena and create a sense of presence in specific locations — such as a particular country or ecosystem — enhanced by interactive, voice, musical, animated, and graphic support [1].

Immersive technologies enable a wide range of studies and analyses of biological objects, the consequences of environmental events, and participation in geographical expeditions and excursions. This innovative form of educational activity facilitates the acquisition of subject knowledge and the development of communicative and cognitive skills.

Immersive technologies also play a significant role in creating an inclusive learning environment, as they allow access to materials in virtual space that can be tailored to the needs and abilities of individual students, taking into account their physical, social, and cognitive limitations.

In Ukraine, VR and AR technologies in education are still in the early stages of development, indicating promising prospects for the future. Currently, the Ukrainian products AR-Book and AR-Teacher are relevant tools focused on implementing effective lessons using modern technologies. It is important to note that each experiment available in these systems is approved by the Ministry of Education and Science of Ukraine.

Immersive educational technologies serve as engaging tools for exploring the present, highlighting the relentless pace of technological progress — an essential aspect for today's younger generation.

In the study of biology, ecology, and geography, it is advisable to combine immersive technologies with other teaching methods — such as the case-study method — which enable the visualization of specific events and the dynamic tracking of real-world natural scenarios. The case method pairs well with immersive techniques, as the educational situations presented in biological, ecological, or geographical cases should reflect environments that can be explored virtually. Various graphs, tables, animations, and videos can also be integrated using immersive technologies.

The virtual laboratory 3D Atlas of the Human Body allows students to examine the anatomical features of the human body from different perspectives [2]. The Mosaic media library [4] enriches numerous natural science disciplines with a broad range of educational materials, illustrating plant and animal structures and behavior in real-world environments, including remote regions. Complex biological structures can be studied using the resources available on the Interactive Simulations site [3].

The GLOBE internet service provides data on temperature, precipitation, and atmospheric pressure. The World Wind geoservice is a three-dimensional interactive virtual globe developed by NASA, capable of displaying administrative boundaries, settlement names, city layouts, and national flags. Google Maps with augmented reality enables students to explore geographical features dynamically and interactively, even using smartphones to access additional information about specific locations.

Thus, teachers can conduct virtual excursions and showcase fascinating geographical sites. Effective use of virtual and augmented reality technologies allows for comprehensive research and experimentation without costly equipment, enhances information retention through increased engagement, boosts concentration and focus, and facilitates accurate assessment of students' individual knowledge. In an era of rapid ICT development, educational approaches are evolving accordingly. With access to the internet, a computer, or a smartphone, teachers can conduct highly engaging lessons, as the digitalization of education offers significant opportunities for enhancing the quality of the learning process.

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THERAPEUTIC POTENTIAL OF THE RESIDENTIAL LANDSCAPE IN THE TOWN OF KREMENETS

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In the modern world, a person stepping outside each day encounters a range of emotions, impressions, and mood shifts — ranging from positive to stressful.

For centuries, individuals facing disorientation or uncertainty about the future have sought therapeutic spaces. For instance, those diagnosed with acute or incurable illnesses often seek solitude, needing time and space to reflect on their significant life or health changes [3]. In a harmonious landscape,

the higher cognitive centers of the human brain have the opportunity to rest and reset.

Recently, social tension has increased due to war, the Covid-19 pandemic, climate change, and general uncertainty about the future. This has intensified the need for individuals to find spaces of emotional rest and healing, making landscape therapy an emerging topic of scientific research [7, 9].

The term “therapeutic landscape” was introduced in 1992 by geographer William Gesler, who defined it as a place where the physical and architectural environment, social conditions, and human perception combine to create an atmosphere conducive to healing [6]. Although this definition has faced criticism, it has evolved over the past two decades. A relational and situational approach to the therapeutic qualities of landscapes has emerged, incorporating social, cultural, material, emotional, and sensory factors [3].

The potential health benefits derived from the properties of a landscape should be viewed as a process of human interaction with the environment. It is evident that healing is influenced not only by the space itself but also by the intentions of the individual engaging with it [4]. The landscape can serve as a factor in maintaining human health [7, 10].

R. Foley and T. Kistemann [5] described therapeutic spaces as those formed through a series of embodied empirical practices that connect affects, emotions, and bodily sensations resulting from immersion in such environments.

In the 19th century, medicine developed specific techniques aimed at achieving therapeutic effects and preventing mental illness, rehabilitating the body, normalizing sleep, and increasing appetite — all through the properties of the landscape. During this time, a form of landscape therapy known as *terrainkur* (from the German, meaning “treatment by terrain”) emerged. It was introduced by the German physician M. J. Oertel. Terrainkur involves regulated physical activity in the form of walking or climbing in mountainous areas along designated routes. It builds endurance, improves the function of the cardiovascular and respiratory systems, and stimulates metabolism and nervous activity.

The methods of terrainkur were quickly introduced at resorts in Germany, Switzerland, and other European countries. Terrainkur was widely practiced in the town of Kremenets during the 19th and early 20th centuries, with its routes popular among the wealthy townspeople.

The town of Kremenets, with its picturesque surroundings, has been called the “Little Volyn Switzerland” and “Volyn Athens.” Situated in a valley between mountains with historical names — Zamkova, Cherche, Divochi Skeli, Khrestova, Osovytsia, Volovytsia, and Kulychivka — the town stretches along slopes and hills above the Ikva River. The most famous and significant mountain in Kremenets is Bona, once the site of a castle, of which only ruins now remain [2].

The town and surrounding villages are rich in natural resources, making them well-suited for the development of ecotourism and green tourism. Ecotourism is a relatively young concept, first mentioned by Swiss researchers at the end of the 20th century. Its primary goal is the preservation and responsible use of the natural environment for tourism. Most of Kremenets’s valuable natural resources for tourism are located within the Kremenets Mountains National Nature Park and the Kremenets Botanical Garden [1].

Favorable factors contributing to the recreational potential of Kremenets and its suburban areas include the presence of open spaces combined with forested areas, a large number of trails and roads, and a certain degree of landscaping. The extent of use of the forest landscapes in the Kremenets region depends on their location, transport accessibility, and aesthetic qualities. Forests near urban areas are used for short-term recreation, offering favorable microclimatic conditions, resilience to recreational pressures, and high aesthetic value.

Forest plantations have a positive effect on both the physical and psychological state of individuals, contributing to the restoration of their productivity. One of the key factors influencing the use of suburban forests for recreation is the forest type, which is determined by the specific composition of tree species and local environmental conditions.

The natural features of the town of Kremenets are enhanced by the aesthetics of the architectural ensemble of the Kremenets Collegium, an architectural monument of national importance. It is located in the historical center of the town, on a terrace that dominates the valley in which the town lies. As a result, the single-nave, two-tower collegiate church serves as the main architectural landmark of Kremenets.

The city’s landscape architecture is further enriched by the Epiphany Monastery, St. Nicholas Cathedral, the Church of the Holy Cross, and the Dziembowski Palace. A distinctly different approach to architectural and landscape

design is evident in Bilokrynytsia Castle and its ancient park, which are situated on flat terrain.

Landscape holds considerable potential for a complex influence on the human senses and possesses both health-related and therapeutic value. This therapeutic method can be likened to Eastern Feng Shui, where harmony in the surrounding space is also central. However, while landscape therapy is grounded in scientific medical theories, Feng Shui is based on the flows of the Qi energy believed to permeate all existence.

Landscape aesthetics is one of the applied fields in landscape science that studies the process of perceiving the beauty of the natural environment in the form of a sensory image. It influences the human psyche and health through the visual qualities of the surrounding landscape, which evoke specific associations, emotions, and feelings. Assessing the aesthetic properties of landscapes allows us to identify those most conducive to a psychologically comfortable human life.

According to their psycho-emotional impact, landscapes are classified into the following groups:

- Useful-irritating — evokes creative inspiration;
- Useful-exciting — induces cheerfulness and optimism;
- Useful-gentle — leads to reverie and introspection;
- Useful-inhibitory — promotes relaxation and complete tranquility.

The therapeutic factors of landscape therapy include various aesthetic elements: the uniqueness of the landscape, the presence of rivers, lakes, and other bodies of water, and the character of the flora and fauna (e.g., tree silhouettes, birdsong), as well as architectural ensembles.

The therapeutic effect of landscape therapy is most effective when combined with other treatment methods. For example, a series of experiments in an American clinic found that patients whose ward windows overlooked trees recovered more quickly, experienced fewer postoperative complications, and reported less pain.

The constant visual environment and its saturation with visual elements affect the human condition, acting like any other environmental factor within a person's habitat. Modern scientific data indicate that when the environment becomes visually homogeneous, it negatively impacts the functioning of certain mechanisms of human vision and can lead to serious disorders of the nervous system.

Video ecology is considered a branch of knowledge that explores the relationship between humans and their visible surroundings, viewed as an important ecological factor. It is based on the laws of visual perception and includes methods for assessing the visual environment.

A diverse and attractive landscape is necessary not only for its beauty but also for the normal functioning of biogeocenoses. It carries psychotherapeutic and educational significance. The visual environment is one of the key factors determining people's quality of life. The integration of nature, culture, and health is essential for creating a therapeutic, health-preserving environment.

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ФОТОГАЛЕРЕЯ



Photo 1. Opening of the plenary session of the II International Conference 'Besser Natural History Studies'. Rector of the Kremenets Taras Shevchenko Academy of Humanities and Pedagogy Prof. Afanasii Lomakovych welcomes the participants.



Photo 2. General photo of the conference participants in the reading room of the library of the Kremenets Taras Shevchenko Academy of Humanities and Pedagogy.



Photo 3. General photo of the conference participants in the courtyard of the primary building No. 1 of the Kremenets Taras Shevchenko Academy of Humanities and Pedagogy.



Photo 4. Photo of the conference participants at the monument to Professor W. G. Besser.



Photo 5. Near the monument to Willibald Besser.



Photo 6. Participants of the conference in the reading room of the library of the Kremenets Taras Shevchenko Academy of Humanities and Pedagogy.



Photo 7. Speech by the Rector of the Kremenets Taras Shevchenko Academy of Humanities and Pedagogy Prof. Afanasii Lomakovych.



Photo 8. Speech by Associate Professor Oksana Galagan.

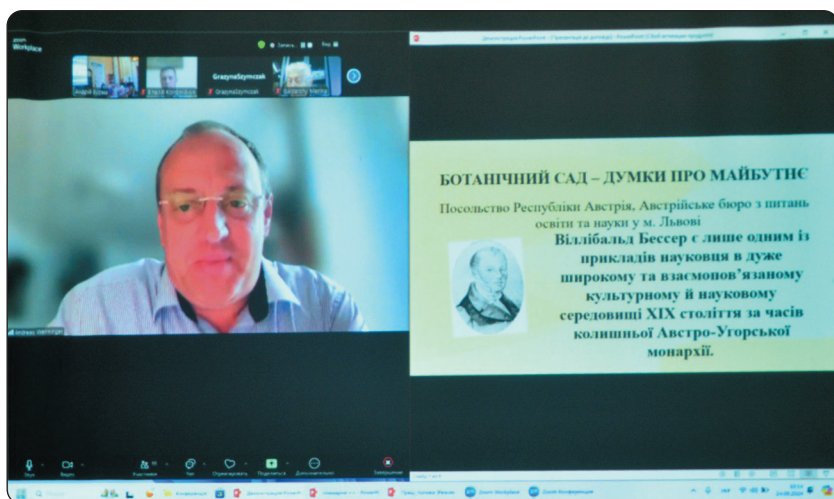


Photo 9. Andreas Wenninger's report at the plenary session of the II International Conference 'Besser Natural History Studies'.



Photos 10. During an excursion to the Kremenets Botanical Garden



Photos 11. During an excursion to the Kremenets Botanical Garden



Photos 12. During an excursion to the Kremenets Botanical Garden



Photos 13. During an excursion to the Kremenets Botanical Garden



Photos 14. During an excursion to the Kremenets Botanical Garden



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