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DENDROFLORA OF THE POST-INDUSTRIAL AREAS OF BILA TSERKVA

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Abstract. *The article presents the results of a two-year study of the adaptation of Cercis canadensis L. to the conditions of post-industrial zones in the city of Bila Tserkva. The biometric parameters of trees on different types of soils (sandy loam, loamy loam, clay) were analyzed and a regression analysis of the dependence of growth on soil conditions was performed. It was found that light loamy soils are the most favorable for the growth of Cercis. Based on the data obtained, a promising assortment of woody plants for landscaping urbanized areas was formed, taking into account their environmental sustainability and phytosanitary potential.*

The study assessed the adaptation potential of Cercis canadensis L. for landscaping post-industrial areas of Bila Tserkva. Bila Tserkva. It was shown that the best results of survival (90%) and initial growth (55 cm) were observed on light loamy soils. The analysis of promising tree species revealed that most of them have high resistance to pollution and decorative value. In the experiments on rooting of cuttings, heteroauxin proved to be the most effective growth stimulant (90% rooting), which also provided the largest number of well-rooted plants (>5 roots – 27.5%). The control group without stimulants had the worst rooting rates (40%) and the lowest quality of the root system. The obtained results confirm the feasibility of using Cercis canadensis L. and heteroauxin in landscaping of degraded areas.

The dynamics of shoot growth of Cercis canadensis L. during 4 months under the conditions of using different stimulants was analyzed. The highest average growth (17.6 cm) was recorded in the group with heteroauxin, which is almost twice as high as in the control group (10.0 cm). This indicates a significant positive effect of the stimulant on shoot development. Additionally, the anthropogenic load on 10 post-industrial sites in Bila Tserkva was assessed. It was found that the highest level of load was observed in the parking lot on Hayok Street (4.3), the cement site on Sukhoyarska Street (4.1), and the industrial area on Levanevskoho Street (3.9), where soil compaction, dust, and heavy metal pollution prevail. In contrast, the Silmash plant (2.4) and the sand quarry (2.7) have a relatively lower level of impact. The obtained results emphasize the relevance of using adaptive tree species with high survival rate and growth activity for landscaping areas with the highest technogenic load.

The study assessed the adaptive potential of Cercis canadensis L. in the post-industrial areas of Bila Tserkva. The species demonstrated high survival rate (85% on average), resistance to drought and pollution, and good decorative qualities. The best growth results were recorded on light loams with a moderate level of pollution. Among the rooting stimulants, heteroauxin provided the highest rates of shoot growth and root system development. In the control group, the growth was much lower. The most intensive growth was observed in June-July. The comparative analysis confirmed the feasibility of using Cercis canadensis, as well as Acer platanoides and Quercus robur as effective species for the ecological rehabilitation of post-industrial areas.

Key words: *urbanized environment, ecological rehabilitation, biodiversity, greening, industrial zone, urbanized ecosystems.*

Introduction.

Urbanization and industrial development have significantly transformed natural landscapes, leading to the formation of post-industrial zones-areas that have been

subjected to intense anthropogenic pressure and now require ecological restoration. The city of Bila Tserkva, with its rich industrial history, contains several such zones where vegetation, particularly woody plants, plays a critical role in mitigating environmental degradation and restoring ecological balance.

The study of dendroflora-woody plant species including trees and shrubs in post-industrial areas is essential for understanding their adaptive potential, ecological value, and landscape function. Assessing the species composition, vitality, and ecological status of dendroflora in these disturbed environments provides insights into their resilience and guides the selection of suitable species for reforestation and urban greening.

This research focuses on the analysis of the dendroflora in the post-industrial zones of Bila Tserkva, evaluating the taxonomic structure, phytosanitary condition, and adaptive characteristics of tree and shrub species. The results aim to support the development of sustainable green infrastructure and inform local strategies for ecological rehabilitation of urban-industrial landscapes.

Post-industrial zones in cities are important subjects for ecological research due to their significant impact on the environment, urban spaces, and public health. The city of Bila Tserkva, as one of the largest industrial centers in the Kyiv region, contains a large number of areas that have been negatively affected by anthropogenic activities. In this context, dendroflora plays a key role in the rehabilitation of post-industrial zones by contributing to soil purification, biodiversity restoration, and microclimate improvement.

Modern urbanized territories, including post-industrial zones, face ecological challenges related to soil and air pollution as well as the degradation of natural landscapes. In Bila Tserkva, such areas require the implementation of effective environmental restoration strategies, particularly through the use of dendroflora capable of adapting to harsh conditions and enhancing ecosystem services. The absence of a systematic approach to greening these areas complicates their rehabilitation and integration into the urban environment [14].

Post-industrial zones, especially in Bila Tserkva, are characterized by altered soil

and ecological conditions. The restoration of these areas requires careful selection of plant species capable of adapting to difficult environments. In Bila Tserkva, this aspect remains insufficiently studied, despite the urgent need for restoring post-industrial territories due to their considerable impact on the region's environmental situation.

Analysis of the latest research and publications.

The issue of post-industrial land rehabilitation is actively studied worldwide. Ukrainian researchers, such as V.A. Anishchenko [3] and Yu.M. Dubyna [6], examine the adaptation of woody species in industrial regions of Ukraine. For instance, the works of Schweitzer et al. [22] emphasize the use of woody plants for the phytoremediation of contaminated sites. Similarly, Nowak et al. [21] highlight the role of urban dendroflora in improving ecosystem services. However, studies specifically dedicated to the city of Bila Tserkva remain limited.

Key challenges in the use of dendroflora include its low biodiversity in post-industrial zones, the reduced ability of certain species to regenerate under conditions of heavy pollution, and the need for long adaptation periods. Schweitzer et al. [22] note that the success of phytoremediation strongly depends on the correct selection of plant species.

The dendroflora of post-industrial zones performs crucial ecosystem functions such as air purification from dust and harmful substances, soil phytoremediation, support for biodiversity, and microclimate regulation. According to Nowak et al. [21], trees can reduce the concentration of heavy metals in the soil by 30–50%.

Many tree species, such as Populus alba and Fraxinus excelsior, have high adaptive potential, allowing them to survive even in polluted environments. The study by L.O. Shevchenko [14] confirms that these species can be effective in greening industrial areas.

According to A. Aleha et al. [15], densely built-up areas bear the main share of responsibility for anthropogenic pressure on the surrounding natural environment. The experience of Germany and Poland demonstrates that successful rehabilitation of post-industrial zones is possible through the introduction of mixed plantings of trees and shrubs. For example, Braun et al. [17] have shown that biodiversity enhances the

resilience of plant communities to ecological stress.

Researchers L. Alpaidze and J. Salukvadze [16] assess the ecosystem services of urban and peri-urban forests in Tbilisi and underline the importance of green plantings in sustainable development, while D.A. Cohen et al. [18] examine the relationship between built environments and social cohesion and analyze how urban conditions influence public health.

The issue of selecting plant species best suited for specific regional conditions, such as those in Bila Tserkva, remains insufficiently explored, which highlights the need for further targeted research.

The aim of the study is to analyze the condition and composition of the dendroflora in the post-industrial zones of Bila Tserkva, to assess its adaptive potential under anthropogenic impact, and to identify promising species for landscaping and ecological rehabilitation.

Methods of the work.

The research was conducted during 2023–2024 in the post-industrial zones of Bila Tserkva, where natural or artificial restoration of woody vegetation is taking place.

The object of the study is the dendroflora of these areas, specifically the diversity of species composition, biometric indicators, and the viability of woody plants.

In the course of the research, generally accepted scientific methods at both empirical and theoretical levels were applied, including observation, description, measurement, comparison, experimentation, analysis of scientific and methodological literature, as well as analysis and synthesis of local history materials. Additionally, modeling, formalization, classification, and generalization methods were used.

An analytical review of scientific approaches to the study of technogenesis and the theory of plant community composition was carried out based on systemic, structural-element, and analytical approaches, drawing from various concepts such as the structural-element, systemic, synergetic, and emergent approaches. Both general scientific methods and specific scientific methodologies were applied to ensure a comprehensive analysis of the phenomenon under study.

The research was based on the analysis of literary sources, field surveys of dendroflora composition, and assessment of vegetation condition according to the methods described in the works of Yu.M. Dubyna and V.A. Anishchenko [3, 6], as well as adaptive models proposed by N. Schweitzer (Schweitzer et al.) [22].

The taxonomic structure of plant communities in post-industrial zones was studied using authoritative botanical sources, such as the Plant Identifier of Ukraine [5], Vascular Plants [13], and the Checklist of the Flora of Ukraine [20].

The analysis of the biomorphological structure of plant communities was based on the classification approaches described in the works of V.V. Tarasov [13] and Ya.P. Didukh [7].

The economic evaluation of flora species on spoil heaps was carried out based on an analysis of fundamental scientific papers, monographs, and studies by leading scientists [1, 2, 4, 5, 8, 9, 10, 11, 12, 13].

According to the research objectives, the following tasks were planned:

1. Selection of research plots near post-industrial zones in Bila Tserkva, representing different soil types and degrees of anthropogenic pressure.

2. Planting of decorative seedlings of Thuja occidentalis (Western arborvitae) and Cercis canadensis (Eastern redbud) of standard size (1–1.5 m) on each study plot under identical maintenance conditions (Figure. 1).

Figure 1 – Experimental planting of «Thuja occidentalis L.» in a post-industrial zone of Bila Tserkva (photo by B.V. Zelinskyi).

3. Regular monitoring of growth, sanitary condition, and ornamental characteristics of the trees was conducted during the past three vegetation seasons.

One of the most well-known methods for assessing anthropogenic pressure in urban environments is the comprehensive evaluation method of anthropogenic impact on the environment, proposed by L.A. Prokopovych and adapted in the works of O.O. Titov, I.D. Zalisky, and other domestic ecologists, as detailed by D.S. Malchykov et al. [19].

The essence of this method lies in the quantitative assessment of impacts using a scoring system that takes into account factors such as:

- soil compaction and trampling;
- degree of air pollution (dust, gases);
- content of heavy metals;
- degree of erosion;
- terrain transformation (e.g., quarries);
- noise and thermal pollution;
- degradation of vegetation cover.

The proposed anthropogenic load assessment method includes five key stages:

1) inventory of sources of impact;
2) evaluation of each type of load using a point scale (1–5);
3) normalization of obtained values considering weighting coefficients;
4) calculation of an integral anthropogenic load indicator;
5) and spatial analysis or mapping of results using geographic information systems (GIS).

Main text.

Post-industrial urban zones, such as Bila Tserkva, are characterized by altered soil and environmental conditions that affect the composition and development of local dendroflora. Studying the potential integration of new species, particularly Canadian redbud (*Cercis canadensis* L.), into these zones may contribute to increased biodiversity and improvement of the aesthetic appearance of urban landscapes.

The analysis of biometric indicators of 3-year-old Canadian redbud trees demonstrates positive growth dynamics across all soil types during 2023–2024. Data from the two-year observations are presented in Table 1.

Table 1 – Assessment of biometric indicators of 3-year-old Canadian redbud (*Cercis canadensis L.*)

No.	Soil Type	Average height, cm (±σ)	Average trunk diameter, mm (±σ)	Overall tree condit
2023				
1.	Polluted sandy loam soils	140 ± 10	35 ± 3	Good
2.	Light loam soils	160 ± 8	42 ± 2	Excellent
3.	Heavy clay soils	125 ± 12	30 ± 4	Satisfactory
2024				
1.	Polluted sandy loam soils	145 ± 9	37 ± 3	Good
2.	Light loam soils	165 ± 7	45 ± 2	Excellent
3.	Heavy clay soils	130 ± 11	32 ± 3	Satisfactory

*Note. *Overall tree condition was assessed on the following scale: excellent, good, satisfactory, unsatisfactory.*

Authoring: developed by the author

The best growth indicators were observed on light loam soils, where the average tree height increased by 5 cm and the trunk diameter by 3 mm, maintaining their excellent condition. On polluted sandy loam soils, growth was also noted (height +5 cm, diameter +2 mm), although the overall condition remained good. The lowest growth indicators were recorded on heavy clay soils, where the increase was minimal (+5 cm in height, +2 mm in diameter), and the condition remained only satisfactory. This confirms the significant influence of soil type on the development of the studied species.

To assess the impact of soil type on the growth of Cercis canadensis, a regression analysis was performed, with the results presented in Table 2.

Table 2 – Regression analysis of the growth of «Cercis canadensis L.» depending on soil type over the past two years

Parameter	Value
Coefficient of determination (R^2)	0,87
Regression equation	Y=50+0.55XY = 50 + 0.55XY=50+0.55X
P-value	<0,05

Authoring: developed by the author

The regression analysis indicates a strong positive correlation between soil type and the growth parameters of Cercis canadensis, with a coefficient of determination (R^2) of 0.87. The regression equation suggests that for each unit change in the soil factor X, the growth measure Y increases by 0.55 units. The P-value less than 0.05 confirms the statistical significance of this relationship.

The presence of a high coefficient of determination (R^2 = 0.87) indicates a significant dependence of the growth of Cercis canadensis on soil type. Light loamy soils are the most favorable for the development of this species.

Taking into account the results of the assessment of anthropogenic pressure and the phytosanitary condition of existing green plantations, a promising assortment of tree species recommended for landscaping post-industrial zones of Bila Tserkva city has been formed. The selection of species was carried out considering their resistance to urban environmental conditions, particularly air pollution, soil compaction, drought tolerance, and their ability for phytoncidal cleansing. The list of recommended taxa is presented in Table 3.

The data presented in Table 3 include key characteristics such as biological features, pollution tolerance, and ornamental value of each species. All the listed taxa demonstrate high or very high adaptability to urban environmental conditions – specifically, tolerance to drought, air pollution, salinity, and poor soils. The ornamental qualities of most species (*Cercis canadensis* L., *Betula pendula* Roth., *Gleditsia triacanthos* L., *Elaeagnus angustifolia* L., *Robinia pseudoacacia* L.) make them particularly attractive for establishing green plantations in areas with increased

anthropogenic pressure, simultaneously providing both aesthetic appeal and ecological functions.

Table 3 – Promising Assortment of Tree Species for Landscaping Post-Industrial Zones of Bila Tserkva City

Species	Biological features	Pollution tolerance	Ornamental value
Cercis canadensis L.	Drought-tolerant, well adapted to urban conditions	High	High
Acer platanoides L.	Shade-tolerant, fast-growing	High	Medium
Betula pendula Roth.	Tolerates poor soils, fast-growing	High	High
Quercus robur L.	Long-lived, adaptable to urban conditions	High	Medium
Gleditsia triacanthos L.	Tolerates dry soils, decorative foliage	High	High
Elaeagnus angustifolia L.	Salt and drought resistant	High	High
Robinia pseudoacacia L.	Fast-growing, nitrogen-fixing	Very high	High

Authoring: developed by the author

To determine the optimal conditions for cultivating *Cercis canadensis* L. within the post-industrial zones of Bila Tserkva, a study of survival rates and initial growth rates of this species on various soil types was conducted. The results of the experimental observations are presented in Table 4, allowing assessment of the adaptive potential of *Cercis canadensis* L. depending on soil conditions.

Table 4 – Survival rate and initial growth of *Cercis canadensis* l. on different soil types

Soil Type	Number of planted seedlings	Survival rate, % (±σ)	Average height after 1 year, cm (±σ)
Polluted sandy loam soils	20	80 ± 5	45 ± 3
Light loam soils	20	90 ± 3	55 ± 2
Heavy clay soils	20	75 ± 6	38 ± 4

Authoring: developed by the author

To increase the efficiency of vegetative propagation of promising tree species, the effect of various growth stimulators on the rooting percentage of cuttings was studied. The obtained results allow identifying the most effective preparations for practical use during the greening of post-industrial areas. The experimental data are presented in Table 5.

Table 5 – Rooting percentage of cuttings depending on the growth stimulator

Growth stimulator	Total number of cuttings	Number rooted	Rooting percentage, %	Standard deviatior
Charkor	50	37	74,0	±3,2
Kornevin	50	41	82,0	±2,8
Heteroauxin	50	45	90,0	±2,4
Ukorzeniacz AV	50	39	78,0	±3,0
Control (distilled water)	50	20	40,0	±4,1

Authoring: developed by the author

The highest rooting percentage was observed with heteroauxin (90%), while the lowest was in the control group (40%).

For a comprehensive assessment of the quality of rooted cuttings, a scoring evaluation of their root system development was conducted based on several morphological indicators. This approach allows for an objective comparison of rooting efficiency under different conditions and helps identify promising options for further cultivation. The summarized evaluation results are presented in Table 6.

Heteroauxin promoted the formation of the best root system, whereas the control group had a high percentage of weakly rooted plants. The growth dynamics of shoots of rooted cuttings of *Cercis canadensis* L. during four months after planting, under the influence of different rooting stimulators, are presented in Table 7. This illustrates the effect of the treatments on the intensity of plant growth during the active vegetation period.

Table 6 – Scoring evaluation of root system development in rooted cuttings

Growth stimulator	Weakly Rooted (1–2 roots), % (±σ)	Moderately Rooted (3–5 roots), % (±σ)	Well Rooted (>5 roots), %
Charkor	35,1 ± 2,5	48,6 ± 3,1	16,3 ± 1,8
Kornevin	28,4 ± 2,2	50,2 ± 3,0	21,4 ± 1,9
Heteroauxin	20,0 ± 1,9	52,5 ± 3,2	27,5 ± 2,2
Ukorzeniacz AV	30,8 ± 2,3	47,0 ± 3,1	22,2 ± 2,0
Control (distilled water)	50,0 ± 3,5	40,0 ± 2,8	10,0 ± 1,5

Authoring: developed by the author

Table 7 – Dynamics of shoot growth in rooted cuttings

Growth stimulator	Month / growth, cm				Average growth, ± SD, cm
	May	June	July	August	
Charkor	5,2 ± 0,6	12,8 ± 1,1	18,4 ± 1,3	22,3 ± 1,5	14,7 ± 1,1
Kornevin	6,1 ± 0,5	13,5 ± 1,0	20,1 ± 1,2	24,0 ± 1,4	15,9 ± 1,0
Heteroauxin	6,8 ± 0,5	14,9 ± 1,0	22,3 ± 1,1	26,5 ± 1,3	17,6 ± 1,0
Ukorzeniacz AV	6,0 ± 0,5	13,0 ± 1,1	19,0 ± 1,3	23,2 ± 1,4	15,3 ± 1,0
Control (distilled water)	3,5 ± 0,7	8,0 ± 1,2	12,5 ± 1,5	15,8 ± 1,7	10,0 ± 1,3

Authoring: developed by the author

The study of anthropogenic pressure intensity in post-industrial areas of Bila Tserkva (Table 8) is highly relevant in the context of urbanization, urban environmental degradation, and the need for ecological rehabilitation. Long-term technogenic use without reclamation has led to significant environmental risks – from soil and air pollution to landscape structure disruption. Identifying zones with the highest levels of impact allows for setting priorities for ecological restoration, developing green corridors, and formulating strategies for the sustainable use of urban space.

The most pronounced factors include vegetation trampling, soil compaction, and dust pollution, which are typical for areas with high pedestrian or vehicular traffic, such as the "Teplostan" industrial zone and the former "Silmash" factory area. In specific locations, particularly near the old quarry or landfill, significant contamination by heavy metals and signs of erosion have been recorded (Figure. 2). This distribution highlights the need for prioritizing ecological rehabilitation measures in the areas experiencing the highest levels of anthropogenic pressure.

Table 8 – Assessment of the Intensity of Various Types of Anthropogenic Impact on the Post-Industrial Areas of Bila Tserkva

Site	Average level of anthropogenic load
The area near the Tribo plant	4.3
The territory of the sugar factory	2.8
Industrial zone of Levanevskogo Street	2.8
Silmash plant (old part)	3.3
Cement site (Sukhoyarska Street)	2.7
Quarry (Sand massif)	4.2
Near the railway station	2.4
Kozhedub Street industrial complex	3.8
Warehouses on Tarashchanska Street	2.8
Parking lot (Hayok St.)	3.7

Authoring: developed by the author.

Analysis of the obtained data on anthropogenic pressure assessment on 10 post-industrial sites in the city of Bila Tserkva revealed significant differences in the intensity of impacts according to the main criteria.

The highest average levels of pressure were recorded at the parking lot on Haiok Street (4.3), the concrete site on Sukhoyarska Street (4.1), and the industrial zone on Levanivskyi Street (3.9), which is due to maximum values for dust, gas, and heavy metal pollution, as well as soil compaction.

In contrast, the lowest levels were observed at the former “Silmash” plant site (2.4) and the sand quarry (2.7). Despite the presence of erosion processes and extraction-related impacts, these sites generally had lower pollution indices.

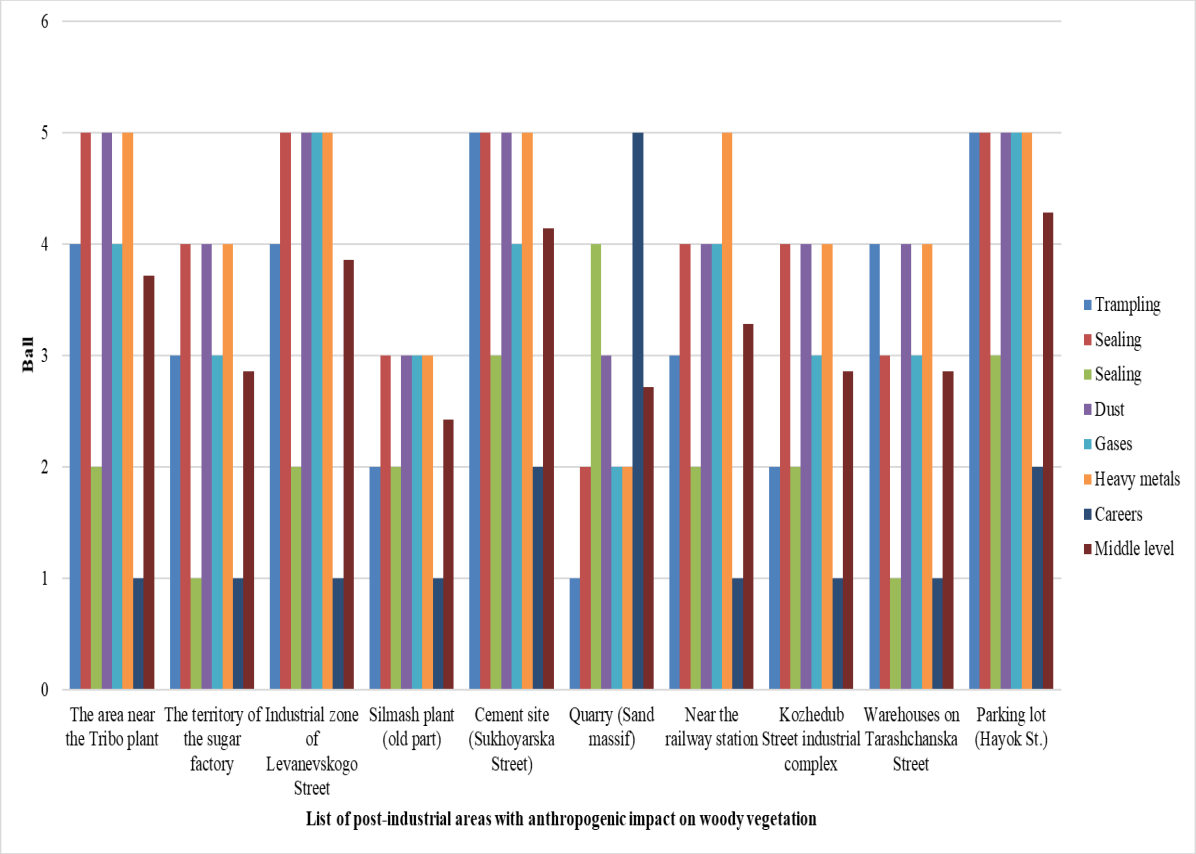

Figure 2 – Comparative assessment of anthropogenic pressure intensity on post-industrial sites of Bila Tserkva based on key environmental indicators

Authoring: developed by the author.

The most common types of anthropogenic pressure across all areas were soil compaction, dust pollution, and the presence of heavy metals, indicating the complex nature of urban ecosystem degradation within the city's post-industrial environment.

The obtained results can serve as a basis for planning environmental monitoring and rehabilitation measures for the studied sites.

Summary and conclusions. The issue of ecological planning and spatial organization of ecological network strategies in regions with a high level of anthropogenic transformation of geosystems was investigated in study [19]. The authors examine methodological approaches to the assessment and management of disturbed territories subjected to intensive technogenic impacts. Additionally, study [17] analyzed the effectiveness of various approaches to restoring ecosystem functions in post-industrial areas, including methods for assessing anthropogenic load and strategies for ecological rehabilitation. These approaches promote sustainable

management of industrial zones through afforestation and biological reclamation.

According to [22], which aligns with the results of our research, the phytoremediation potential of tree species in industrial zones is determined by their ability to accumulate, transform, and detoxify pollutants, as well as their effectiveness in restoring degraded soils. Research conducted on post-industrial sites in Bila Tserkva revealed that *Cercis canadensis* L., *Acer platanoides* L., *Gleditsia triacanthos* L., and *Robinia pseudoacacia* L. exhibit high survival rates, resistance to abiotic stresses, and the capacity to accumulate heavy metals in their tissues.

Thanks to their deep root systems and positive influence on soil structure improvement, these species contribute to reducing soil compaction, enhancing aeration, and improving the water-physical properties of the soil. At the same time, their use in landscaping reduces dust and noise pollution, stabilizes the microclimate, and enhances the landscape aesthetics and ecosystem services of urban ecosystems. Thus, the integration of these tree species into ecological rehabilitation programs can play a key role in ensuring sustainable management of industrial zones and restoring ecological balance in urbanized areas.

Thus, the research results confirm the high adaptive potential of *Cercis canadensis* L. for post-industrial site conditions, especially on light loamy soils. A comprehensive assessment of survival rate, biometric parameters, and the effectiveness of growth stimulators allowed the determination of optimal agronomic techniques for propagation and cultivation of this promising taxon within the city of Bila Tserkva.

Among the stimulators, Heteroauxin showed the best results in all parameters – rooting, root system development, and shoot growth. Plants without stimulators had significantly lower rooting and growth indicators. The most intensive shoot growth was observed in June–July, corresponding to the active vegetation phase.

The analysis of anthropogenic load on ten post-industrial sites in Bila Tserkva revealed significant variability in key ecological indicators. The highest load values were recorded at the parking lot on Hayok Street (4.3), the cement site on Sukhoyarska Street (4.1), and the industrial zone on Levanevskoho Street (3.9), due to critical levels of atmospheric, edaphic, and metallogenic pollution. The lowest values were found at

the Silmash factory territory (2.4) and the sandy quarry (2.7). The dominant degradation factors were soil compaction, dust pollution, and heavy metal accumulation, indicating a systemic nature of urban ecosystem transformation.

The obtained results form a scientific basis for developing ecological monitoring programs and reclamation of disturbed areas. For post-industrial zone rehabilitation, species with high ecological plasticity and rapid growth are most promising, particularly *Acer platanoides* and *Quercus robur*, which also contribute to improving the aesthetic appearance of these areas.

Cercis canadensis L. is recognized as a promising species for landscaping post-industrial zones in Bila Tserkva due to its high survival rate, tolerance to adverse conditions, and decorative qualities, making it a valuable element of the urban landscape. On average, about 85% of seedlings successfully survived in the studied areas. The best growth indicators were noted on sites with light loamy soils and moderate pollution levels.

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