

Original researches

Received: 27.05.2024

Revised: 09.07.2024

Accepted: 21.07.2024

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Cite this article: Kunakh, O. (2024).
The black locust (*Robinia pseudo-*
acacia) population vital state in the
urban ecosystem. *Agrology*, 7(3),
87–94. doi: 10.32819/202412

The black locust (*Robinia pseudoacacia*) population vital state in the urban ecosystem

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Abstract. Many European countries have extensively practiced the cultivation of black locust. This species is characterised by rapid growth, the application possibility for degraded land reclamation and other useful properties, but its adventiveness and invasive status require more thorough research. The aim of the research was to assess the viability of a population of black locust (*Robinia pseudoacacia*) in urban environment by determining its vital status and measuring height of the plants and diameter of their trunks as the main morphometric indicators. The research was conducted in the recreational area of the Oles Honchar Dnipro National University Botanical Garden. There were recorded 178 plants of *R. pseudoacacia*. Tree heights were measured by a Suunto PM-5 mechanical height meter in three-time repetition for each plant, and the average value was calculated based on these data. The trunk diameter was measured at the small fork as a distance between two parallel tangents. The vital status of the trees was determined by the 5-point scale of V. A. Alekseev. The height of the vast majority of the studied trees varied 25 to 30 m. The height of one species representative reached 32 m. The trunk diameter of the most trees in the territory ranged 30 to 40 cm. Plants with a trunk diameter of between 40 cm and 50 cm were the next largest group. A 101 cm trunk diameter was found in just one tree. Most plants in the research area had a vitality score of 2 – good state. Accordingly, these were the plants that had the largest trunks of examined trees. The fewest number of plants was in a very bad state and had a score of 5. The good and satisfactory vital conditions were observed in plants whose trunks were the tallest and had the largest diameter, and whose morphometric indices slightly varied (the height-diameter trunk correlation was reliable). Plants in depressed and poor vital state were characterised by significant variability in the morphometric parameters (the correlation between height and trunk diameter was not reliable). The ecological condition of the black locust population in the area was assessed, and it was concluded that its morphometric parameters cannot be used as indicators of plant vitality.

Keywords: tree height; trunk diameter; green areas monitoring; human ecology.

Introduction

There are many environmental factors in urban landscapes that can significantly impact human health and well-being, and addressing them can involve substantial economic costs (Livesley et al., 2016b). With a sustainable approach to urban planning, ecosystem services and functions can be used to address these problems. Trees are therefore a key aspect of urban green space planning. In addition to aesthetic considerations, structural characteristics such as size, shape and density, surface complexity, and crown transparency are among the most important factors that determine their ecological features and benefits (Gómez-Baggethun & Barton, 2013). Urban trees are not only important for pedestrian comfort, providing aesthetic benefits, rain protection, shade, and wind mitigation (Mochida et al., 2008; Mochida & Lun, 2008), but can also help save energy on a larger scale through air purification, cooling (Rahman, 2017), wind buffering, and shading (Speak et al., 2020; Meili et al., 2021). Potential noise reduction (Fang & Ling, 2003; Zhao et al., 2021), temperature control (Akbari et al., 2001; Akbari & Konopacki, 2005; Gillner et al., 2015), water flow regulation and water runoff mitigation (Villarreal & Bengtsson, 2005; Pataki et al., 2011; Steele et al., 2014), wind flows (Mochida et al., 2008; Mochida & Lun, 2008), air purification (Nowak & Crane, 2002; Escobedo & Nowak, 2009), and habitat functionality (Tews et al., 2004) are also directly related to the structure of tree (Bayer et al., 2018). Urban biodiversity is being recognised as an increasingly important issue. This is partly a consequence of rapid urbanization. The urbanization has a negative overall impact on biodiversity, and particularly on native flora and fauna in growing territories (Pauchard et al., 2006; Grimm et al., 2008). However, the impact of urbanization is difficult to assess, especially when long periods and indirect effects are taken into account. For

example, cities are home to a variety of plants that have been intentionally introduced into gardens and parks, as well as species that have spread unintentionally into cities (Ööpik et al., 2013). Furthermore, not all native species are affected by urbanization. The abundance and species diversity in some parts of urban areas, especially on the city fringes, can be significantly higher than in the adjacent countryside (Vähä-Piikkiö et al., 2004). Although urbanisation is often presented as a threat to biodiversity, urban development based on integrated planning can also serve as a tool for conserving and enhancing biodiversity. Urban ecologists often emphasise the need to integrate ecological, social and economic factors into urban biodiversity analysis and management (Ruban & Dreval, 2023).

Urban green spaces are intended to compensate for the emission of greenhouse gases, to remove pollutants from the air and water, to cool the micro climate, and to improve the health of the population. Benefiting from these services requires implementation of "green infrastructure" based on ecosystem services in the urban environment (Pataki et al., 2011). People are increasingly influencing the biogeochemical cycles on a global scale (Rojstaczer et al., 2001), and the role played by cities in this regard is starting to be recognized. As cities concentrate more and more people, they are also involved in the transformation of waste, materials, and energy within small areas. Although the concentration of populations in smaller areas may offer certain benefits with regard to the utilization of land and other resources, it is imperative that methodologies and strategies are devised to facilitate the creation of more efficient and sustainable urban environments. One strategy for enhancing sustainable urban development is the incorporation of "ecosystem services" to mitigate pollution and other environmental concerns (McPherson et al., 2011; Livesley et al., 2016a). The concept of ecosystem valuation has provided the basis for classifying the benefits

that ecosystems provide to society into different categories. These categories are known as ecosystem services and include provisioning services, which involve the provision of food and materials; cultural services, which provide benefits related to aesthetics and psychology; and regulating services, which affect the state and quality of the environment. The functioning of these services is based on essential ecological processes that can be identified and, in the majority of cases, quantified by experts in the relevant scientific fields. It is crucial to recognise the significant role that the public green landscapes play in regulating the climate, water and atmosphere. This includes urban forests, parks, gardens are other green areas.

Buildings change the energy and material flows in urban ecosystems, often causing environmental problems. These problems can be partially mitigated by changes in the properties of surfaces of buildings. Roofs are important factors in determining the building's energy flow and water balance. Adding vegetation and soil to the roof surface can reduce some of the negative impacts that buildings have on the local ecosystems and reduce the buildings' energy consumption. Living or green roofs have been shown to improve sound insulation, fire resistance, and roof durability (Lepp, 2008). They can reduce the energy needed to maintain the indoor climate, as the vegetation and the environment in which the plants grow intercept and dissipate solar radiation. Green roofs can also mitigate rainwater runoff from building surfaces by collecting and retaining rainfall, thereby reducing the runoff into drainage infrastructure and urban waterways. Other potential benefits include increases of the green space attractiveness and wildlife habitats, air quality improvements, and reduction of the urban heat island effects (Getter and Rowe, 2006; Shaharuddin et al., 2019). There is a growing body of literature on the potential benefits of designed urban green spaces, often called "green infrastructure" (Nowak & Crane, 2002; Oberndorfer et al., 2007; Livesley et al., 2016a). However, we should not forget about the potential environmental costs, or 'dysfunctions'—the negative impacts or trade-offs related to the implementation of such green infrastructure. Inadequate urban green spaces can lead to ecosystem dysfunctions, such as increase in allergenic species, the spread of invasive species, and emergence of pathogens or pests. It can also impair the population mobility, increase the level of danger, and contribute to the climate change (Lyytimäki et al., 2008).

Increasing green space in cities is a frequently proposed strategy to mitigate the urban heat island effects, as plants have the potential to have a cooling impact on cities by evaporating moisture and providing shade. However, plants also change wind flows and urban aerodynamic roughness, which may potentially restrict inter-city heat transfer. The existing studies demonstrate that the potential for urban trees to cool an urban environment varies according to the climate zones in question and the time of day. These variances have not yet been systematically explained, as it is difficult and impossible to separate the tree's individual effects by observations alone (Meili et al., 2021). Urban ecosystems often have a specific climate regime, including the so-called "heat islands" (Akbari et al., 2001). Heat islands are a phenomenon observed in cities and megacities when they become significantly warmer than the surrounding countryside or natural areas. This is due to combination of several factors that form a specific microclimatic zone. First and foremost, it is the impact of building materials used in construction. Cities are largely made up of buildings, roads and other man-made structures. These materials absorb the sun's heat during the day and radiate it outward at night, which leads to a temperature increase in these areas. Another reason may be air pollution. A large number of cars, factories, and industries in cities contribute to the heat and pollutants released into the air. This can also lead to higher temperatures. In addition, cities often have ornamental plants and trees that can absorb heat. However, they can be less efficient at heat dissipation than natural vegetation. At the same time, buildings and roads can retain warmth during a heatwave and radiate it later, when the environment has already cooled down (Akbari & Konopacki, 2005).

These factors combine to create "heat islands" where average temperatures can be several degrees higher than in the countryside or outside the city. This can have a significant impact on human comfort, energy consumption for cooling spaces in hot weather, and even health, increasing the risk of heat stroke and other health problems (Akbari et al., 2001). Elevated summer temperatures in urban heat islands increase energy consumption for cooling and accelerate urban smog formation. With the exception of central city districts, summer heat islands are created mainly due to vegetation absence and high solar

radiation absorption by urban surfaces. Temperature trends over the past 100 years in several major US cities show that since 1940, urban temperatures have risen by about 0.5–3.0°C. Typically, the demand for electricity in cities increases by 2–4% for every 1°C of temperature increase. Thus, 5–10% of the current electricity demand in cities is spent on building cooling just to compensate for a 0.5–3.0°C temperature increase. Due to the heat island effect, rising temperatures can have significant consequences. Urban trees and high albedo surfaces can compensate for or reverse the heat island effect (Gillner et al., 2015).

Trees play a crucial role in urban cooling. An in-depth understanding of the trees' ability to reduce heat load in urban spaces can improve the effectiveness of urban cooling strategy. In particular, black locust (*Robinia pseudoacacia*) can have a significant impact on air cooling in cities due to several factors. First of all, black locust is a tree with a dense crown that creates a large shadow zone under it. This helps to decrease the ambient temperature by reducing direct solar radiation to the ground. In addition, the plant is also able to release water vapour through the process of evapotranspiration, which also helps to cool the air. Moreover, black locust, like other trees, absorbs carbon dioxide (CO₂) during photosynthesis. This is important because carbon dioxide is known for its ability to trap heat in the atmosphere. Thus, more trees can help to decrease CO₂ concentrations and reduce the heat load. Trees, including *R. pseudoacacia*, can also influence the microclimate in city, lowering the ambient temperature and providing more comfortable conditions for walking and outdoor activities (Stanley et al., 2019; Martin, 2023). Black locust, like other tree species, can therefore play an important role in reducing temperatures and improving air quality in urban environments, making it an important element in creating more comfortable and environmentally friendly urban areas.

Noise is an everyday occurrence in cities, and with over 50% of the world's population living in cities, it has a negative impact on quality of life and health worldwide (Brown & van Kamp, 2017). Prolonged exposure to environmental noise can lead to sleep disturbances, hypertension, and cardiovascular diseases (Clark & Paunovic, 2018; Owolawi, 2021). The World Health Organisation (2011) estimates that at least one million years of healthy life are lost annually in Western Europe due to traffic-related noise. Field studies have shown that dense, tall canopies of large hardwood trees growing in wide strips reduce noise levels from point and line sources. For example, research by Ow & Ghosh (2017) has shown that moderate to dense vegetation barriers on roadsides can reduce traffic noise by 9–11 dB. They found that natural vegetation, if it is sufficiently tall, wide and dense, reduces traffic noise. Vegetative noise barriers are environmentally friendly, natural-looking, and often subject to careful sorting, but the effectiveness of screening depends on the thickness of the vegetation and foliage density (e.g., vegetation type). Reports show that the effect of noise screening by vegetation is generally considered to be low unless the planting is dense and the vegetation strip is deep. However, where effective, noise barriers can reduce noise levels by 10–15 dB (Fang & Ling, 2003). Like buffer zones, natural vegetation as a noise barrier may not be feasible in many large cities and urban centres due to the large area it takes up. The main disadvantage is the high cost of land and the time needed for the vegetation to take root and become effective (Ow & Ghosh, 2017). There is also a lot more research on noise reduction with green lanes (Pal et al., 2020; Schäffer et al., 2020) than by a mosaic of individual trees in urban forests. It was found that increasing the proportion of green space in residential areas was connected with a decrease in traffic and railway noise, but an increase in aircraft noise. The overall effect corresponded to an equivalent reduction of about 6 dB for road traffic and 3 dB for railway noise, but an increase of about 10 dB for aircraft noise (Schäffer et al., 2020). Moreover, tree height, crown density, and tree type (needle or broadleaf) have also been shown to have different effects on noise levels (Baldauf, 2017).

Numerous medical researches have linked adverse health effects to spending a significant amount of time near high-traffic neighbourhoods with increased levels of air pollution from particulate matter, gaseous pollutants, and toxic substances emitted by vehicles near highways (Luo et al., 2022). The significant impact of transport emissions on urban populations around the world has motivated research into methods to reduce exposure to these pollutants. While technologies and programmes of controlling vehicle emission directly reduce the amount of pollutants emitted from vehicles, these practices often take a long time for full implementation and can be offset by increased vehicle activity. Thus, other mitigation options will be needed to fully and

comprehensively reduce the impact of air pollution on these urban populations. Researches have shown how roadside vegetation can provide an opportunity to reduce the concentration of pollutants in urban roadside areas. This roadside vegetation can include the existing trees and shrubs. At the same time, landscaping may be one of the few short-term mitigation strategies available to urban developers and facilities already experiencing high levels of roadside pollution. These mitigation methods, if successful, can complement existing pollution control programmes and regulations, and provide measures to reduce the impact of hard-to-control sources such as brake and tyre wear and road dust re-suspension. In general, vegetation and green infrastructure have been shown to promote overall health benefits, including increased physical activity, reduced obesity, improved mental health, overall improved birth outcomes, reduced risk of cardiovascular disease, and lower mortality. Dedvand et al. found improved cognitive development in schoolchildren associated with an increase in green space, especially near schools (Dadvand et al., 2015). The authors partially explain this relationship by reduction of the nearby air pollution. In addition to air quality and general health benefits, roadside vegetation can improve aesthetics, increase property values, reduce heat, control surface water runoff, and reduce noise pollution (when dense, thick, and tall). However, dense vegetation can also affect driver visibility, create overhangs in open areas along highway rights-of-way, contribute to littering, create a fire danger, and provide a pathway for pests and invasive species. Thus, all the benefits and potential unintended consequences of roadside vegetation must be considered in any application (Baldauf, 2017).

Vegetation in cities can have a significant effect on the redistribution of wind flows, which is important for the urban climate and residents' comfort. There are several ways in which this happens. The first is the reduction of wind speed by plants. Plants, such as trees and bushes, can physically obstruct wind flows, reducing their speed. This is due to the resistance created by the plant's branches and leaves, as well as various turbulent effects resulting from the interaction of wind and different parts of the plant. Plants help to redirect wind flows. Large plants, such as black locust can function as barriers that redirect wind flows in the city. This can create new wind directions and change the local microclimate. By influencing wind flows, vegetation in cities creates specific microclimates where wind speed, humidity, and temperature can differ from the surrounding environment. For example, green spaces and parks can create oases of coolness in the urban landscape. Plants can also help to retain soil, preventing erosion due to wind flow. This is particularly important in cities, where soil can be vulnerable to loss because of the large area of hard surface. Overall, vegetation in cities plays an important role in redistributing wind flows, contributing to a more comfortable and healthy urban environment. This allows cities to reduce the heat load, reduce the risk of extreme weather events, and improve the quality of life of their residents (Mochida & Lun, 2008).

Air pollution has become the biggest public health problem in the world. Poor air quality harms the physical health of the population (Schlenker & Walker, 2016), creates a huge economic burden, and reduces people's well-being. Therefore, it is very important to find cheap and effective ways to solve this problem. A popular approach of many city governments is to tackle air pollution by using vegetation and green spaces to reduce the concentration of air pollutants (Nowak et al., 2006), especially particulate matter (Diener & Mudu, 2021). At the national level, Novak claims that urban trees and shrubs have the capacity to absorb considerable quantities of airborne pollutants, thereby enhancing the quality of life and human well-being. He points out that plants mainly remove atmospheric gaseous pollution mainly by absorption through the stomata of their leaves, although some pollutants can be removed by the surface of the trees. Once within the leaf, the gases migrate into the intercellular spaces, where they can be taken up by water films and to undergo acidification or react with the leaf's internal surfaces. Plants also reduce pollution by capturing particles in the air. Some of the particles can be taken up by the tree, although most intercepted particles are trapped on the vegetation surface. Therefore, for many particles in the atmosphere, vegetation is only a temporary storage site. On the one hand, some literature supports the thesis that increasing the area of green space reduces air pollutants. Novak et al. (1996) found that vegetation foliage reduces air temperature through transpiration and blocking solar radiation. Since the emissions of many pollutants or precursor chemicals are temperature-dependent, lowering

air temperatures improves air quality. In addition, Novak et al. (2006) also estimated the annual uptake of air pollution by urban vegetation by modelling and using meteorological and air pollution data from the United States. Vegetation can reduce the concentration of particulate matter in the air by depositing it on leaves and changing the rate of airborne dispersion (Morakinyo & Lam, 2016). The main mechanisms of air pollution control by plants are deposition of particulate matter, degradation of light organic pollutants in the rhizosphere by soil microbiota, and absorption of these and other gaseous pollutants by through the stomata during photosynthetic activity (Dela Cruz et al., 2019). On the other hand, some researches have found that vegetation has a negative impact on air quality. Janhäll studied the deposition and dispersion of pollutant particles of all size classes and showed that the impact of urban vegetation on air quality at the local level is complex, as we do not yet understand all the parameters that influence the impact of vegetation on air pollution (Janhäll, 2015). Abhijith et al. found that in a street canyon environment, arbovitae forests contributed to poor air quality, while low shrubs improved air quality conditions (Abhijith et al., 2017). In an open environment, low-density vegetation helps to reduce downwind pollutants, while high-density vegetation leads to unimproved or even worse air quality. However, in the real world, the factors affecting green spaces and air pollutants are complex and variable, and the parameters used in the models are often approximate simulations. In addition, each sub-model has uncertainties that increase the uncertainties of the entire model. Furthermore, there are few researches that draw empirical causal conclusions between green spaces and local air quality in the real world. Whether increasing green space is an effective tool for improving local air quality remains to be seen (Ai et al., 2023).

Quantifying the cause and effect of green space on air pollution faces several challenges. The first problem is the mutual influence of green spaces on air pollution. On the one hand, green spaces can affect air quality through vegetation's ecosystem functions. Vegetation filters inhaled airborne particles by trapping them in its leaves, cleansing the air of harmful pollutants and improving the environmental quality in the region. On the other hand, air pollution can have a negative impact on the condition of green spaces. Therefore, when air pollution in a region is severe, the level of green space should be higher (Diener & Mudu, 2021). The diversity of vegetation cover in cities is directly related to the habitat heterogeneity hypothesis, which is one of the cornerstones of ecology. It suggests that structurally complex habitats can offer a greater diversity of niches and facilitate the utilization of environmental resources in a more diverse manner, thereby increasing the diversity of the species (Bazzaz, 1975). In the majority of ecosystems, the physical structure of the environment is largely determined by the plants, and accordingly, have a significant impact on the distribution and interaction of animal species (McCoy & Bell, 1991). For example, MacArthur & MacArthur (1961) showed that the physical structure of the plant community, i.e. the vertical distribution of leaves, may be more important for bird diversity in forests than the actual composition of plant species (MacArthur & MacArthur, 1961). With the growing awareness of the potential benefits of urban green spaces, it is becoming increasingly important to better understand how and under what circumstances the services provided by trees can be expected, designed, planned, and optimally operated. In order to select the right trees for planting in the city, to ensure the health of the trees and their benefits, knowledge of the growth of the respective tree species and their structural development from planting to maturity is essential. However, even for the most common urban trees, research on tree structure, morphology, and growth is insufficient. This is especially true when we take into account the variations in these characteristics at different ages of trees and in different urban environments, such as streets, public squares, car parks, etc. Since the conditions of urban areas are completely different from those of forest areas (Nowak et al., 1996; McPherson et al., 1997), knowledge from forest research cannot be applied. Moreover, even existing data on urban trees cannot be simply transferred to other cities and other climates due to different maintenance practices and different lengths of growing seasons (Lerman et al., 2014). This necessitates a thorough study of black locust ecology in the specific climatic conditions of a particular city. The objective of this research was to assess the vital status of the black locust population of the Dnipro Botanical Garden to determine the species' further application for urban landscaping success.

Materials and methods

The study of the black locust (*R. pseudoacacia*) vital status was carried out in the recreational territory of the Oles Honchar Dnipro National University Botanical Garden in September 2023. Sampling points were located on a quasi-regular grid. The distance between sampling points was 14.0 ± 0.28 m and ranged 7.1 to 31.0 m. The sampling point coordinates were recorded by means of a mobile GPS device. The total of 178 black locust trees were recorded, and their height and trunk diameter were measured, as well as the plants' vital status.

The height of the trees was measured by means of a Suunto PM-5 mechanical height meter in triplicate for each plant, and the average was calculated based on the obtained values. Tree diameters were measured using a fine tuning fork. Diameters were measured as the distance between two parallel tangents. Tree vital status was determined using a 5-point scale by Alekseev (1989). The stand damage index was calculated using the following formula:

$$L_n = \frac{100n_1 + 70n_2 + 40n_3 + 5n_4}{N},$$

where L_n is the relative vital status of the stand; n_1 is the number of healthy trees; n_2 is the number of weakened trees; n_3 is the number of severely weakened trees; n_4 is the number of dying trees; N is the total number of trees (including deadwood) on the sample area or 1 ha. Stands with a condition index of 90–100% were classified as "healthy", 80–89% as "healthy with signs of weakening", 70–79% as "weakened", 50–69% as "damaged", 20–49% as "severely damaged", and less than 20% as "destroyed" (Chongova et al., 2022).

The vital status of plants was determined according to the 5-point Alekseev's scale (Alekseev, 1989).

Results

We recorded 178 black locust trees, which is 25% of the total number of records of all tree species in the research area of Oles Honchar Dnipro National University Botanical Garden. Black locust trees are not uniformly distributed and mainly occupy the periphery of the surveyed area.

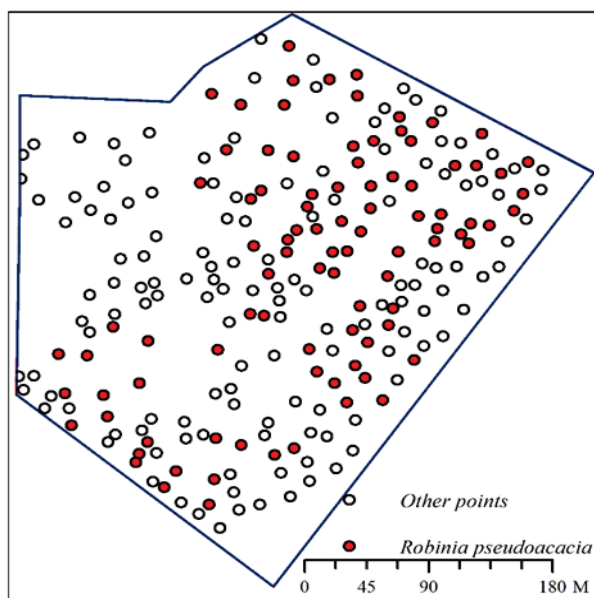


Fig. 1. *Robinia pseudoacacia* location in the recreational area of DNU Botanical Garden

The analysis of distribution of the black locust trees by their trunk height showed that the largest number of trees (over 70) was characterised by a significant height – from 25 to 30 m. The second largest group consisted of trees with a height of 20 to 25 m (46 representatives), and the third largest group included trees with a height of 15 to 20 m (42 representatives). One 32 m tall tree was also recorded in the research area. Other height groups were not numerous. The largest number of species representatives had the trunk diameter varying 30 to 40 cm (47 trees). In the next largest group, the trunk diameter ranged 40

to 50 cm (31 trees). The groups with trunk diameters of 20–30, 50–60, and 60–70 cm were also quite numerous, each of them including 21 black locust representatives. In 12 trees, the trunk diameter ranged 10–20 cm. Two plants had diameters of 80 to 100 cm. One tree reached the trunk diameter of 101 cm.

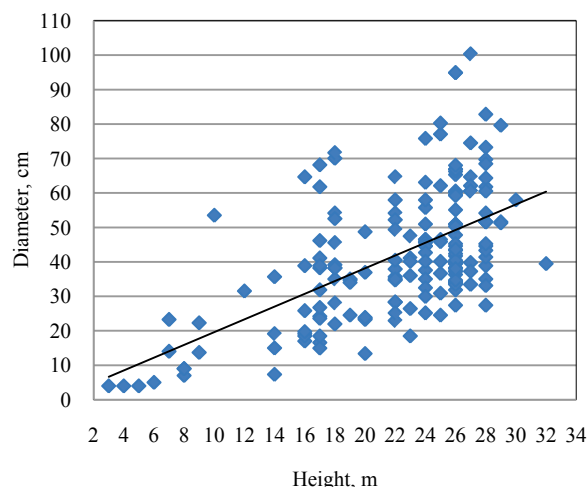


Fig. 2. Height-diameter correlation of the *R. pseudoacacia* trees

With increasing plant height, there was seen a tendency towards increase in the diameter of their trunks. The tallest recorded black locust plants had a height of over 25 m and trunk diameters of 60 to 80 cm, and some up to 100 cm. However, the trunk of the tallest, 32 m tall, was 40 cm in diameter, and the largest trunk diameter of 101 cm was found for a 27 m tall tree.

Table 1

Morphometric parameters of *R. pseudoacacia* depending on the vital status

Vital status	The number of individuals	Height, m	Diameter, cm
2	94	23.7 ± 5.9	47.1 ± 20.3
3	64	21.2 ± 4.9	37.2 ± 14.8
4	13	19.1 ± 5.1	36.7 ± 16.2
5	7	18.3 ± 3.9	37.8 ± 8.7

The largest number of trees (94 representatives) had a vital status score of 2, which means good condition. This group included plants with the highest morphometric indices. Total of 64 plants were characterised by a score of 3 – satisfactory condition, 13 plants were in a depressed state - score 4, and the least number of trees (7 representatives) were found to be in very poor condition, having a score of 5. Visually, those were the smallest plants with a small crown. The overall vitality score was 81% – healthy plants with signs of weakening.

There was a clear correlation between height of the black locust trees and their vital status – the better the vital status of the plants, the taller they were. Plants with a score of 2 (good condition) had an average trunk height of 23.7 m, and those with a score of 3 (satisfactory condition) were 21.2 m tall. The lowest plants were characterised by the worst vital status scores – 4 (depressed condition) and 5 (very poor condition). They had trunk heights of 19.1 and 18.3 m, respectively. At the same time, representatives of those groups of plants whose vitality has been reduced were the most variable in terms of their trunk heights.

The correlation between the black locust trees' trunk diameters and their vital status was rather ambiguous. Plants in the best vital status with a score of 2 (good condition) were characterised by the largest trunks. Black locust plants with vital status scores of 3 (satisfactory), 4 (depressed), and 5 (very poor) were characterised by approximately the same average trunk diameters, measuring 37.2, 36.7, and 37.8 cm, respectively. At the same time, plants in the depressed state had the greatest variability in the size of trunk diameters.

Figure 3 shows the correlation between the height and diameter of *R. pseudoacacia* plants of different vital states. All of them are described by linear regression equations. As the tree trunk height increases, their diameter increases too. However, this correlation is reliable only for trees with vital states 2 and 3, which were the most numerous in the research area ($P < 0.0001$ and $P = 0.0069$, accordingly).

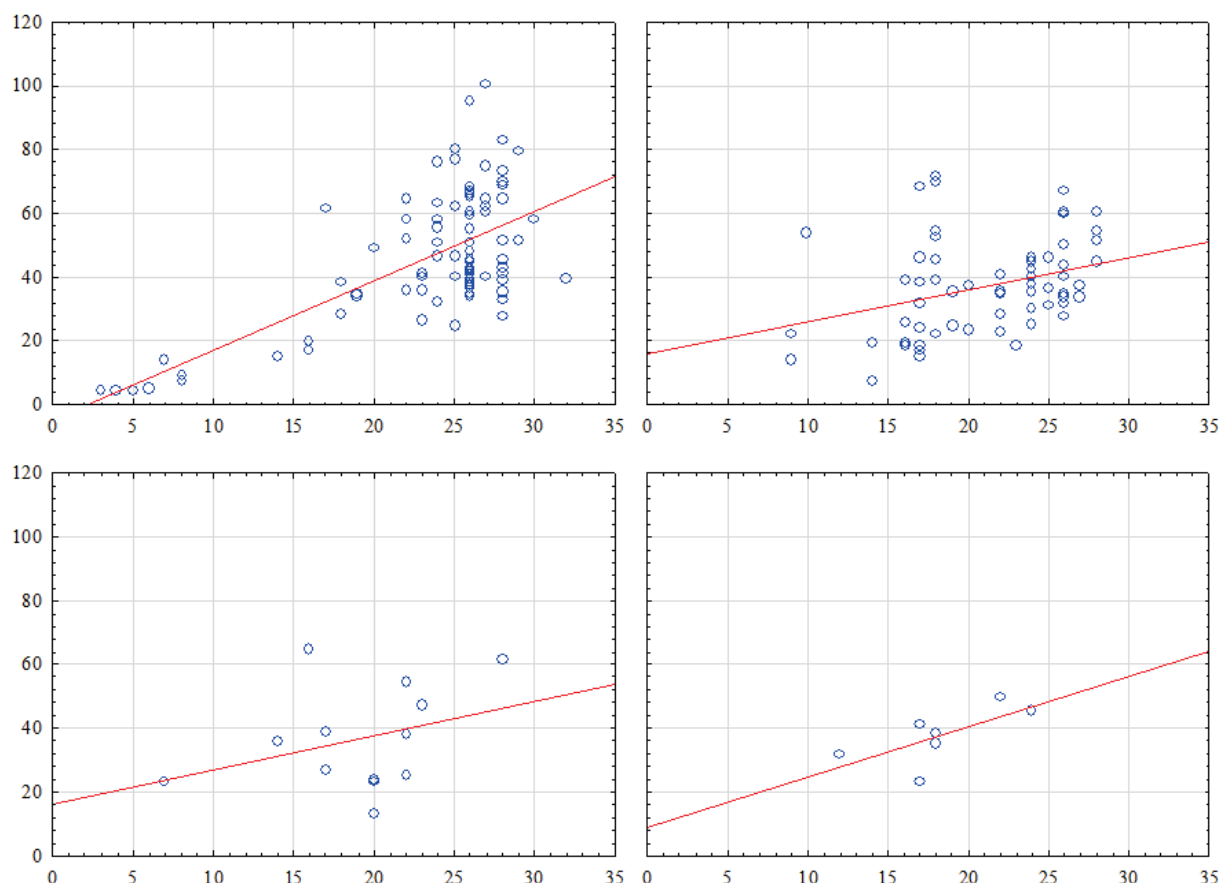


Fig. 3. Height-diameter correlation of the *R. pseudoacacia* trees of different vital states:

a is the vital state 2 ($Y = -4.61 + 2.18 \cdot X$; $r = 0.65$, $P < 0.001$); *b* is the vital state 3 ($Y = 15.69 + 1.02 \cdot X$; $r = 0.33$, $P = 0.007$);
c is the vital state 4 ($Y = 15.97 + 1.08 \cdot X$; $r = 0.34$, $P = 0.25$); *d* is the vital state 5 ($Y = 8.85 + 1.58 \cdot X$; $r = 0.70$, $P = 0.08$)

The correlation between the height and trunk diameter of *R. pseudoacacia* trees with vital status score 4 and 5 is not significant ($P = 0.2518$ and $P = 0.0791$, respectively). Significant variability of morphometric parameters and insufficient sample sizes of the plants with this vital state in the experimental area did not allow us to establish statistically significant relationships.

Discussion

The black locust is phanerophyte, oligotrophic megatroph (plant of saline soils), able to tolerate prolonged drought and excessive humidity; requires moderate ambient temperatures, light-loving, entomophilous, ballistic, sylvan. It is an adventive species, originally from North America (Tarasov, 2012).

It is well known that some trees are identified by researchers as naturalised or invasive (Richardson & Rejmánek, 2011). It was also suggested that of all the invasive species, trees are one of the greatest threats to biodiversity and ecosystem functioning (Richardson & Rejmánek, 2011) and human life (Shackleton et al., 2015). This is why they dominate the widely cited list of the "100 Worst Invaders in the World" (Luque et al., 2014). One of these globally widespread and highly invasive trees is *Robinia pseudoacacia* (Martin, 2019). The list of invasive species includes those that are clearly invasive (Protopopova & Shevera, 2019), rather than those that have just become naturalised or have established themselves only in highly disturbed areas such as roadsides or in heavily human-altered landscapes. This definition means that alien species must have stable populations that have been self-regenerating for at least 10 years without direct human intervention – or even in cases where human intervention occurs – by germinating from seeds or shoots capable of self-growth, and producing reproductive offspring at significant distances from their parent plants, thus having the potential to spread over a large area.

Black locust is a fast-growing nitrogen-fixing tree that is planted in mild regions around the world. It is considered a controversial species due to the presence of many positive properties and simultaneous possible negative impact on environment. Thus, it was listed as one of

the most invasive species. Although this tree is well studied, most of the scientific papers on it are one-sided and focus on either economic aspects or environmental risks. Similarly, the management of black locust plantations tends to be one-sided, focusing on economic benefits and neglecting environmental concerns (Vítková et al., 2015; Puchalka et al., 2021). Black locust is an economically and ecologically important plant native to the eastern United States that has been introduced to several countries, both intentionally and unintentionally. It was introduced to France in the early 1600s and has since spread throughout Europe and Asia (Masaka, 2013); it has also significantly expanded its area compared to its natural distribution in North America. In the areas where the tree has expanded in the United States, it had a number of negative environmental and economic impacts and is therefore considered an invasive species in a number of states. Black locust has also been introduced to a number of countries in the Southern Hemisphere through the ornamental plant trade and forestry. The tree's biology, ecology, economic potential, and environmental impacts have been extensively studied in the US, Europe and China, leading to a number of reviews (Cierjacks et al., 2013; Sádlo et al., 2017; Vítková et al., 2020; Puchalka et al., 2021). However, there is no scientific literature or literature reviews on this tree in the Southern Hemisphere. Literature on black locust control is also limited, and the available literature from the USA and Europe is often not suitable for controlling this species in other regions. In addition, as biological control of black locust is not feasible on any continent, it has not been considered as a control measure for implementation in other countries.

The recent literature argues that soils will be eutrophic due to symbiotic nitrogen fixation by *R. pseudoacacia*, leading to the displacement of native plant species and the increased success of nitrophilic invasive plants. However, these case studies were unable to demonstrate the ecological impact of this species due to the critical problem of "correlation does not imply causation" in research design. Instead, the results of these studies should be seen as illusory correlations, as some researchers report little difference in understory plant diversity between native and *R. pseudoacacia* stands. Land use in floodplains and the discontinuation of vegetation management in coastal pine forests have

led to the invasion of *R. pseudoacacia*. Information on the toxicity of *R. pseudoacacia* to humans and other animals is limited and some data are fragmentary. There are suspicions that the toxicity data for this species may be accidentally overstated and concealed. *Robinia pseudoacacia* supports crop pollination by providing a food source for bees which are managed through beekeeping. Control of *R. pseudoacacia* requires a public consensus based on reliable information (Masaka, 2013). On the other hand, we cannot forget about the ecological characteristics of black locust that are highly beneficial for the restoration of vegetation in territories that have been significantly impacted by the human activity. Urban forests have a number of benefits, including mitigation of the impact of urbanisation on the environment, improvement of climate, absorption of carbon dioxide, improvement of water quality, noise reduction, provision of shelter for wildlife, and enhancing aesthetics of the urban landscape, and others (Silva & Eyng, 2012; Calfapietra et al., 2016). Urban greening is one of the tools that can be used to improve the quality of life and environmental comfort. At the same time, there is a need for careful planning of tree planting, as the incorrect or inappropriate use of trees can cause damage to the environment, as well as to energy, water and sewage systems, which is a common occurrence in cities (Silva et al., 2018). Therefore, urban plantations should be analysed and designed based on planning tools, through quantitative inventory and diagnostics of planted trees, to ensure proper management (Silva et al., 2018).

Tree inventories can be used to provide applied data and information about urban forests. This data is obtained by analysing each individual plant, and the overall information is presented in aggregated values such as totals, averages, percentages, graphs, or tables to support the management of the plant ecosystem (da Silva et al., 2017). The inventory can be conducted through a continuous census or a sample survey. For locations where urban trees are not homogeneous, such as neighbourhoods, public roads or small towns, a continuous inventory is more appropriate. The data obtained from the inventory is used to analyse morphometry and study the relationship between trees and the urban environment. Methods for assessing morphometry, its relationships and tree form dynamics have become indispensable in the management of planted and native forests, but these methods are rarely used in urban forests. The morphometry of urban vegetation can provide important variables for planning the introduction of species for urban forestry. This includes setting minimum standards for pruning interventions, assessing the vitality of each species, and understanding the interactions between trees in urban street (Karlinasari et al., 2021; Zhao et al., 2021). Morphometry allows us to find out the growth dynamics of the urban tree component, to predict the space required for its development and stability, greening measures, and appropriate management in the urban environment. There are studies that have measured the total trunk height, the height of the first bifurcation, the crown height, the average trunk diameter, the average diameter and the average crown area of trees of different species. Based on these measurements, conclusions were drawn about the overall average age of the plantations and their vitality (Matheus Santos Costa et al., 2023).

Due to tree importance in the urban landscape, research of tree characteristics is critical to the ecosystem services in order to ensure adequate planning of the size of the canopy and the growth direction of a particular tree. Research on tree growth and morphometric characteristics is important for understanding the dynamics of tree form and behaviour. Morphometric indices act as tools that assist in afforestation planning and tree management by providing useful knowledge about the characteristics of each species. For example, tree architecture, as one of the parameters of tree morphometry, is determined by the genotypic factors underlying the development of buds and branches of each species. Trees in urban environments can be phenotypically influenced by the anthropogenic environment and may develop differently than in open growing conditions or in forests (Karlinasari et al., 2021). The measurements of morphometric parameters are often used to assess the ecological role of different tree species in urban ecosystems. There is still much to learn about the physical characteristics of urban trees, particularly how these characteristics vary due to changes in their urban surroundings. However, tree structure and function are closely intertwined. In fact, knowledge of structural attributes is essential to better understand the functions and services of urban ecosystems. Several studies have utilized ground-based laser scanning and adopted appropriate methodologies for examining common urban tree species, such as black locust (*Robinia pseudoacacia* L.) and small-leaved lime (*Tilia*

cordata Mill.). These studies aimed to provide a more comprehensive analysis of the spatially explicit and detailed structural attributes of these trees in various urban environments. The study analysed 52 small-leaved linden and 41 black locust trees within the city of Munich (Germany). The species as well as the location of growth had a significant influence on the height-diameter ratio. Small-leaved linden was found to have a larger crown volume. However, the black locust had a larger crown projection area and probably a more efficient crown shape for a similar volume. The trunk inclination of the black locust was higher in parks than in street canyons with city squares located between them. In addition, there was a strong asymmetry in the crown of the black locust in park areas, probably caused by competition with neighbours. The angles of inclination of the main branches did not differ significantly between the two species, nor between the habitats. Branch angles, branch bending, branch length, as well as species and location had a significant impact on the vertical position of the crown centre, i.e. the overall crown shape. The surface complexity of linden was lower than such of the black locust, with its lowest manifestation in parks. The fractal structure of the crown surface, which increases the roughness and complexity of the surface, was more pronounced for the black locust than for small-leaved linden. Thus, the black locust had the highest crown surface complexity in parks, and the lowest in street canyons. These results suggest that research of spatially expressed tree structures can contribute to more targeted tree planting and thus more efficient use of ecosystem services and benefits (Bayer et al., 2018).

In general, data on tree height and diameter are very important and provide information for calculating wood volume, tree biomass, carbon stock, growth parameters, and productivity of plantations (Wang et al., 2019). City services use tree height information to optimise the urban environment and planning to create aesthetically pleasing landscapes and to decide on the number of plants needed and their placement in the city (Zhao et al., 2020). Information about the decrease in tree height can be interpreted as the emergence of negative stress factors that lead to a deterioration of the vital condition of green spaces (Chongova et al., 2022). Knowledge of tree size can also be used to understand their impact on the microclimate by providing shade and lowering air temperatures, as well as to improve air quality, because large trees with a larger leaf area deposit more pollutants and dust from the air (Vasagadekar et al., 2023). Among the plants of the black locust *R. pseudoacacia* in the recreation territory of the Oles Honchar Dnipro National University Botanical Garden, not a single plant was recorded that had a score of 1 (excellent condition) on the vitality scale. It was found that the most plants were in good vital condition (score 2), which correlated with the size of their trunk - plants with the highest values of morphometric parameters were in good vital condition, while the variability of their morphometric parameters was insignificant. The morphology of the plants exhibiting depressed and poor vital condition displayed notable variability in the morphometric parameters. Thus, the morphometric parameters for the studied territory cannot be used as unambiguous markers of plant vital status.

Conclusions

The black locust has a long historical tradition of being used for reforestation, which has led to its popularity as a widespread forest tree. This species has a wide range of valuable characteristics that make it a primary component of a forestry system, offering substantial advantages in both environmental and economic terms. On the other hand, a side effect of planting this tree is its reproduction and spread, which poses a problem for nature conservation. Therefore, the importance of black locust in European ecosystems remains a subject of debate. Such contradictory opinions of experts require a comprehensive understanding of this species and various studies, including the identification of plant vitality and assessment of the tree's morphometric parameters in a particular area. In the research, we assessed the vital status and measured the morphometric parameters of the black locust population in the recreation area of the Botanical Garden of the city of Dnipro to determine the possibility of further use of this species in urban landscaping. A total of 178 black locust plants were recorded, of which the significant majority of the trees (94 representatives) had a vital status score of 2, indicating good condition. Thus, these were the plants with the largest trunks of all the trees of the species studied. Total of 64 plants were characterised by a score of 3 – satisfactory condition, 13 plants were in a depressed state and had a score of 4, and the smallest group of

plants by number (7 representatives) was in a very poor condition and had a score of 5. Plants with the largest height and trunk diameter had a good or satisfactory vital status, while the variability of their morphometric parameters was insignificant (the correlation between height and trunk diameter was reliable). Plants with depressed and poor vitality displayed notable variability in morphometric indices. This was evidenced by the lack of reliability in the correlation between height and trunk diameter. Thus, the morphometric parameters for the studied area cannot be used as unambiguous markers of plant vital status. The overall vitality index was 81% – healthy plants with signs of weakening, which allows us to conclude that the species can be used for urban landscaping.

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