PLANTS IN URBAN AREAS AND LANDSCAPE

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PLANTS

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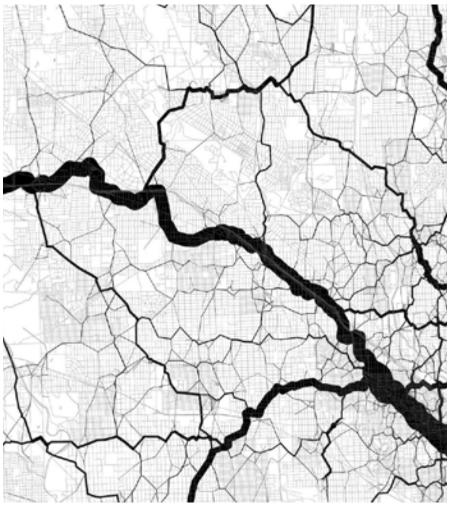

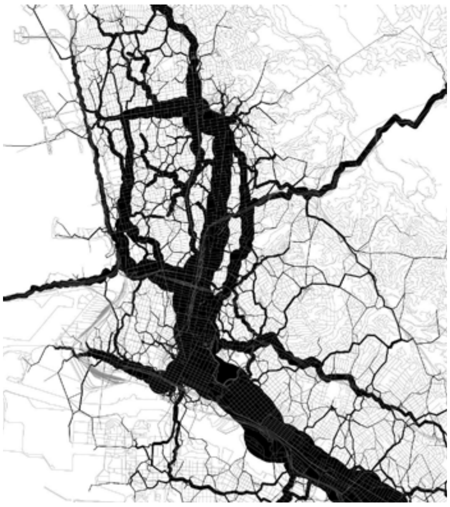

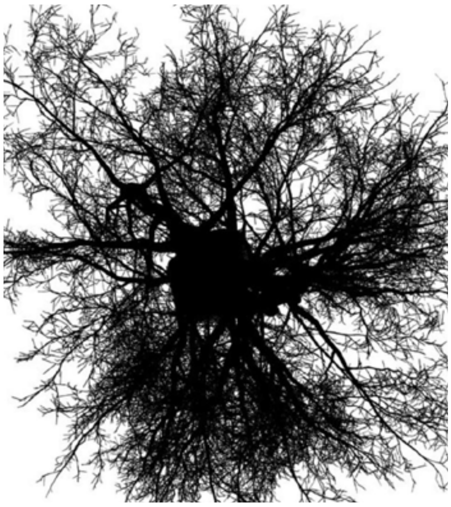

2020

PLANTS IN URBAN AREAS AND LANDSCAPE

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TREES IN THE CITY – PERCEPTION AND AESTHETIC EXPRESSION

Erwin Frohmann

University of Natural Resources and Life Sciences, Vienna, Austria

The present article deals with the aesthetical impact of trees and their relating importance for people in the urban context of open spaces. Indeed, trees therefore have ecological and climate compensating effects, but also social, individual importance, which is noted through the human perception of their spatial effect. Methodologically, this article is based on a literature analysis and sums up essential research results of the design and spatial impact of urban trees. Thereby, the results show that the importance of trees in the urban context and in their symbolical effect offers a reconnection to our phylogenetic heritage and fulfils our longing for the natural. The aesthetic appearance contributes essentially to the revaluation of the urban realm, but, furthermore, the health promoting impact on the human being is of particular significance.

Keywords: Phylogenesis, relationship to the natural, tree aesthetics, health promotion, contemplation

1 Introduction

Open spaces are mirrors and creative expressions of people's requests and, therefore, they are built upon natural and cultural requirements of a city. On the other hand, green and open spaces are places of personal experiences, which, only by perception, are getting real. In this sense, people develop emotional relationships towards landscapes and urban areas, next to all the ecological interactions. Therefore, the constructive experience of urbanity is very much depending on the substantial part of our personal relationship towards this realm. Based on this approach, the article explores the perceptual and aesthetic significance of urban trees and green areas with the aim of demonstrating the associated health benefits and promoting the understanding of the holistic access to the landscape space. The psychologically and physically relevant perception reactions in relation to space atmospheres and their health-promoting effects are compared, brought together and discussed in the context of different studies.

2 Methods

The present article has been prepared by using the method of literature research and analysis. As part of the literature analysis, scientific publications on the aesthetic, atmospheric, symbolic and health-promoting effects of green spaces and trees were evaluated in the context of spatial perception. The focus lies on perception and the associated psychological effects of natural landscape green spaces and trees, based on their design quality, aesthetic effects and atmosphere. Empirical, artistic and theoretical articles are included in the work.

3 Results and discussion

Within the context of urban public green and open spaces, there can be named four factors. As a central design element of green and open spaces in the urban realm, the micro landscape of an urban tree can also be looked at with these four factors in mind which are divided in the Aesthetic factors, the Individual and Social factors, the Ecological factors and the Economic factors (see Table 1).

The focus of this work lies on the constructive experience of urbanity and refers to its:

1. esthetic,
2. individual factors.

Both are to a significant extent carried by our personal relationship towards open spaces, which are based on the personal experiences with the design qualities of open space. Upon the relationships with spaces, we generate inner images from every spatial encounter.

Erwin Frohmann, University of Natural Resources and Life Sciences, Vienna, Department of Landscape, Spatial and Infrastructure Sciences, Institute of Landscape Architecture, Vienna, Austria
e-mail: erwin.frohmann@boku.ac.at

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Table 1 Central factors of greenery, trees, and open spaces

Aesthetic factors	Individual and social factors	Ecological factors	Economic factors
– cultural-aesthetic function	– motion range – living space	– habitat flora & fauna	– spatial reserves for urban development
– spatial development in the urban realm	– personal development	– soil protection, water filter, groundwater	– site quality
– spatial structure	– communication and socialisation	– air hygiene, oxygen, temperature compensation	– production area – agriculture and forestry
– vegetation structure	– recreation – nature experience	– securing a healthy vital surrounding	– infrastructure areas

Source: Frohmann 2019 after Bochnig/Selle 1992

3.1 On phylogenetic importance of trees

After Bourassa, these personal and collective acquired patterns of experience are based on three factors of perception. On ontogenesis as a factor of the personal experience of the recognition of a subjective-worldliness; on sociogenesis as a factor of the collective spatial experience of the cultural environment, and on phylogenesis which functions as a biological link towards the natural. Thereby, the focus lies on the levels of experience, which relate to the aesthetic-spatial evolution of human beings and the nature. As a personally and collectively manifested relationship towards the natural, the longing for nature functions as a soul-bond in our inner world (Bourassa, 1990; Guski and Blöbaum, 2003).

If we are now looking at trees and their phylogenetic origin, they belong to the oldest and biggest plants in this world. The average size of naturally grown deciduous trees is around 25–40 m and of coniferous trees around 30–50 m. Besides, the trees' diversity is wide-ranging and shows various forms, structures, rhythms and colours. Urban trees thereby convey a variety of images, experiential spaces and utilization potentials. Based on the design effect, the evolutionary older coniferous trees (gymnosperms) are defined by a distinct main shoot growing upwards. Various species already develop their stems close to the ground for rejuvenation towards the top. On the other hand, deciduous trees develop the crown after a few meters of main shoot growth, with characteristics such as ramified branches in sphere and oval or cylindrical shapes unfolding towards the sky. The changeability of deciduous trees is also observable during the change of all the seasons, where their design characters also transform. The ramified branches are more and more seen with the winter's sun gleaming above them. From spring to autumn, this dense leafy canopy is a realm shade–seeking people are enjoying. Thereby, it is not only about the favoured microclimatic effect, but the spatial quality of a sense of security and of being accepted into the tree's realm. The transformational processes of deciduous trees reach from a clear branch language, over colourful blossoms to a fully covered crown and, therefore, stand for a versatile quality of experience. Coniferous trees are more self-concentrated and only in exceptional cases undergo the seasonal change. As a general rule, their gestalt character stays the same throughout the year. They convey stability and perseverance (Zauner, 1992.)

If we now look at trees in the context of their natural origin and impact, trees are parts of our phylogenetic heritage and stand for the natural. They connect us on the level of experience with nature and are, therefore, especially with their aesthetic impact the central factor for natural experiences in the urban realm. Within the aesthetic experience of trees, this present work of gestalt impact refers to trees not only influencing the physical, but also mental-psychological conditions of human beings.

3.2 On aesthetic importance of trees

The aesthetical dimension of trees plays an essential roll for as people are not only ecologically interlaced but also through the experiences of trees emotionally connected with the urban realm.

The aesthetical dimension of trees plays an essential role for humans, because people are not only ecologically interlaced to nature elements, but also interact emotionally with the trees.

One single space pervades all beings here: an inner
world-space. Silently, the birds fly through us still.
Oh, I who want to grow, can gaze outside: a tree
will rise inside me...

(Rainer Maria Rilke – translated by David Young[1])

1 RILKE, R.M. – translated by YOUNG, D. The Cortland Revies. http://www.cortlandreview.com/features/13/summer/young.php, 4.7.19

The poem of Rainer Maria Rilke shows the emotionally effective force of a tree. He describes the communication between the own unconscious inner world and the outer world, by using the symbolic analogy of him, who wants to grow and the tree, standing outside and at the same time growing inside of him. In this point of view, the one realm – the inner world realm – reaches through all beings.

In this context, the psychoanalyst C. G. Jung (1995) names the archetypical relationship of humans towards landscape and trees, where outer images are being consciously saved in form of inner images as personally or collectively lived experiences. These images as primary images build the foundation for the experience of landscape.

Already in 1802, the painter Otto Runge wrote that landscape exists for humans to see themselves, their characteristics and passions within all flowers, plants, and all natural phenomena; in every flower and tree it is getting more and more distinct, how in each and every plant a sense of human spirit, idea or perception is underlying (Runge in Barz, 1995). Therefore, the aesthetic relationship of human beings exists through the sensual encounter of landscape and its individual elements, which embody an inner and outer reality. This relationship resembles a conscious stream flowing between human beings and trees. The logic of the tree experience is a psychological one, where the human being exchanges emotional and psychological realities with trees (Salber in Scholz, 1993).

The tree itself has an important role in mythology, various legends, fairy tales and traditions. The tree inspires artists and takes part in the art of painting, poetry and music, thus turning into a tree of world, life, knowledge, phylogenetics, and into a sacred tree. This great importance is the result of a collective force of the tree itself, which was developed through all the people over all the thousands of years, and still to this day, is personally being experienced and perceived.

> *"Trees are sanctuaries. Whoever knows how*
> *to speak to them,*
> *whoever knows how to listen to them,*
> *can learn the truth.*
> *They do not preach learning and precepts,*
> *they preach,*
> *undeterred by particulars, the ancient law of life."*
>
> (Hermann Hesse, 2014[2])

Therefore, trees represent the origin of all living. The trees' holistic aesthetics stands for the fundamental principle of growth and development, but also for vitality within the rhythm of life, intertwined between the interactions of sky-scape and land-scape. All its branches reach for the sun in the sky to catch ever little beam of light and warmth. All its roots are strongly embedded in the soil and nourish it with nutrients of life. In this interaction of heaven and earth, it grows, blossoms, bears fruits and dies apparently when winter is coming, for being born again in spring.

3.3 Trees and their importance for health promotion

Urban images influence the well-being of human beings. What kind of special impact plants and especially trees have on health promotion is shown in numerous studies (ST Leger, 2003). In his study, Ulrich proves that 23 patients having a view into green space with natural qualities need less time to recover and, therefore, stay shorter in hospital compared to 23 patients having a view to house facades without any greenery. Furthermore, they needed fewer painkillers and had better mood (Ulrich 1984). In a later article, he noted: "Findings from several studies have converged in indicating that simply viewing certain types of nature and garden scenes significantly ameliorates stress within only five minutes or less" (Ulrich, 2002).

Kaplan shows that naturally equipped open spaces near the working environment have a great positive impact on the people working there. "The addition of flowers and converting some mowed areas to more natural landscaping could not only enhance the appearance of the workplace, but have substantial environmental benefits. At the same time, such changes can contribute to the well being of those who participate, as well as their co-workers" (Kaplan, 2007).

For the importance of places, which enable a natural experience in direct context to the built environment and direct closeness of buildings itself, Hartig notes: "Environmental evaluations, motivations for outdoor recreation, and benefits attributed to contact with the nature all speak to the existence of experiential bonds between the natural and the built" (Hartig, 1993). Özgüner and Kendle compare the emotional impact of natural versus formal designed parklands in Sheffield (UK), where quantitative surveys showed, that visitors of the naturally designed green spaces ("wild nature") especially felt naturalness and freedom, whereas visitors of the formal green spaces ("formal nature") felt more of an overall peaceful, calm and stress

2 HESSE, H. – Translation by goodreads. https://www.goodreads.com/quotes/266635-trees-are-sanctuaries-whoever-knows-how-to-speak-to-them, 4.7.19


1 – Rock area


2 – Beside the waterfall


3 – Copse

■ **Figure 1:** The different types of the investigated sites and places near the Krimmler Waterfalls/Austria

relieving encounter. The wilder natural park offers more possibilities for socialisation (Özgüner/Kendle, 2006). Kaplan and Austin confirm that vegetation--specific open spaces with trees, forests, and meadows, and a natural characteristic, raise the satisfaction of residents in near lying neighbourhoods. This means peri-urban forests upgrade adjacent districts and are being experienced as attractive (Kaplan and Austin, 2004).

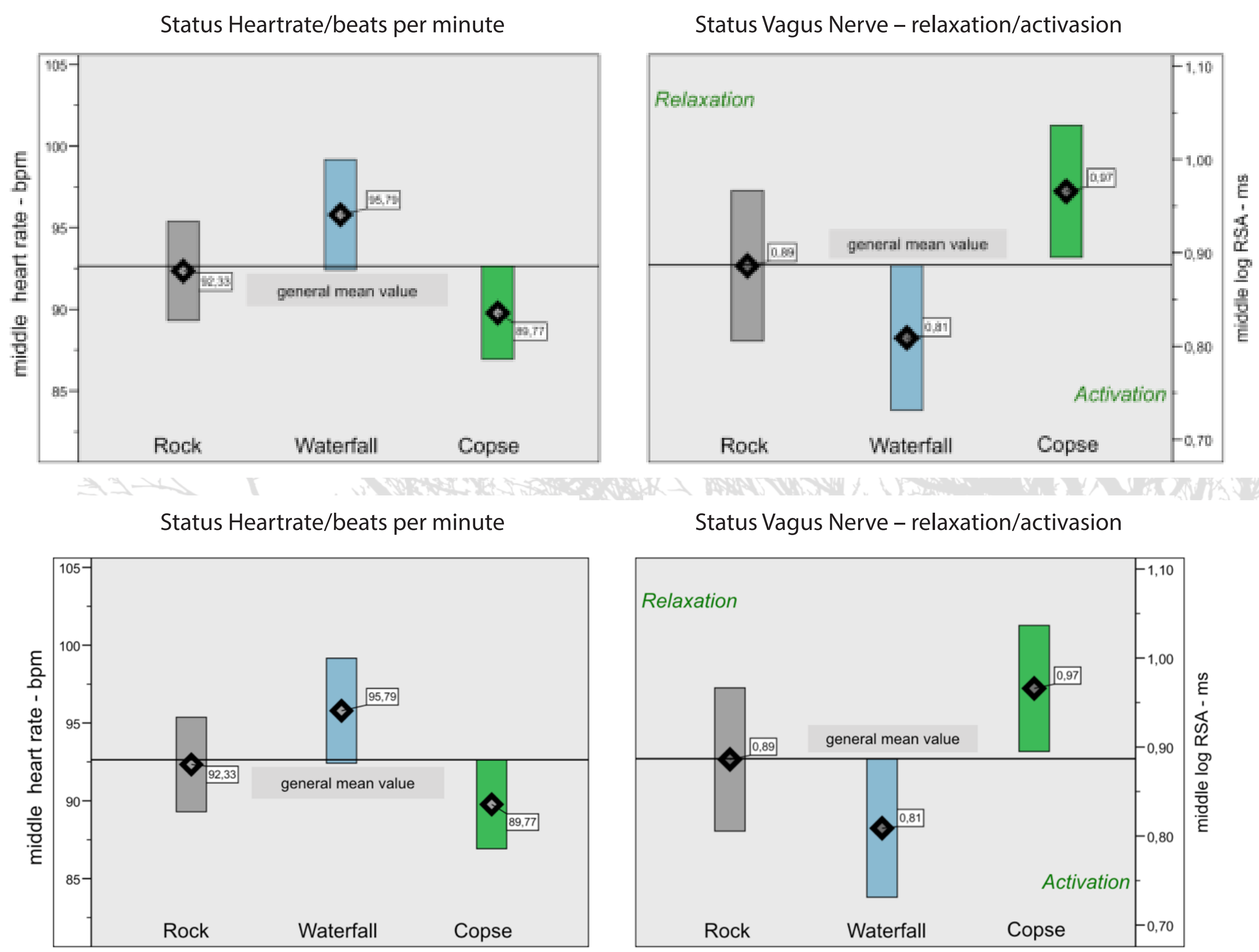
Let us come to the Biophilia aspect, which is based on the biologist Edward O. Wilson. This hypothesis gives an important basis when discussing nature and its effects on human beings. This theory establishes the love of man for nature on the innate emotional relationship with plants and animals. It is a very popular theory that is discussed in many studies. Wilson states that Biophilla "... is the innately emotional affiliation of human beings to other living organisms. Innate means hereditary and hence part of ultimate human nature" (Kellert and Wilson, 1995; Majors, 2019). The Biophilia Hypothesis also builds a bridge to Bourrassa's phylogenetic warfare mode. Both theories are based on our phylogenetic heritage, which makes the sense of naturalness a matter of course.

The following two studies refer that urban residences pose a higher risk of psychiatric disorders, but the causes remain unknown. In this context, the two studies confirm the factor that naturally shaped open spaces having a positive effect on health. Besides the attractiveness that green spaces provide, Grahn and Stigsdotter prove that people who spend more time in urban green spaces are less vulnerable for stress--related disorders. The accessibility of these green areas plays hereby a major key role (Grahn and Stigsdotter, 2003). The health-promoting effect of green spaces on the human psyche described by Grahn and Stigsdotter is confirmed by a Danish study (Engemann et al., 2019). This paper deals with the research of children in contact with green open spaces. Between 1985 and 2013, the landscapes around the parental homes of one million Danish children up to 10 years were investigated on the basis of high-resolution satellite pictures in the vicinity of places of residence. In the center of the research stands the analysis of the normalized difference vegetation index within a 210 × 210 m square around each person's place of residence. The results show that the longer the children grew up in contact with green spaces, the lower the risk of becoming mentally ill. The children who grew up in the "green" had by 55 percent lower risk of becoming mentally ill than people without natural surroundings. "Our results show that green space during childhood is associated with better mental health, supporting efforts to better integrate natural environments into urban planning and childhood life“ (Engemann et al., 2019).

The health-promoting effect of green spaces as well as trees is related to the previously described aspect of the phylogenetically related perception of space so close to the natural. In accordance with this point of view, open spaces and trees are spaces of resonance, which connect people in their perceptive encounters with trees with their own inner nature and, therefore, satisfy the evolutionary longing for nature. The sociologist Hartmut *Rosa* explains the tree as a plea for the experience of the natural, as a retreat into the untouched outer nature is one of the most reliable ways of getting to hear the voice of our inner nature (*Rosa*, 2018).

On the basis of the objective that different green spaces influence the state of well-being of the human beings, the question arises to what extent differently spatially shaped spatial structures affect humans accordingly. To this end, a study was carried out in 2004 near the Krimml Waterfalls in Salzburg. One of the aims was to investigate the atmospheric and contemplative effects of different landscape types on the human circulatory system. The investigation was carried out in 2004 by Frohmann et.al at the Krimmler Waterfalls in Austria where 3 different places were examined regarding their atmospheric effect.

The rock area lies at the foot of a rock moraine and is shaped with different little rocks. The area next to the waterfall is also an area without trees and is featured by the dynamics and freshness of water. The third place is marked with an open and bright tree structure (copse).



■ **Figure 2:** Results of heart rate measurement and the RSA activation of the examined people in context to the investigated sites and places

The copse show a lower Heart Frequency by 6 beats per minute against the waterfall. The Relaxation Factor iof the Vagus Nerv confirms the heart frequency

Source: Fromann et al., 2004

The framework conditions at the three landscape scenes were working. The sun was shining on both days. Temperature: (1) 19 °C/(2) 20 °C/(3) 20 °C. Air humidity: (1) 28%/(2) 31%/(3) 28%. Noise volume: (1) 55 dpi/(2) 69 dpi/(3) 60 dpi.

The experimental procedures were carried out in two days with opposite experimental sequence. As many as 14 people were measured for 10 minutes for each spot, always standing in the same posture with their eyes closed. The examinations were done with the method of the heart rate variability (HRV) as an indicator for the vegetative nervous system's activity. Two parameters were important:

1. the heart frequency (HR) is one of the most significant vegetative values as it varies greatly with physical or emotional activity;
2. the respiratory sinus arrhythmia (logRSA) is a measure for vagus nerve activity, state of rest and relaxation.

The measurements show particularly an interesting result in terms of the effect of the 3 compared sites. At the place with the "copse" character the calming effect was significant. The heart rate decreased by up to 6 beats per minute compared to the "Waterfall". The "Rock" place lies between the waterfall and the copse, although this place was quieter than the copse. It is interesting as it shows the two points in the context of the atmospheric effect of trees. The first point shows that trees compared to the rock and waterfall areas help to reduce stress by lowering the Pulse Rate and encouraging calmness through the Vagus Nerve. The second point relates to the fact that the atmospheric effect of spaces in the perception reaction by humans also takes place with closed eyes (Frohmann et al., 2010).

4 Conclusion

From the obvious relationship between the natural experience and symbolic importance of trees it becomes clear, that not only ecological factors are reasons for planting trees in cities. At the same time, it is necessary to pay attention to the species selection, the estimated size and the site tolerance, so that the trees have the opportunity to fully develop their phylogenetic and health-promoting effects on humans. Therefore, it is important to maintain healthy and vital trees and city forests in urban areas.

The connection between the perception and the recovery potential of trees enable a contemplative encounter with their atmospheric radiance. The special impact refers here to their vitality, where it is assumed that the atmosphere of trees is shifting people into a physically and psychologically pleasant disposition. In this sense, groves and individual trees allow personal experiences of tranquillity and inner contentment. And this will take place also with closed eyes. The empathetic encounter with trees forms a basis for psychologically relaxing spatial experiences – processes which can be compared with contemplative experiences and, therefore, have calming effects on human beings.

Theories on the effect of the Nature experience and the Biophylla effect and the phylogenetical perception are based on numerous studies that show that the common evolution between nature and culture is anchored in the subconscious mind of human beings. The love for nature is innate to us humans and a part of the living relationship between trees and people. In this sense, trees promote the emotional relationship of humans to rural and urban landscapes. Especially, the stay under trees has a calming effect on humans through the contemplative perception of its atmosphere. In summary, the phylogenetic relevance of trees is an essential basis for their health-promotion effect on the psychological level for humans and, therefore, it plays a central role in the perception of nature in urban areas. In addition, it can be stated that apart from the aesthetics, the atmospheric effect of trees also has a recreational significance.

All the named design-relevant and health-promotional effects of trees combined together with their ecological and economic importance for appreciation in the urban realm justify their planting, maintenance, and relational perception.

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PLANTS
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BIOTOPE CITY – VIENNA AS A CONTRIBUTION TO SUSTAINABLE, CLIMATE-SENSITIVE URBAN OPEN SPACES

Zita Ring*, Florian Reinwald, Doris Damyanovic

University of Natural Resources and Life Sciences, Vienna, Austria

The ongoing population growth leads to urban densification which results in a loss of urban green and open spaces and an increase in building mass. In addition, changing climate conditions and the urban heat island effect pose challenges for cities. New approaches are needed to maintain and improve the quality of life, especially for urban population. The urban planning model "Biotope City – the city as nature" is a promising strategy. It promotes the increased use of urban green infrastructure, and, therefore, has a positive impact on the microclimate and creates quality living space for people, flora, and fauna. This paper follows a case-study design, with in-depth analysis of changes in building-related, urban open spaces during the planning process. The plan comparisons show an increase in sealed surfaces from master plan to submission plan and a decrease in urban green infrastructure. The material and vegetation shift have a major impact on the overall ecological assessment of the "Biotope City – Vienna" area. Although the project is based on the urban planning model "Biotope City – the city as nature", there are qualitative and ecological losses during the planning process. These results further support the idea of binding quality assurance and implementation in formal planning instruments to support quality, climate-sensitive urban open spaces.

Keywords: urban green infrastructure, quality assurance, Biotope City – Vienna, climate-sensitive urban planning

1 Introduction

As more than half of the world's population lives in cities and urban migration is ongoing globally, cities face some difficulties. The increase in population leads to urban densification. Cities must stand up to population pressure, which results in an increase in building mass and sealed surfaces. Due to limited space within the city, urban densification puts pressure on green and open spaces, leading to a loss of unsealed areas. In addition, there is a constantly increasing number of days of excessive heat due to the interaction of the Urban Heat Island (UHI) effect and climate change-related rising temperatures (Kromp-Kolb, et al., 2014). Due to the constant migration into cities, the general vulnerability increases as people live in areas most affected by the UHI effect (Lemonsu et al., 2015).

Vienna is confronted with precisely these difficulties. It is a rapid-growing city with an estimated population increase of 20% until 2050 (Statistik Austria, 2016) and experienced noticeable changes in climatic conditions in the last decades (ZAMG, 2012). This means that the current standards for the population must not only be maintained, but also improved. The densification of urbanity and the loss of unsealed open spaces require structural measures with regard to long-term sustainable settlement design in order to provide a high quality of living.

1.1 Aims and objective

In addition to these changing, verifiable, and measurable physical requirements, the need to ensure high quality of life poses numerous challenges for urban development. The discussion of high-quality open spaces in the city and the current relevance of the increased use of green infrastructure as an option for adaptation to climate change and the reduction of urban heat islands raise the question of how this is applied in current planning projects.

This study is unable to encompass the entire field of the usability of green and open spaces and inter- and transdisciplinary planning processes, but it is embedded in a broader research context. Preliminary work was done

Zita Ring, University of Natural Resources and Life Sciences, Vienna, Institute of Landscape Planning, Department of Landscape, Spatial Infrastructure Sciences, Peter-Jordan-Straße 65, 1180 Vienna, Austria
e-mail: zita.ring@boku.ac.at

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in a one-year research project "Biotope City is smart"[1]. One major issue was, if and how the amount and quality of greening measures change along with the progressing planning status. The master thesis "Zukunftsfähige städtische Freiräume" (in English; "Sustainable urban open spaces") (Ring, 2018) dealt more comprehensively with the topic of plan comparisons, the definition of quality criteria, and their implementation in everyday planning life.

The two main goals of this study are:

1. to investigate which greening measures exist in the planning area (case study "Biotope City – Vienna");
2. to ascertain how these can be secured along the planning process in order to obtain quality open spaces.

Firstly, this paper gives a brief overview of the benefits of urban green infrastructure, as they bring ecological, economic, and social advantages and are indispensable for sustainable urban open spaces. The second chapter is concerned with the methodology used for this study. Chapter three analyses the results of the plan comparisons on the basis of the case study "Biotope City – Vienna", an urban development area in Vienna with the promising approach of increasing the use of green infrastructure. Research question 1) is dealt with in Chapter 3.1 and the second question is discussed in Chapter 3.2. It is of particular concern to identify alterations in the planning process so that negative outcomes can be prevented in the future. The findings make an important contribution to the field of landscape planning by highlighting the importance of building-related open spaces and the need for mandatory quality assurance.

1.2 Urban green infrastructure and ecosystem services

A large and growing body of literature has investigated urban densification, climate change and urban green infrastructure (UGI). The following is a brief description of the state of the art, in order to highlight the relevance of the link between high-quality urban open spaces and urban and climatic changes, as it is of particular interest for the research topic.

Ecological benefits

Green infrastructure as a strategy for achieving resilience and a sustainable, functioning urban system is essential in urban planning. "(...) green infrastructure (...) relates to a fine-scale urban application where hybrid infrastructures of green spaces and built systems are planned and designed to support multiple ecosystem services" (Pauleit et al., 2011). The term "infrastructure" illustrates the need to place green infrastructure (GI) on the same level as the structural infrastructure. Through the use of GI, not only ecological but also social and economic demands can be met. Nevertheless, GI currently still plays a *minor* role in urban development and is in conflict with scarce land resources and urban densification (Mell et al., 2016; Pauleit et al., 2011).

There is a large volume of published studies (Campbell-Lendrum and Corvalán, 2007; Coseo and Larsen, 2015; Qin, 2015; Sukopp and Werner, 1982; Susca, Gaffin and Dell'Osso, 2011; Wang, 2016) describing the role of green infrastructure and its positive impact on the microclimate, especially in cities. To sum it up, results show that vegetation cools and humidifies the air, and fine dust deposition filters the air and stores CO_2 (Hatvan et al., 2014). The larger the connected green area, the greater the effect on cooling the urban climate (Sutter-Schurr, 2008). Still, small-scale green structures and open spaces have an influence on the UHI effect and the microclimate of a city (Vienna Environmental Protection Department – Municipal Department 22, 2018). At the microclimatic level, the effects of the urban green infrastructure (UGI) mainly includes shading, wind, and evapotranspiration (Wang, 2016). This can primarily be achieved by façade greening, roof greening, and planting trees. The radiating surface of the buildings is decreased and thus the air temperature is reduced. Façade greening serves as a buffer zone for buildings, improves the indoor climate and thus reduces operating costs. In addition, the peak discharge into the sewage system is reduced by decreasing the sealed areas through water retention and evaporation (Hatvan et al., 2014; Kuttler, 2011).

Chosen materials also influence the sustainability of urban development projects. The material has an impact on thermal comfort and rainwater runoff. As already mentioned, the increase in building density is accompanied by an expansion of development areas and thus in sealed areas. There is potential for the reduction of greenhouse gases through energetic

1 Biotope-City als innovativer Prozess zur Lösung von Zukunftsherausforderungen am Beispiel des Coca Cola Areals Wien. Funded by the Climate and Energy Fund within the framework of the programme "Smart Cities Demo", 7th call for proposals. The project partners were: Institute for Landscape Planning – BOKU Vienna (Lead), Stichting Biotope City, wohnbund:consult, Dr. Ronald Mischek ZT GmbH, Green4Cities GmbH, Auböck + Kárász Landscape Architects, Rüdiger Lainer + Partner Architekten ZT GmbH. Project registration number: 858177.

savings in flooring materials, through the consideration of their transport, repair capability and lifespan (Hatvan et al., 2014).

- **Social and economic benefits**

The impact of UGI is not only ecologically valuable, but also very beneficial for the residents. Green spaces enrich the quality of life in many ways: they form a contrast to the built environment, they provide space for recreation, improve mental and physical health, well-being and enable social contacts. Green spaces and UGI have an aesthetic effect, but they do much more than simply embellish. UGI fulfils various ecosystem functions and thus provides ecosystem services for humans. The benefits that society derives from ecosystem services can be of a material, health, or psychological nature. There is no doubt that the use of green infrastructure in cities is essential for environmental and socioeconomic benefits, among others the mitigation of the urban heat island effect, improvement of air quality, increase of well-being (Ecosystem Services, Grunewald and Bastian, 2013; Millennium Ecosystem Assessment, 2005). In summary, UGI influences the urban quality of life and there is an interaction between UGI, ecosystem services, and social benefits, but the mere existence is not sufficient. UGI needs to be well structured to be both effective and beneficial to people (Böse, 1989; Sutter-Schurr, 2008).

The requirements for building-related open spaces in cities are high and diverse. On the one hand, there must be room for retreat, on the other hand, social contacts and communication should be promoted. Open spaces must be usable, (multi-)functional, aesthetic, of high quality and must not neglect ecological concerns (Brückner and Lüke, 2002; Schmitt, Sommer and Wiechert, 2014). However, these high standards must fit all users who have varying social affiliations, origins, cultural backgrounds, and different ages. The users' tastes and ideas of "their" open spaces are often diverse. In addition, they change in the course of their life situations. Open spaces must be able to meet all these demands and planners have to consider them. Well-functioning open spaces significantly contribute to housing satisfaction and in turn reduce tenant fluctuation (Fassbinder, 2017; Schmitt, Sommer and Wiechert, 2014).

The usability of open spaces is determined by their availability, accessibility and the possibility of appropriation – i.e. the possible behaviours of users within the open space. These conditions are linked to the spatial structures of the building since the position of the buildings and their heights and shapes determine the size and proportion of the open space. Attribution to the buildings takes place, which determines the social character of the open space (public, semi-public, private) (Lička et al., 2012; Sutter-Schurr, 2008).

Urban planning and the development of building-related open spaces have to respond to people's subjective perceptions and demands. On the one hand, the composition of vegetation must be chosen in such a way as to create a functioning green system that can react to climate change and external influences by using nature's regenerative mechanisms (Fassbinder, 2017). On the other hand, the green and open spaces on the plot must not only be functionally designed, but also aesthetically harmonious.

1.3 Biotope City – the city as nature

The urban planning model "Biotope City – the city as nature" (Fassbinder, 2002) provides a promising basis in which it pursues the approach of using the regenerative mechanisms of nature (Fassbinder, van Helmond and Aarsman, 2004). It is a reaction to the changes in urban development caused by climate change and the increasing exposure to noise, particulate matter, and pollutants, especially in densely built-up areas. The urban development model includes quality guidelines as well as positive climatic effects, such as reduction of midsummer temperatures, rainwater retention, CO_2 emissions, and an improvement in biodiversity, through the increased use of greenery. Greenery as an integral component of the buildings, minimisation of sealing, green and open space design across all sites and tenant participation in planning and maintenance are among the quality approaches. The fusion of buildings and open space creates new urban typologies, which should form a resilient system against weather extremes. Thus, the quality of life should be improved sustainably and comprehensively.

The strategy of UGI to mitigate the effects of climate change is part of the urban planning model "Biotope City – the city as nature" (Fassbinder, 2002). It also calls for additional inter- and transdisciplinary planning processes in order to meet the challenges of the interfaces in open space. In this paper, the urban planning model "Biotope City – the city as nature" (Fassbinder, 2002) is analysed on the basis of the case study "Biotope City – Vienna".

2 Material and methods

Case Study "Biotope City – Vienna"

The planning area lies in the 10th district of Vienna. It is located in the former area of the Coca-Cola Company, on approximately 5.6 ha of sealed industrial area. The new urban quarter under the urban planning model "Biotope City – the city as nature" (Fassbinder, 2002) is the re-use of the industrial area and by 2020 approximately 950 new residential units, 730 jobs, areas for commercial use, community facilities, development areas, and a school, as well as a kindergarten, will be created (Glück et al., 2015; Studio Vlay, 2014).

The planning process for "Biotope City – Vienna" differs from conventional urban developments, because the urban planning model "Biotope City – the city as nature" (Fassbinder, 2002) was introduced from the very beginning. Subsequently, an interdisciplinary planning team drew up a master plan with a quality catalogue in a cooperative planning procedure. The property developers have declared their willingness to comply with the criteria by making a voluntary commitment. The quality catalogue contains the Biotope City criteria – all those criteria that cannot be defined and prescribed in the zoning plan and development plan. The quality catalogue with the Biotope-City criteria can be regarded as a quality assurance instrument.

Methodological approach

The dimension of the study is the physical-material provision of urban open spaces on the basis of planning documents. This paper follows a case-study design, with in-depth analysis of changes in building-related, urban open spaces during the planning process (planning phases: master plan, preliminary

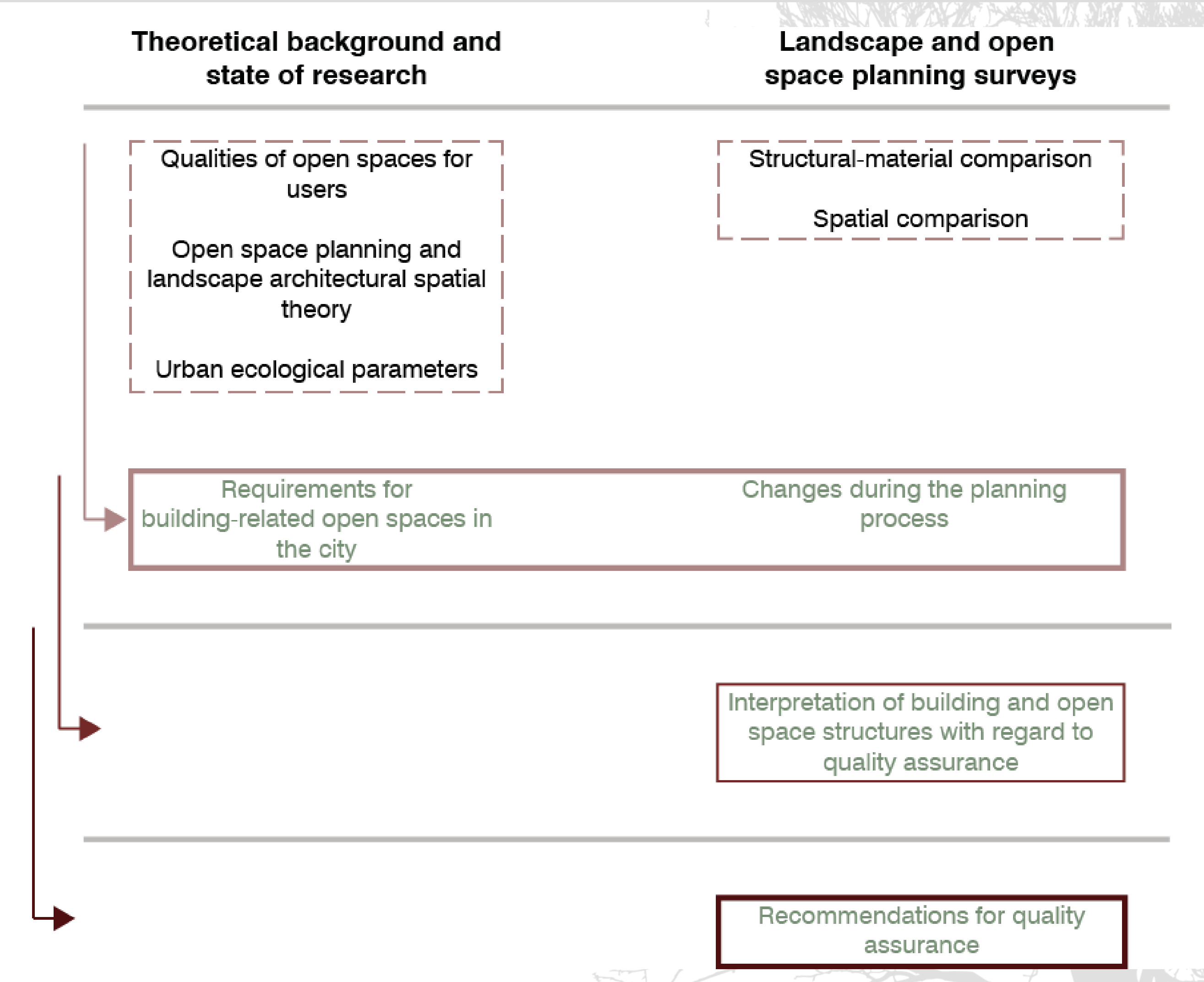

Figure 1: Research design
Source: Ring, 2018, own revision: 2019

draft, submission plan). The state of research, based on the theory of landscape and open space planning and urban ecological parameters, is combined with decomposition sketches as a landscape architectural method (Lička et al., 2012) to capture the different planning levels and elements of open spaces. The interdisciplinary approach was chosen to meet the complex requirements of ecological, climatic and social issues.

In the preceding Master's thesis (Ring, 2018), the requirements for building-related open spaces were developed on the basis of a comprehensive literature research. This paper summarises the most important findings. The literature research served as a basis for the selection of the criteria (path connections, materials, vegetation, spatial formation and division, and their zoning) for the plan comparisons. The three planning phases (master plan, preliminary draft, and submission plan) are divided into different components of the building and open space structures, which form the foundation for comparability and analysis. All three planning phases were compared with regard to these criteria in order to illustrate changes. Every single plan was prepared according to the relevant criteria by decomposition sketches. This paper focuses on material and vegetation comparison. In order to formulate suggestions for improvement in quality assurance, the changes were interpreted from the perspective of open space planning and contextualised with the theoretical background (planning theories) and the state of research regarding urban green infrastructure.

3 Results and discussion

3.1 Interpretation of building and open space structures on the basis of plan comparisons from the open space planning perspective

■ Material comparison

The structural-material comparison of each planning phase reveals changes in the planning process. Table 1 shows the main differences in numbers.

The proportion of vegetation is highest in the master plan and is reduced only slightly from the preliminary draft to submission plan, which is positive in terms of the importance of urban green infrastructure. The central result of the material comparison is the disappearance of the terraway and the increase in asphalt. As a result, the change in the surface materials increases the proportion of paved areas from the master plan to the submission plan from 38 to 51%. In summary, the unpaved area is reduced by 13 percentage points. As already explained, the choice of materials has an impact on the urban heat island effect and the sustainability of urban development projects (Susca Gaffin and Dell'Osso, 2011). The ecology and sustainability of construction projects can be controlled by the choice of materials, mainly because of the energy savings and the reduction of greenhouse gases (Hatvan et al., 2014). In addition to the ecologically negative feature that asphalt is a sealed surface from which the water must be drained, it has a higher energy balance, because it has to be heated for installation (Hatvan et al., 2014). According to a Viennese guideline (Preiss, 2011), asphalt has one of the worst ratings in terms

Table 1 Main differences of the materials

	Master plan	Preliminary draft	Submission plan
Asphalt (sqm)	4,299	3,785	8,751
***In situ* concrete (sqm)**	8,255	7,383	693
Terraway (sqm)	2,625	2,449	–
Lawn (sqm)	17,663	11,616	9,711
Planting (sqm)	–	1,826	2,696
Concrete paving (sqm)	–	–	5,137
Paving (water-permeable) (sqm)	–	–	1,743
Total area of vegetation (sqm)	17,873	18,526	17,427
Sum of the sealed areas (sqm)	12,554	12,865	15,276
Sum of the unsealed areas (sqm)	20,711	16,689	14,856
Percentage of sealed areas	38	44	51
Percentage of unsealed areas	62	56	49

Source: Ring, 2018, own revision: 2019

of transport and fuel consumption, energy balance, durability, recyclability and runoff coefficient. Concrete pavement is also similar to asphalt from the ecological point of view. However, these are the two most frequently used materials among the sealed surfaces (see Table 1). This result is likely to be related to the cost pressure on open spaces and to cost-cutting measures. The change of pavement to asphalt, therefore, has a major impact on the overall ecological assessment of the "Biotope City – Vienna" area. There is abundant room for further progress in determining the reason for the change of pavement.

Vegetation comparison

What follows is an account of the different greening measures at the "Biotope City – Vienna" area and their interpretation. As can be seen from table 2 (below), the comparison reveals that the proportion of total vegetation is highest in the preliminary draft and lowest in the submission plan. The difference to the master plan is about 500 m^2. The number of trees, on the other hand, has increased in each planning phase up to the submission plan.

The comparison of plans shows that the "Biotope City – Vienna" quarter offers a broad spectrum of urban green infrastructure. In addition to lawns, shrubs, bushes, and trees, façade and roof greening is also used. A large part of the green areas is on naturally grown soil. The underground parking areas are located almost exclusively under the buildings. In some cases, they are two-storey in order to maintain as much pristine open space as possible (approximately 70% of the total open space). In comparison to other new urban development projects, where often almost the entire open space is on underground carparks, this leads to positive effects on rainwater management and enables the use of large trees, since sufficient root zone is available.

Roof and façade greening

In the case of façade greening, the non-planted areas account for approximately 90%. The positive influence on the microclimate in urban areas can mainly be achieved by greening buildings (Kuttler, 2011; Wang, 2016). Façade greening is a complex system, as apart from fire police restrictions there are also uncertainties in planning and implementation with regard to technical execution, maintenance, plant knowledge and cost calculation ("ÖkoKauf Wien", Arbeitsgruppe 25, Grün- und Freiräume, 2013). However, trough greening with trellises is being used more and more, as there is hardly any space for ground-based façade greening due to the shape of the buildings and the private gardens.

In the case of roof areas, the proportion of non-vegetated areas is smaller (~50%). A likely explanation is that roof greening, especially extensive roof greening, has been used in Vienna for several years and is state-of-the-art. Since June 2002, there is a green roof guideline "ONR 121131". The construction method and costs are known and, therefore, minimise the risk for the developers in comparison to façade greening. However, the potential of green roofs has neither been fully exploited yet. In Vienna, only 5% of roofs suitable for green roofs, are greened (Hatvan et al., 2014). Green roofs and façades are particularly important in densely built-up urban

Table 2 Main differences in vegetation

	Master plan	Preliminary draft	Submission plan
Trees (new plantings) (pcs.)	223	271	295
Trees (existing) (pcs.)	–	20	15
Hedge (running metre)	597	808	830
Climbing plants (running metre)	–	–	596
Bushes (sqm)	–	1,405	1,241
Perennials and grasses (sqm)	–	716	1,455
Urban gardening (sqm)	210	221	123
Lawn (sqm)	15,837	13,374	10,980
Private gardens (sqm)	1,826	2,810	3,614
Total area of vegetation, ground floor (sqm)	17,873	18,526	17,413
Roof greening (%)	–	–	48
Façade greening (%)		–	12

Source: Ring, 2018, own revision: 2019

structures as they contribute to mitigating the UHI effect through shading and air purification (Vienna Environmental Protection Department – Municipal Department 22, 2018). They increase the proportion of urban green infrastructure in the city without taking up additional space. Their increased use should be encouraged. The comparison of roof and façade greening shows that there is a potential for increased use due to the high proportion of non-vegetated areas (90% and 50%).

3.2 Plan comparison with regard to quality assurance

The entire development project "Biotope City – Vienna" is based on the urban planning model "Biotope City – the city as nature" (Fassbinder, 2002), which involves the extensive use of urban green infrastructure and the use of nature's regenerative mechanisms (Fassbinder, van Helmond and Aarsman, 2004). The project is new and innovative compared to other urban development projects in Vienna. By means of a quality catalogue, planners and developers have committed themselves to ensure that the "Biotope City – Vienna" criteria are actually implemented. In the implementation of innovative ideas or ideas that deviate from everyday planning processes, such as the urban planning model "Biotope City – the city as nature" (Fassbinder, 2002), the complexity of the coordination and cooperation process also increases (Reinwald et al., 2017; Selle, Sinning and Sutter-Schurr, 1997).

Open spaces are subject to high-cost pressure as they are built at the end of the construction phase. At this point, the money required has often already been used up (Lička et al., 2012). Especially because of the agreement to fulfil the "Biotope City – Vienna" criteria, there should be no loss of green infrastructure during the entire planning and implementation process. The plan comparison of the vegetation (see Table 2) has shown that from the master plan to the submission plan there is a decline in the total vegetation of around 500 m^2. Even though the compared plans are situated in the first third of the entire planning process, it was hypothesised that the greening measures changed successively with the progressing planning status. The most obvious finding of the comparison is that there is a reduction in vegetation areas even before the cost pressure on the landscaping work increases. This confirms that the mere existence of an urban planning model such as "Biotope City – the city as nature" (Fassbinder, 2002) is not sufficient to prevent a decline in green and open spaces. Taken together, these results suggest that the idea must be supported by the entire team and above all by all external participants, property developers and property managers. This underlines the statement that the complexity of the coordination and cooperation process increases when innovative ideas, or ideas that deviate from everyday planning procedures, are implemented (Selle, Sinning and Sutter-Schurr, 1997). Therefore, quality assurance must be demanded by a formal planning instrument.

The differences in the level of detail of the plans (master plan, preliminary draft, and submission plan) can be attributed to the process-oriented development of urban development projects. For evaluation and quality assurance, it is, therefore, necessary to decide at which stage quality assurance measures should and can be taken. Difficulties arise, however, when an attempt is made to implement the urban planning model. It must be considered whether specifications can be given in adequate detail before the master plan is drawn up without negatively affecting the creative and innovative approach of the planners, or whether they will be introduced after the adoption of the master plan. If quality and quantitative requirements are demanded at a later stage in the planning process, it may be that the projects are so different that implementation of the required criteria is no longer possible. Taken together, these results suggest that the planning teams should be informed of the desired quality and quantitative criteria right from the very beginning. The recommendation is to embody the urban planning model at a strategic planning level. Then, the "Biotope City – Vienna" quality criteria should be introduced at the project level in order to be adaptable, specified and operationalized by the planning teams in the course of the planning process for the respective project. This grants design flexibility and more specifically, allows linking up with informal and formal planning instruments in order to demand and guarantee the desired quality. Despite these promising results, questions remain. Further research should be undertaken to investigate the challenges and potentials in coordination and, above all, the implementation of quality assurance for future urban development projects.

The main goal of the current study was to determine how to achieve quality assurance for quality and climate-sensitive open spaces. It seems as if the open space has to be able to do "everything" on various levels and for different users (see chapter 1.2). This shows that the mere presence of green is not sufficient without meaningful design and structuring. However, everything mentioned previously provides challenging conditions for urban planning and requires new approaches to provide high-quality open spaces. Open spaces are important for people in two respects. They have an ecological function and a use value, if they can be used (Sutter-Schurr, 2008). From the point of view of open space planning, the residential location and the associated open space are seen as a place for coping with everyday life and as a space for human action (Böse, 1989). Consequently, the significance of open space must not be neglected, and it must not be ranked behind architecture. In order to meet the complex requirements of a sustainable open space, it makes sense to develop an instrument that includes quality and social criteria as well as ecological ones, since people and their demands are the central point of the open space planning theory. "When it is understood that nothing can be sustainably protected in urban landscapes where the majority of people live without the acceptance of these people the nature conservation research in cities must be orientated more to social aspects" (Breuste, 2004).

4 Conclusion

The effects of the growing population and the associated urbanisation lead to a decline in green and open spaces in cities. These results further support the idea of binding quality assurance.

As the plan comparisons showed, there are challenges in the implementation of some "Biotope City – Vienna" criteria and potential for more consistent adherence. The "Biotope City – Vienna" site is a pilot project and the added complexity of the planning process and the time and cost pressure on open spaces leave open questions regarding control possibilities. The sole requirement for checking is not sufficient. The quality criteria must be incorporated in formal planning instruments in order to be able to refer to them. The master plan with the quality catalogue is an informal planning instrument based on commitments. There is no clearly defined quality committee with decision-making authority to demand fulfilment of the criteria. Continued efforts are needed to make the importance of sustainable, urban open spaces more accessible to politicians, stakeholders, planners, developers, and residents in order to achieve a new way of thinking, and thus support implementation.

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CONTENTS

PLANTS
IN URBAN AREAS AND LANDSCAPE

FROM SPONTANEOUS TO DESIGNED: SCENARIOS FOR OPEN SPACE CONVERSION IN A HISTORICAL TOWN CENTRE

Attila Tóth[1, 2]

[1]Slovak University of Agriculture in Nitra, Slovak Republic
[2]University of Natural Resources and Life Sciences (BOKU), Vienna, Austria

Fortifications formed European cities for centuries, from the ancient to modern times. Fortresses and city walls were always linked to open spaces – be it for strategic (wide open spaces, including moats from the outside of the city walls) or functional reasons (open spaces for leisure and food growing). The Nové Zámky Fortress built in the 16th century and demolished in the 18th century has still a strong historical legacy in both local identity and urban form. The paper elaborates on a challenging design assignment – to convert an informal open space with spontaneous and partly invasive woody vegetation to an attractive public park with new open space qualities. The design methodology consisted of three main working phases – field work, analytical work and design work. The results provide three different design scenarios with various approaches to introducing a contemporary layer to the historical urban fabric.

Keywords: fortress, landscape architecture, research by design, studio teaching, urban design

1 Introduction

The Department of Landscape Architecture at the Slovak University of Agriculture in Nitra was commissioned by the Municipality of Nové Zámky in 2018 to elaborate a landscape architectural study with different design scenarios for a publicly accessible open green space at the boundary of the historical town centre. The open space is located at the site of one of the six former bastions of the 16th century Renaissance fortress that has not been preserved. The introductory paragraph is dedicated to history of fortification landscapes in Slovakia and Central Europe from ancient to modern times. It elaborates on the mutual relationship and diverse urban design situations between fortification systems and open spaces, both from the historical and contemporary perspective. The design setting is historically contextualised by a brief insight into the history of the Nové Zámky fortress.

1.1 From ancient to modern: A brief history of fortifications in today's Slovakia

Fortifications formed European cities for centuries. Limes Romanus (Roman Limes), an extensive fortified 5,000 km long borderline of the Roman Empire that reached its greatest extent in the 2nd century AD was perhaps one of the most famous fortified frontiers in human history. A part of this borderline stretched along the river Danube and led for instance through Vindobona (now Vienna, Austria), Gerulata (now Rusovce, Slovakia), Kelemantia (now Iža, Slovakia), Brigetio (now Komárom, Hungary) and Aquincum (now Budapest, Hungary) or the partly preserved Carnuntum in today's Lower Austria that used to be the capital of Upper Pannonia with some 70,000 inhabitants (Bruckmüller, 2001; Institute of Monuments Preservation, 2002). Another famous part of the Limes was built on the orders of Emperor Hadrian around 122 AD. The 118 km long Hadrian's Wall (now in the United Kingdom) was the northernmost limit of the Roman province of Britannia (UNESCO, 2008).

Most of the fortified castles and towns across European cultural landscapes date back to the Middle Ages (5th to 15th century AD). In today's Slovakia the most famous castles were built or re-built in the 13th century, after the Mongol (known also as Tartar) invasion in 1241, including the Bratislava Castle, the Spiš Castle, the Ľubovňa Castle and the Komárno (Comorra/Comar) Fortress (Dvořáková et al., 2017). The Ottoman invasions in the 16th century, especially the Battle of Mohács (1526)

Attila Tóth, Slovak University of Agriculture in Nitra, Department of Landscape Architecture, Tulipánová 7, SK-949 76 Nitra, Slovakia; University of Natural Resources and Life Sciences (BOKU), Institute of Landscape Planning (ILAP), Peter-Jordan-Straße 65, A-1180 Vienna, Austria
e-mail: attila.toth@uniag.sk; attila.toth@boku.ac.at

A

B

C

■ **Figure 1:** Fortresses in Komárno, Nové Zámky and Leopoldov (A–C) in the 19th century
Source: Second Military Survey of the Habsburg Empire (Hungarian Kingdom, 1819–1869); Mapire – Historical Map Portal, Arcanum Database Ltd.

and the Siege of Buda by the Turks (1541) brought the necessity to fortify or rebuild already existing castles (e.g. Modrý Kameň, Červený Kameň and the Levice Castle), existing fortresses (e.g. Komárno) and to build new fortresses (e.g. Nové Zámky and Leopoldov) or fortifying existing monasteries (e.g. Bzovík). The Komárno Fortress was rebuilt into a typical Renaissance bastion fortress in 1540–1550 s (Gráfel, 1999), the Nové Zámky (Castellum Novum) Fortress was being built from 1573 to 1580 and the Leopoldov (Leopoldina/Leopoldstatt) Fortress was built in 1660s after the siege of Nové Zámky (Pisoň, 1973). Fortresses in Komárno and Leopoldov have been preserved until today. The one in Nové Zámky was demolished in 1724–1725 (Figure 1). Only the urban design structure – the shape of the former fortress and the orthogonal road system are still readable from maps and aerial views. Similar fortresses to the one in Nové Zámky have been partly or completely preserved across Europe, for instance in Karlovac (Croatia), Bourtange and Naarden (both in the Netherlands). After the Ottoman invasions, most of the medieval and modern fortresses have partly or completely lost their strategic importance and protection function, however, they have been rediscovered in later war times.

1.2 Behind the walls: There was no fortress without open space

Fortification systems were normally accompanied by open spaces of different type, size, function and strategic importance within or outside the fortified complex. Ancient Egyptian, Persian, Greek and Roman gardens were all fenced by walls. Bostans – open spaces along the Theodosian Wall that used to protect Constantinople (today's Istanbul, Turkey) have been used for growing crops and vegetable for centuries and have gradually become an important landmark and a living agricultural heritage of the city (Timpe, 2014; Keil and Heimig, 2018). The St. Wenceslas Vineyard in the Eastern part of the Prague Castle area was established already in the 10th century and was later enclosed by a wall under the reign of King Charles IV (1316–1378). The Agdal Gardens in Marrakech (Morocco) with extensive groves of orange, lemon, fig, apricot and pomegranate trees planted in rectangular plots, linked by olive lined walkways, cover some 4 square kilometres and date back to the 12th century. Their name is derived from the Berber language and means "walled meadow" (Navarro et al., 2017). Medieval castles usually had enclosed gardens – Hortus Conclusus, while medieval monasteries had enclosed, centrally located rectangular and orthogonally organised Eden Gardens, as well as orchard cemeteries and production gardens with herbs and vegetables (Wiede, 2016).

Modern city fortifications and fortresses were normally surrounded by wide open spaces for defensive reasons. The city walls of Vienna were surrounded by the Glacis (1529–1858), a wide open field that served as a protection zone and later was used by the inhabitants as an urban open space from the 16th to the mid-19th century. In 1857, a decision was made by Emperor Franz Joseph I. to demolish the fortifications and establish a boulevard. As many as 85 planning projects were submitted in 1858 for the new Ringstraße. This large-scale urban-design intervention enabled the construction of important public buildings (e.g. the state opera, the museums of natural history and art history, the parliament, the city hall and the university), as well as the establishment of new or the redesign of the existing green spaces (e.g. Stadtpark, Burggarten, Volksgarten, Rathauspark and Sigmund-Freud-Park) (Faber et al., 2014).

In Nové Zámky, being just a provincial town, there was no urban design competition or urban planning for extending the city after the demolition of the fortification in 1724–1725 and the surrounding water moat in 1822. The city has organically grown outside the walls, without developing specific urban design solutions for the wide open spaces left after the deconstruction of the wall and the moat and the open spaces of the surrounding open spaces. Only some of the former bastions have remained as open spaces – the Calvary Hill on the former Forgách Bastion, and spontaneous green spaces on the former Zierotin and Friedrich Bastions, all three located in the South. The northern bastions were completely built up or sealed for parking.

Nonetheless, whether preserved, reused or demolished, fortifications formed urban landscapes across most of European cities for centuries and have led to the establishment of typologically diverse urban landscapes – unique historic sites such as the one in Komárno, modern planned boulevards with public buildings and parks such as the one in Vienna, restricted areas like the fortress prison in Leopoldov or everyday landscapes with a specific, yet not distinctively articulated historical legacy such as the one in Nové Zámky.

A

B

■ **Figure 2:** View of Nové Zámky (A) and its siege by Ottoman Turks in 1663 (B)
Source: Slovak National Gallery – Web Umenia Portal; Galéria umenia Ernesta Zmetáka v Nových Zámkoch – public domain – engraving by Gaspar Bouttats (B)

1.3 Historical contextualisation – the rise and fall of the Nové Zámky Fortress

The Nové Zámky Fortress (Castrum Novum/Castellum Novum/

Neuhäusel/Érsekújvár) was built between 1573 and 1580 based on the project of Italian architects Ottavio and Giulio Baldigara. The construction works were led by Friedrich Zierotin. The fortress had a hexagonal ground plan with six bastions at its vertices, an orthogonal road system, a centrally located rectangular square, two gates (Viennese and Esztergom Gates) and an extensive underground tunnel system. The fortress was surrounded by a water moat fed by the river Nitra. At the time of its construction, it was the most advanced state-of-the-art Renaissance fortress in the empire. The fortress was first conquered in 1621 by Gábor Bethlen (1580–1629), prince of Transylvania (soon reacquired by the Holy Roman Empire within the Peace of Mikulov). The Ottoman army managed to conquer the castle in 1663 when it became the northmost point of the Ottoman Empire. The fortress was reconquered by the Holy League (established under the auspices of the Holy See and composed of the Holy Roman Empire, Poland, Venetian Republic, Tsarist Russia, Bavaria, Brandenburg and Saxony) in 1685. The fortress of Nové Zámky acquired city rights in 1691. The fortified city was united with the surrounding medieval settlements Nyárhíd, Lék, Györök and Gúg in 1733 by the Letter of City Privileges. The fortress was occupied by Kuruc troops (anti-Habsburg rebels) in 1704 (reconquered by the Empire in 1710). The Nové Zámky fortress was demolished in 1724-25 on the order of Emperor Charles VI (1685–1740). With the destruction of the fortress, a century and a half lasting strategic function of Nové Zámky ended. The water moat was destructed in 1822. The original urban design of the fotress – the hexagonal shape and the orthogonal road system – has been preserved until today.

1.4 The challenge of designing a former fortress landscape

Re-designing open spaces in historical town centres with unique urban landscapes represents a real challenge for landscape architects and urban designers. In these historical places, many time layers have heaped up, which should open a completely new field of cooperation, while exploring the boundaries of the landscape architecture profession and integrating landscape archaeology that approaches human history and cultural monuments at a rather complex landscape scale (Fairclough, 2012), as well as historical geography that acts as a bridge between historical and cultural sciences and helps uncovering the essential time-depth of any landscape that is to be developed by landscape architects (Kleefeld and Schenk, 2012; Hunt, 2016).

Design studios provide the opportunity to implement project-based and hands-on teaching in landscape architecture (Jørgensen et al., 2019). The diversity of project and space typologies is very wide, reaching from public to private, from large-scale to small-scale, from urban to rural (Halajová et al., 2018b). Previous design studios in Nitra were dealing for instance with hospital open spaces (Halajová et al., 2019), environmental education landscapes (Tóth et al., 2018), primary school open spaces (Feriancová, 2014), a public park at a medieval castle, open spaces of a university campus or rural open spaces in several villages and small towns, just to mention some of the most recent projects (Halajová et al., 2018b).

2 Material and methods

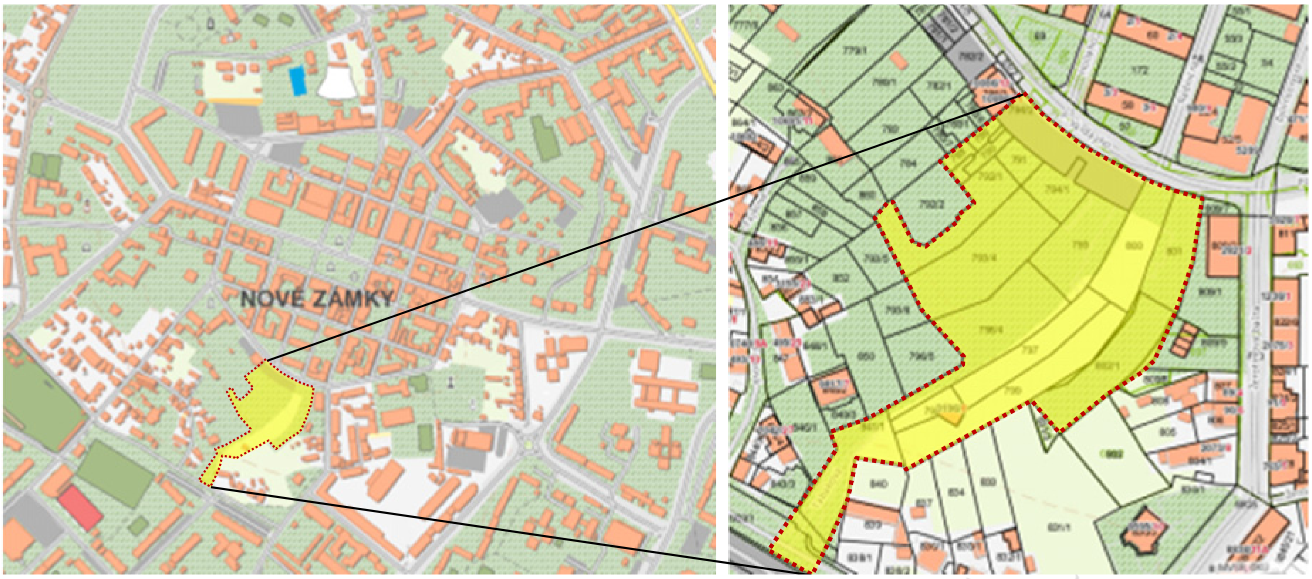
Following a successful design studio dedicated to the re-design of the Main Square in Nové Zámky led by Professor Feriancová in 2016/17, the Department of Landscape Architecture (SUA Nitra) was commissioned to develop design scenarios for a public open space located at the boundary of the historical town centre by the Municipality of Nové Zámky in 2018 (Figure 3). The open space is situated at the site of one of the six former bastions of the hexagonal Renaissance fortress from the 16th century.

Currently, the open space has a rather informal character. It is used by the public to shorten everyday routes between the city centre, the bus station and the train station in the North and a large residential zone in the South of the historical town centre. The area is currently covered by grassland and spontaneous woody vegetation creating a vast, yet informal urban green space in the city centre with a great potential for creating a high-quality open green space for the citizens and visitors of Nové Zámky. There is also a small building of "Astrokabinet" with a small-scale amphitheatre for observing the dark sky and organising events in the summer.

The assignment of the Public Space Design Studio (winter term 2018/2019) was to develop three different design scenarios by three student working groups, supervised by Dr. Attila Tóth (Assistant Professor of Landscape Architecture SUA Nitra).

The methodological process of the design studio followed a standard studio methodology as defined by Halajová et al. (2018a). It can be divided into three main working steps:

1. **Field work** – within this working step, mainly descriptive strategies such as observation, secondary description, complex description,



■ **Figure 3:** Delimitation of the assigned area in the urban fabric of Nové Zámky
Source: Geodesy, Cartography and Cadastre Authority of Slovak Republic, drawn by Tóth (2019)

inventory of woody plants, and collection of site-specific data (Deming and Swaffield, 2011) were applied. The field work included the method of walking the site with local stakeholders (Van den Brink et al., 2017) and discussing positive and negative aspects, potentials and expectations.

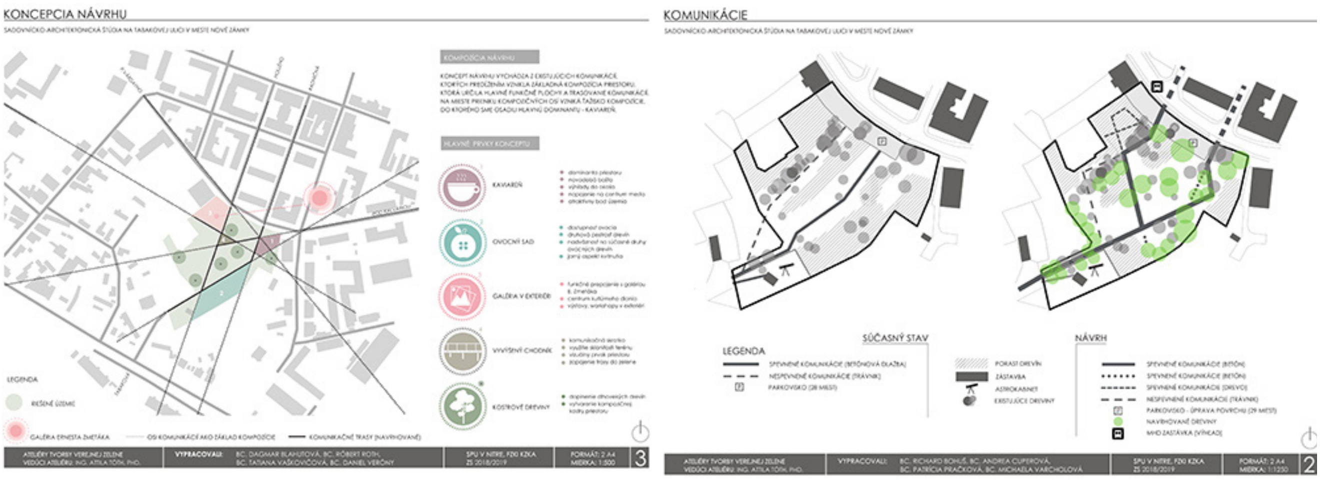
2. **Analytical work** – within this step the data collected and documented on site and materials gained from online search (e.g. the current Land Use Plan of Nové Zámky, maps, texts and historical pictures) were further processed within seven thematic analyses – 2.1) analysis of wider relations (Figure 4A), 2.2) functional and spatial analysis, 2.3) landscape analysis, 2.4) urban-design, architecture and transport analysis, 2.5) compositional analysis, 2.6.1) vegetation analysis – inventory of woody plants (Figure 4B), 2.6.2) vegetation analysis – thematic layer maps, and 2.7) historical analysis (Stahlschmidt et al., 2017; Kuczman, 2018).
3. **Design work** – the design process itself provided opportunities for further research of the site, such as identifying urban-design and compositional relations or developing site-

■ **Figure 4:** Situation of the open space in the urban fabric (A) and inventory of woody plants (B)
Source: Department of Landscape Architecture, SUA Nitra – Public Space Design Studio 2018/2019 (students: Blahutová, D., Roth, R., Vaškovičová, T., Veróny, D.; teacher, head of the studio: Tóth, A.; assistant: Čibik, M.).

specific solutions following the conception of Research by Design as defined by Deming and Swaffield (2011) and Van den Brink et al. (2017). In the design process, theoretical groundings of function and form generation (Herrington, 2017) and other open-space design principles (Štěpánková et al., 2012) were applied. The design process included two direct interactions with local stakeholders from the municipality of Nové Zámky in the form of 3.1) interim critique and feedback, and 3.2) final presentation and feedback.

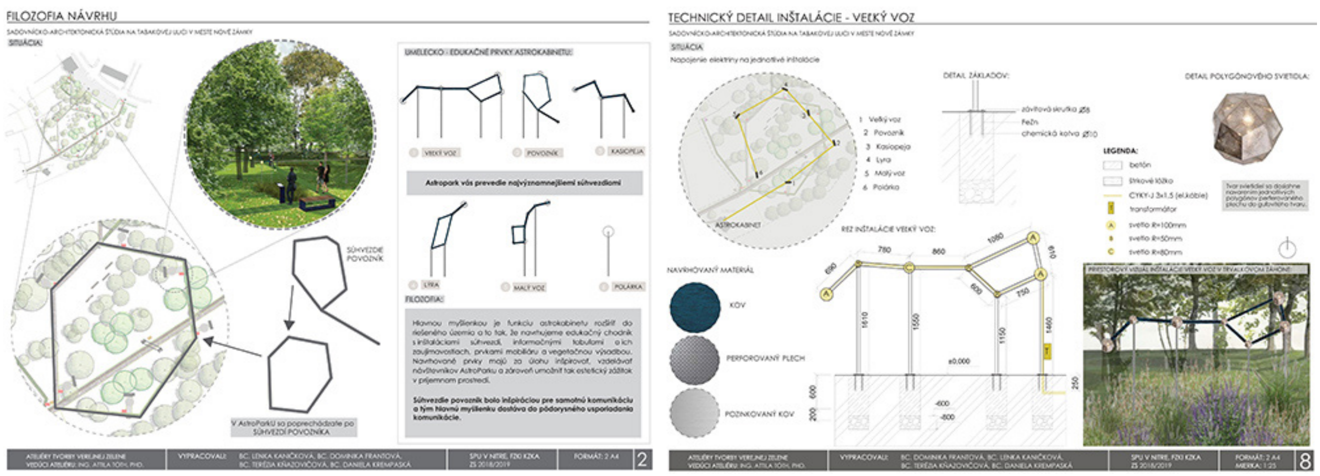
3 Results and discussion

The results of the Public Space Design Studio 2018/2019 consist of three different design studies/ scenarios for public open green space conversion in the town centre of Nové Zámky. Two working groups developed their spatial composition based on the existing urban structure of the historical town centre (Figure 5). One of the working groups extended the surrounding roads and streets and used this layout as their compositional framework (Figure 5A). The other group extended two of the orthogonal streets of the historical town centre and indicated the former bastion in the form of a circular walking trail with information



A B

■ **Figure 5:** Developing design scenarios based on the existing urban fabric, generating new forms (A) and re-using historical site-specific forms (B)
Source: Department of Landscape Architecture, SUA Nitra – Public Space Design Studio 2018/2019 (students: left – Blahutová, D., Roth, R., Vaškovičová, T., Verómy, D.; right – Bohuš, R., Cuperová, A., Pračková, P., Varcholová, M.; teacher, head of the studio: Tóth, A.; assistant: Čibik, M.)



A B

■ **Figure 6:** A symbolic approach to generating form inspired by constellations
Source: Department of Landscape Architecture, SUA Nitra – Public Space Design Studio 2018/2019 (students: left – Kaničková, L., Frantová, D., Kňazovičová, T., Krempaská, D.; teacher, head of the studio: Tóth, A.; assistant: Čibik, M.)

■ **Figure 7:** Comparison of the current situation of the open space with three different design scenarios
Source: Department of Landscape Architecture, SUA Nitra – Public Space Design Studio 2018/2019 (students: A and B – Blahutová, D., Roth, R., Vaškovičová, T., Veróny, D.; C – Bohuš, R., Cuperová, A., Pračková, P., Varcholová, M.; D – Kaničková, L., Frantová, D., Kňazovičová, T., Krempaská, D.; teacher, head of the studio: Tóth, A.; assistant: Čibik, M.)

panels on the six former bastions (Figure 5B), creating thereby an allusive reference to the former bastion.

The third working group applied a different approach. Their form generation followed a rather symbolic approach and made reference to the existing "Astrokabinet" through designing the central circular walking trail in the shape of the Auriga Constellation (Figure 6A). This symbology makes its way from the conceptual thinking down to design details and artistic site elements inspired by famous constellations, asterisms and stars – the Big Dipper/Plough as part of Ursa Major, the Auriga, Cassiopeia, Lyra, Ursa Minor, and Alfa Ursae Minoris (α UMi) (Figure 6A and B).

The Public Space Design Studio generated three different design scenarios for converting the centrally located public open green space. All three bring new ideas for further development of the site and provide a good framework for further discussions in the municipality. The current condition of the area with prevailing spontaneous and partly invasive woody plants (Figure 7A) would gain new open space qualities, while a new public park could be created that would enhance the urban green infrastructure and existing green space structures across the town (Supuka et al., 2008). The following scenarios were developed by the three working groups:

Scenario No. 1 "Urban Park" (Figure 7B) integrates most of the existing vegetation and enhances the site with a modern café (Figure 8A), a public orchard, an open-air gallery, terraces and walkways, while enhancing the existing tree species composition by native long-lived tree species. It introduces a new urban form and new functions to the site.

A B

■ **Figure 8:** Visualisations of the café design (A) and the thematic walk under wooden gates in a flower meadow (B)
Source: Department of Landscape Architecture, SUA Nitra – Public Space Design Studio 2018/2019 (left – Blahutová, D., Roth, R., Vaškovičová, T., Veróny, D.; right – Bohuš, R., Cuperová, A., Pračková, P., Varcholová, M.; teacher, head of the studio: Tóth, A.; assistant: Čibik, M.)

Scenario No. 2 "Green Valley" (Figure 7C) enhances the existing open space with a design reference to the former bastion and the fortress. This scenario enriches the public space with information panels on the history of the fortress and its bastions, an open-air library and areading room, a terrace in the existing black-locust grove, a flower meadow with wooden gates referring to contemporary monuments of the town (Figure 8B) and many new site-furniture elements.

Scenario No. 3 "Astropark" (Figure 7D) builds upon the theme of astronomy and star observation through stylizing stars, asterisms and constellations. When implementing this scenario, the site would become an open-air dark-sky observatory with interesting design features such as lighting artistic elements in the shape of star formations, combined with perennial plantings.

4 Conclusion

The Public Space Design Studio 2018/2019 has provided the municipality of Nové Zámky with three different design scenarios for converting the informal open green space in the town centre with prevailing spontaneous and invasive woody vegetation into an attractive public open green space. The different design scenarios serve for the municipality as a useful material for internal and public discussions on the future of this open space. From the scientific perspective, the design studio provided a great opportunity to implement landscape theory and design principles in the teaching process and to conduct an interesting research by design on fortress landscapes and open space conversion. The new knowledge that was obtained within this process includes knowledge on the importance and specificities of fortress landscapes across Europe. The most important results are represented by three design scenarios. The scientific significance of the work consists in furthering research in landscape architecture through design in Slovak conditions. The practical significance of the project consists in the implementation of project- and problem-based teaching and providing landscape architecture students with practical knowledge and skills and the opportunity to work on real sites, deal with real challenges and interact with local stakeholders. A recommendation for the city of Nové Zámky would be to initiate discussions with elected representatives of the local government and the public, to proceed to the project design phase and subsequently to the implementation of one of the scenarios. Further research could be geared towards exploring other medieval and modern fortress landscapes across Slovakia, to verify the applicability of the developed design approaches in other local conditions.

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PLANTS
IN URBAN AREAS AND LANDSCAPE

SHAPING AN URBAN RIVERSCAPE THE PLANNING AND DESIGN OF DANUBE ISLAND AND THE NEW DANUBE IN VIENNA, 1969–1988

Ulrike Krippner*, Dagmar Grimm-Pretner

University of Natural Resources and Life Sciences, Vienna, Austria

Within the last 150 years, two major flood-protection projects have fundamentally changed the Danube riverscape in Vienna. The first project, in the 1870s, involved straightening the river in one main bed with a large parallel inundation area. Between 1969 and 1989, the inundation area was transformed into a 21 kilometre long island and a parallel flood-relief channel. The paper investigates the development of the project, the shift in planning strategies, and its effect on the design of the island and river banks. The research is based on a literature review and analyses of urban planning concepts, design concepts, site construction plans, and planting schemes.

An interactive planning process, the Vienna Model, was developed to coordinate the large number of actors and manage their controversial planning strategies and goals. Owing to the long ongoing planning and realization process, the requirements and objectives of this large urban riverscape project have changed over time. Besides the need for flood protection, concerns about urban recreation, ecology, and landscape protection have gained in importance. Within the Vienna Model's organizational structure, the flood-protection project with all its technical requirements evolved into a multifunctional riverscape. Today, Danube Island and the New Danube are crucial elements in Vienna's urban fabric. This artificial landscape is extremely popular for urban recreation and activities; it contains vital semi-natural sections and has coped with five major floods since 1991.

A close look at the complex planning process and the successful landscape design of the Vienna Danube region provides crucial indicators for large urban river projects. Urban riverscape projects need to be innovative and require a multidisciplinary team to tackle the diverse challenges. They need a strong design framework to cope with and respond to changes in demand, use, and management. And, above all, they need to serve multiple functions, including flood protection, recreation, ecology, and nature conservation.

Keywords: Danube, flood protection, landscape design, recreation, Vienna

1 Introduction

Today, the artificial Danube Island and the New Danube are crucial elements in Vienna's green and blue network (Stadtentwicklung Wien, 2015). They are the result of two major flood-protection projects that have had a fundamental impact on the Danube riverscape in Vienna. From 1870 to 1875, the branching river was straightened into one main riverbed with a large parallel inundation area of 8.25 square kilometres of almost flat ground. Overflows of the swiftly moving Alpine river were then limited, but flooding remained a risk. In view of this, 100 years later, the inundation area was transformed into a 160 metre wide flood-relief channel and an artificial island parallel to the main stream. The island is 21.1 kilometres long and 200 metres wide on average. A mere technical project in 1969, the island and the flood-relief channel were later transformed into a multipurpose riverscape in the course of an interactive planning process that lasted almost twenty years.

Taking the artificial Danube Island and the New Danube as a case study, the paper focuses on the interrelationship of the site, the planning process, and landscape architecture. With this in mind, the objectives of this paper are:

- to review the history of the island and the interaction of the actors involved;
- to analyse the shift in planning strategies and the consequences this has had on form, function, and meaning at the site scale;

Ulrike Krippner, University of Natural Resources and Life Sciences, Institute of Landscape Architecture, Department of Landscape, Spatial and Infrastructure Sciences, Peter-Jordan-Strasse 82, 1190 Vienna, Austria
e-mail: ulrike.krippner@boku.ac.at; dagmar.grimm-pretner@boku.ac.at

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- to analyse the spatial and design qualities of the island; and
- to discuss how the findings can inform the design of an urban riverscape.

Background and Literature Review

The planning and design of open spaces, in general – and green and blue infrastructure, in particular – are based on specific concepts and ideas that are influenced by distinct planning traditions, values, and scientific approaches. All of these reflect specific relations of power and change over time (Jongman, Külvik and Kristiansen, 2004). The extremely long planning and realization period of Danube Island and the New Danube clearly shows these interrelations.

From the urban planning perspective, Danube Island serves as a "green corridor". In the urban development plan 2015, called STEP 2025, "green corridors" and their smaller counterparts "greenways" are important types of linear open spaces in a network model, aiming at a better connection of major green spaces and enhancing the living conditions in densely built-up urban areas. Green corridors have a particular significance for all four network functions of green and open space, which are "everyday life and recreation", "structuring the urban fabric", "ecosystem services", and "nature conservation" (Stadtentwicklung Wien, 2015). The ecological relevance of linear green structures has been intensively researched (e.g. Jombach et al., 2016), but little has been published on the design aspects. Walmsley (1995) discusses the impact greenways have on urban form, but does not address design on the site scale.

Danube Island and the New Danube form an artificial landscape, they are planned and constructed – they are designed. Four square kilometres of land and a 3.3 square kilometre expanse of water have become an integral part of the fabric of the city, providing diverse outdoor spaces. Seeing Danube Island as a "large park" gives us new ways of looking at a complex open space in the city. James Corner stresses the fact that large parks "are larger than the designer's will for authorship, they exceed over-regulation and contrivance, and they always evolve into more multifarious (and unpredictable) formations than anyone could have envisaged at the outset" (Corner, 2007). The challenge to design such a complex and dynamic system is – according to Corner (2007) – the equation of fixed form, open process, and meaning. Corner stresses the importance of designing a framework that is robust enough to provide structure, but retains the flexibility "to adapt to changing demands and ecologies over time". He describes a framework as a "highly specified physical base from which more open-ended processes and formations take root" (Corner, 2007). We can safely assume that Corner sees the physical elements of a design, like topography, planting, or infrastructure, as contributing to the "physical base".

However, we consider it equally important that a framework should guide planning and decision-making processes, while also addressing the question of how different actors can be integrated. Julia Czerniak engages with these planning, social, and political aspects, pointing out that "in addition to size, the term 'large' implies ambition", "'large' invokes thinking beyond the given", and "large also implies a considerable amount of energy, vision, commitment, and innovation – by designers, administrators, politicians, and the public they serve – to make these parks happen" (Czerniak, 2007).

The landscape architect Martin Prominski stresses the importance of interlinking the issues of flood protection, ecology, and the accessibility and use of open space (Prominski et al., 2012). This understanding has gained importance in recent years in urban river design, owing in no small part to the fact that rivers have been elevated into prestigious areas for social urbanites to gather in (Prominski et al., 2012; Way, 2018).

The development of Vienna's Danube flood-protection project from 1969 to 1989 is a complex case that allows us to study the interrelationship of planning and design in an urban riverscape in the second half of the twentieth century.

2 Material and methods

The findings of this paper are based on a review of publications on Danube Island, thus following an inductive approach to research. The literature review covers the history of the area, the island, the planning process, and the actors involved. Urban planning concepts and development plans are analysed to determine the role of the river and of the artificial island in planning strategies for open-space development, protection, and design. The interrelationship between site and design is elaborated by analysing regulation schemes, site construction plans, and planting schemes.

3 Results and discussion

3.1 Planning process and switch in planning strategies

Danube Island in its existing form is the result of a planning process that spanned twenty years. Internal and external factors have influenced this process and shifted the project's focus, transforming it from a purely technical structure into a multifunctional riverscape.

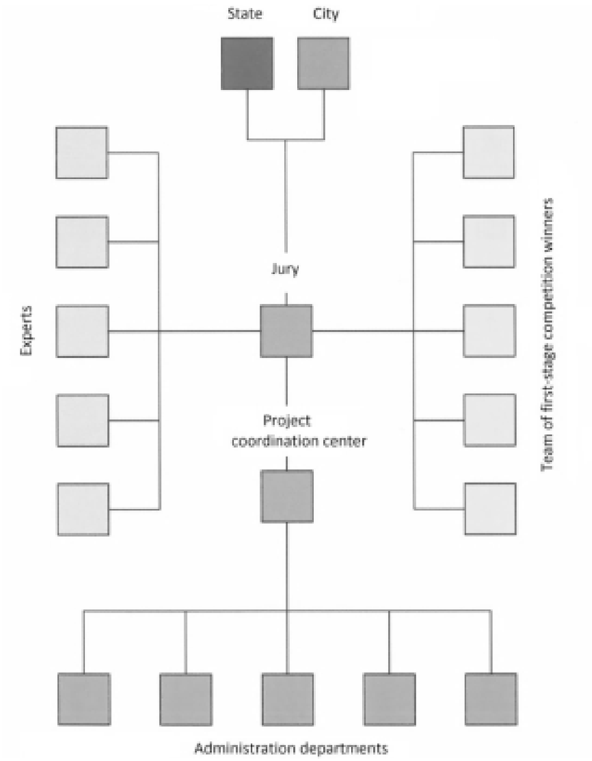
The basis was laid with the first flood-protection project in the 1870s, when the branching Danube was straightened into one main riverbed with a large parallel 450 metre wide inundation area (Figure 1). Rapid urban expansion started on the right bank of the new riverbed, while the inundation area on the left bank soon developed into an informal recreation area. The character of this area was defined by meadows, scattered clumps of trees, and floodplain relicts. Users were attracted by its size, its wild character, and the absence of strict regulations, which offered multiple recreational uses and a feeling of freedom in a time of urban densification.

A major flood in 1954 made flood protection an imperative once again. This gave rise to a technically oriented project involving a straight flood-relief channel and an island of trapezoidal cross section. Experts were critical of the fact that this project did not provide for any recreational needs or ecological functions. One of the critics, architect Ernst W. Heiss (1964), who was responsible for landscape planning at the municipal department of urban planning, stated that the river required a new open design that would be sensitive to "the great spirit of the river" and allow for diverse recreational use, just as the inundation area had done so far. According to Heiss (1980), the Danube area should become the core and spine of a generous green structure in Vienna, while Danube Island should upgrade the floodplain relicts. However, these early critics made only minimal changes to the technical flood-protection project. A municipal landscape design dating from 1968 shows institutionalized recreational facilities such as swimming pools, a variety of ball courts, golf, and camping on the island. The fundamental attributes of the technical project – like the straight banks and the trapezoidal cross section – were retained. The design did not provide any access to the water. Besides, the development of new residential areas on the island was still being considered up until 1976.

■ **Figure 1:** Danube network in Vienna in 1960: the cut-off Old Danube (left), inundation area and the Danube River (right)
Source: WStLA FL3138

The first construction work on the technical project began in 1972. But it was only in the wake of the global rise of postmodern environmentalism in the early 1970s and, at the local level, serious public concern over the continuous destruction of the urban wetland relicts that the planning process was politicized (Redl and Wösendorfer, 1980). Expert advisers strongly recommended the initiation of a landscape design process (Gruen, 1972) and stressed the crucial importance of the Danube and its adjacent landscapes as a greenway linking and developing the urban fabric (Woess and Loidl, 1974). As a consequence, the city launched a two-stage design competition in 1973–1975, parallel to the ongoing construction work.

In response to the competing solutions and visions, an interactive planning process, the "Vienna Model", was developed. This model brought together different actors and decision-makers in planning, urban, and landscape design as well as in water engineering. It systematized the cooperation of external experts, representatives of administrative departments, the state and the city, and the five winning teams from the first stage of the competition (Figrue 2). Landscape architect Bruno Domany from the municipal department coordinated the long ongoing discussions and the planning process. In the end, the different planning approaches gradually merged into one project, which stressed the infrastructural, ecological, and societal functions



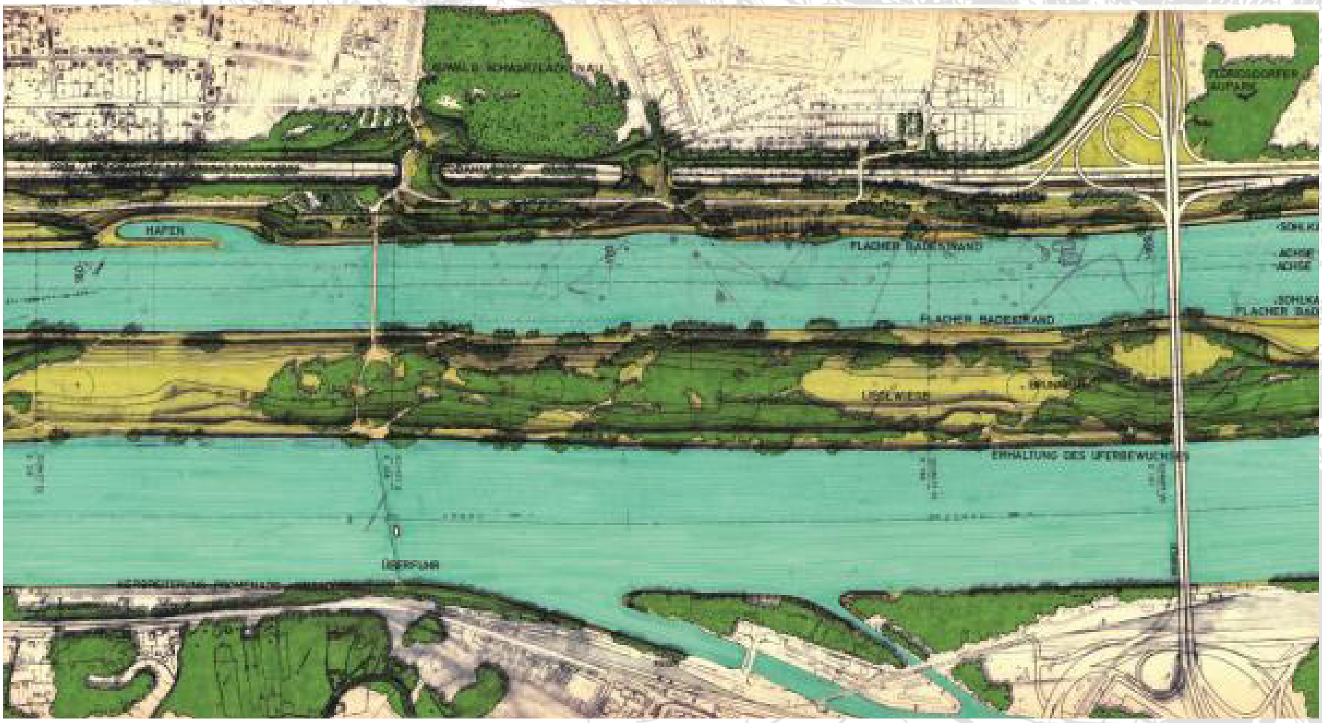
■ **Figure 2:** "Vienna Model", model of project organization for the second stage of the design competition, which brought experts, representatives of the administration, and the winning teams of the first stage into collaboration
Source: Seiß, 2001

of the river within the urban network. The overall concept referred to the former character of the site, the floodplain forest. The newly constructed land should complement and refine the remains of this habitat. However, the planners recognized that "it is not possible to construct a fully fledged new landscape at the first attempt... but only a supporting physical structure" (Domany, Schwetz and Seidel, 1982) or "a shell construction of a landscape" (Heiss, 1980).

The final landscape design by Gottfried & Anton Hansjakob and Wilfried Kirchner, which dates from the early 1980s, acknowledges the site's tremendous potential for recreational activities and upgrades the landscape qualities of the former inundation area. Their design shapes the island's topography and bank line and – for the first time – offers access to the New Danube as a place to swim.

3.2 Spatial structure and design principles

The design categorizes the 21 kilometre long island and its riverbanks into three sections of diversified character and potential. The middle section of the island, which is close to residential neighbourhoods on both sides of the Danube and connected to public transport, is designed like an urban park and accentuated with architectural elements like retaining walls, terraces, and stair seating. In contrast,



■ **Figure 3:** First draft of the northern section of Danube Island and the New Danube, Gottfried and Anton Hansjakob, 1976
Source: Archiv Österreichischer Landschaftsarchitektur LArchiv, BOKU Vienna, Collection Hansjakob, VL-HAN-20

the northern and southern sections of the island are designed to support processes of natural succession. Here, the design interventions set out to be modest and respectful in order to preserve as much of the informal character of the former inundation area as possible (Domany et al., 1982). All over the island, meadows and woodland alternate and form enclosed areas as well as zones that open up to the Danube and the New Danube. Vistas and access to the water were a key requirement (Figure 3).

The landscape architects developed a comprehensive typology of banks, which should guarantee an attractive design of the roughly 60 kilometre long riverbanks of the New Danube and the left bank of the Danube (Figs 4a–b). This typology was required to meet flood-protection regulations and ecological needs and to offer different structures for recreational use. Steep, architecturally designed sections alternate with shallow, semi-natural banks; the line of the bank was modelled to create a slight meander, the riverbed broadened out into coves, and small islands were constructed offshore. Specific parts of the island were lowered to allow for occasional flooding and for succession in the riparian vegetation.

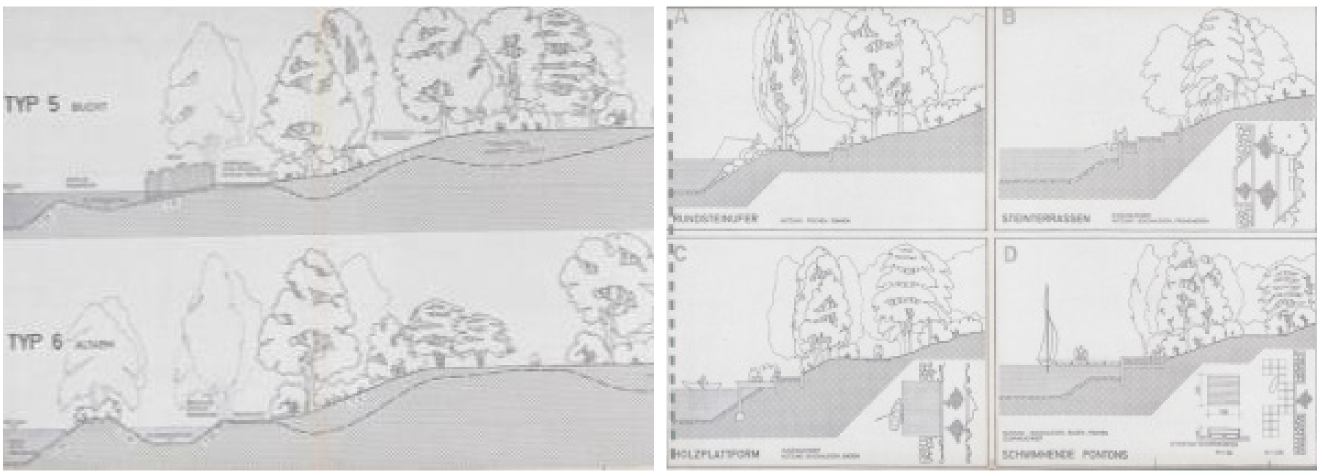
3.3 Planting

The overall planting scheme varies between the semi-natural areas in the northern and southern sections of the island and the urban, park-like character of the middle of the island. At both ends of the island, the density of the planting amounts to 50 to 70 per cent ground coverage; extensively used woodland alternates with spacious meadows. In contrast, the middle is less densely planted; here avenues, single trees, and groups of trees and shrubs predominate. All over the island, the plantings offer open vistas, making it possible to perceive and enjoy the entire extent of the river landscape (Figure 5). During the last five decades, many vistas have become overgrown and need extensive treatment to restore the essential spatial and planting concept.

The landscape architects geared their planting scheme to the vegetal remnants of the Danube floodplain. As the island's stony structure is permeable to water, a specific soil-management plan indicated trenches and berms, where fine-grained material was deposited to create moist and water-retaining habitats. The planting design, which is informed by the ecological understanding of the early 1980s, ranges from reed belt and willow fringe communities on the stony banks, through riparian hornbeam and scrub woodland, to riparian lime woodland above the projected flood line (Hansjakob and Hansjakob, 1980; Knapp, 1984). These extensively designed areas provide new aquatic habitats, where flora and fauna typical of river wetlands have gradually evolved. Nowadays, these semi-natural sections of the island are landscape-protected areas.

3.4 Functional concept and recreational facilities

The functional concept is based on the spatial idea of differentiating the island into an intensely designed middle section resembling an urban park, and extensively designed peripheral sections. The middle section should thus provide an environment of urban recreation. As the operating companies, with their business structures and concepts, were not known during the planning process, the landscape architects created a spatial framework for a recreational landscape,



A B

■ **Figure 4:** Bank typology – steep sections with stone banking, terraces, wooden decks and swimming pontoons (A), and shallow semi-natural banks (B), 1975
Source: WSTLA, Kleine Bestände-Besondere Projekte A44-2 Städtebaulicher Wettbewerb Donauraum 1–54

■ **Figure 5:** View from a bridge across Danube Island to Leopoldsberg – the New Danube is in the foreground, while the Danube River is behind the island and not visible
Source: Grimm-Pretner, 2007

which facilitates a large variety of recreational uses and clearly indicates the focal points for different activities (Domany et al., 1982). In the middle section, two main paths are situated above the high-water mark and form a kind of boulevard with small squares and terraces. These wide, paved paths are connected to towpaths running along the bank line. Today, the middle section of the island and of the New Danube is equipped with playgrounds, sports fields, barbecue equipment, and swimming pontoons. All these facilities are publicly accessible at no charge. Restaurants, small takeaways, and toilets enable visitors to spend a whole day on Danube Island.

The extensively designed sections at the northern and southern end of the island serve as ecological habitats. However, people are invited to use these areas; one main path above the high-water mark and additional towpaths run the length of the island and offer contrasting experiences of active recreation – such as running, walking, cycling, swimming, and boating – and wildlife observation. The functional concept recommended flexible facilities for these remote parts of the island and suggested "central sites for recreational use" with takeaways, toilets, and boat or cycle rentals.

Over the last decades, Danube Island has turned into a riverscape of major recreational and ecological importance for the city. Today, three underground lines link the island and the New Danube with the city centre and zones of new urban densification on both sides of the river.

4 Conclusion

- **Urban riverscape projects need to be innovative**

The invention of the "Vienna Model" was an innovative approach for team work and for decision making. During the long process of planning and realizing a large urban riverscape project, requirements and objectives change, with a variety of forces and actors influencing the project's development over time. A staged approach makes it possible to adapt to changing needs.

- **Urban riverscape projects need a multidisciplinary team**

Engineers, ecologists, landscape architects, urban planners, and architects need to be ambitious and ready to tackle challenges beyond their immediate professional sphere. A part of this is the need to find a common language.

- **Urban riverscape projects need a design framework**

The construction of the island, its banks, infrastructure, and structural plantings determine the form and characteristics of the artificial landscape. This framework should be strong enough to cope with and adapt to changes in demand, use, and management. Thus, later modifications will not change the overall character of the landscape.

- **Urban riverscape projects need to be multifunctional**

Danube Island and its adjacent channel meet the major goals of urban riverscape design – flood protection, ecology, and the accessibility and use of open space. Five heavy floods between 1991 and 2013 have shown that the New Danube can serve its purpose as a crucial flood-detention basin. The intensive use of the open space by a wide range of local residents confirms its relevance for recreational purposes. Multifunctionality can only be achieved in a riverscape by connecting the technical flood-protection project with a landscape architectural project.

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CONTENTS

PLANTS
IN URBAN AREAS AND LANDSCAPE

INTERACTIVE EXPERIMENTAL GARDEN – A PLATFORM FOR LIFELONG LEARNING AND RESEARCH IN INNOVATIVE PLANTING DESIGN

Dagmar Hillová*, Viera Šajbidorová, Ladislav Bakay

Slovak University of Agriculture in Nitra, Slovak Republic

The Interactive Experimental Garden is an educational platform for experiential education, lifelong learning, and self-education in the perennial herbaceous planting design at the Horticulture and Landscape Engineering Faculty of the Slovak University of Agriculture in Nitra. Garden is a "living textbook", which presents the collection of perennials, bulbous plants, annual and biennial plants and their combinations. The garden serves as the platform for investigating an innovative way of acquiring knowledge and experience by carrying out construction and maintenance activities in the garden, as well as research activities in the field of innovative planting design (evaluating of low-cost planting design, flowering phenology monitoring, pollinator species and spontaneously spreading weeds monitoring). The Interactive Experimental Garden is also the platform for discussion in the field of herbaceous planting design for students, experts and the public, and what is more, it increases awareness of innovative planting design.

Keywords: perennial, planting design, pollinators, phenology, lifelong learning

1 Introduction

Rapid urbanization is destroying natural ecosystems and damaging the environmental quality of towns (Alberti and Marzluff, 2004). Climate change, biodiversity loss, environmental degradation and the desire to intensify cohabitation with the nature have all enhanced our interest in the ecological trend of the planting design. The interest of landscape architects focuses on the innovative planting design with:

- the possibility of cost reduction in planning, establishment and maintenance,
- enhancing habitat and food for fauna within extended flowering,
- providing multiple ecosystem services.

The low-cost planting design, for example pictorial meadow or prairie planting requires only annual mowing once established, with no fertilizers or fungicides, and few if any herbicides (Diboll, 2004). The extended flowering meadow and prairie grasses and flowers create high-quality habitats for birds, butterflies, and other wildlife. The self-sustaining plant communities of planting meadow and prairie provide landscape beauty for decades to come and participate in ecological services: temperature reduction, erosion control on slopes and disturbed ground, stream and riverbank stabilization, excess nutrient absorption in wetlands, soil phytoremediation of contaminated soil, or provides food and/or habitat for wildlife (Iuliana, et al., 2011; Seiter, 2016). The deep-rooted forb plants encourage infiltration of rainwater into the soil, thus reducing stormwater runoff and flooding, and can also serve as buffer strips between maintained turf and wetland areas, such as ponds, waterways, and marshes (Diboll, 2004).

The research experience and expertise of innovative planting design must be continuously transformed into lifelong learning and determination for new research. The Interactive Experimental Garden at the Horticulture and Landscape Engineering Faculty of the Slovak University of Agriculture in Nitra has become an educational and research platform for experiential education, lifelong learning, and self-education within the innovative planting design.

The aim of this article is to present the importance of the Interactive Experimental Garden and their website as an opportunity platform for:

- comparison of approaches in the innovative low-cost planting design;

Dagmar Hillová, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Planting Design and Maintenance, Tulipánová 7, Nitra, Slovak Republic
e-mail: dagmar.hillova@uniag.sk; viera.sajbidorova@uniag.sk; ladislav.bakay@uniag.sk

- determination of value of spontaneously spreading weeds for innovative planting design;
- setting revitalization principles (changes in planting plans) in the garden according to phenology and pollinators monitoring.

2 Material and methods

Interactive Experimental Garden – study area

The Interactive Experimental Garden (also garden will be used later in the text) aims to be a "living textbook", which presents the collection of perennials, bulbous plants, annual and biennial plants and their compositions (Šajbidorová and Hillová, 2018). The garden was established within the Cultural and Educational Grant Agency of Ministry of Education, Science, Research and Sport of the Slovak Republic (project registration number 035SPU-4/2016). The aim of the project was to create an area for practical education in the study programs the Landscape and Garden Architecture and Biotechnics of parks and Landscape Arrangements (see Figure 1–3).

Students from various study programmes took part in the project under the professional tutorship of teachers from the Department of Planting Design and Maintenance of the Horticulture and Landscape Engineering Faculty. In the practical courses Landscape Floriculture, Designing in Landscape Floriculture, Production of perennials and bulbous plants, Planting design and maintenance and Budgeting of landscape design and architecture, students got involved in all work duties of a landscape architect, i.e. from drafting

■ **Figure 1:** Site plan of the Interactive Experimental Garden showing the sections of the garden and the connection to the surroundings. IEG 1 – IEG 10 means Interactive Experimental Garden

■ **Figure 2:** Aerial image showing the geometric layout of the garden; June 2019

the project proposal until proper completion and design of the garden covering the total area of 750 m^2 including:

- terrain works,
- installation of an original irrigation system,
- construction of flower bed borders from terraced panels,
- construction of gravel footways (40 m^3 of macadam),
- placing of soil into flower beds (170 m^3 of compost soil),
- planting of 7 solitaire trees, 260 pieces of shrubs, 1,330 pieces of perennials and 6,650 pieces of bulbous plants.

The garden was completed between September 2016 and June 2018. Designing the garden served as experimental education for students since its very beginning. Regarding all the experience and abilities they were able to acquire, the whole process was a great contribution to their future profession. After completion, the garden has become an educational platform for various subjects in the study program at the Horticulture and Landscape Engineering Faculty thus ensuring its long-term sustainability.

The Interactive Experimental Garden promotes creative thinking of both students and teachers. It provides the experimental environment for semestrial projects and theses of students dealing with composition principles of the landscape design, production of new plant species and varieties or evaluation of differentiated approaches to planting design and many others. From the pedagogical point of view, the garden enables to apply new forms of creative and experimental education of students in the study programmes of the Horticulture and Landscape Engineering Faculty. The garden is an effective tool for simulating working conditions in an office of a landscape architect.

The Interactive Experimental Garden provides professional background for teachers in the Department of Planting Design and Maintenance. The cooperation between the university, experts and the public through the garden activities has a brand-new dimension now. Official Garden Debates, three times a year, bring possibility to present students, teachers and faculty activities, and provide place for meeting and co-working.

■ **Figure 3:** Aerial image showing the garden segments and the surroundings; November 2018

3 Results and discussion

Research opportunity of the Interactive Experimental Garden

The garden is the platform for investigating an innovative way of acquiring knowledge and experience by carrying out research activities in the field of innovative planting design. The garden creates space for solutions in actual research topics: low-cost planting design, phenology monitoring, pollinators monitoring, and monitoring of spontaneously spreading weeds.

■ Low-cost planting design

One of the experimental approaches in the garden is to determine maintenance requirements in different planting compositions of the garden (IEG 1: Stylized nature: woodland and woodland edge with elements of monocultural drifts, IEG 2: Stylized tallgrass and forb plant communities with monoculture drifts, IEG 3 and 4: Non-formal planting in the style of a pictorial meadow – blue and yellow, IEG 5: Stylized pictorial meadow – white and green, IEG 6, 7 and 8: Stylized pictorial meadow – red and purple and IEG 9 and 10: Traditional herbaceous border planting in blocks with random dispersion). Additional information about the herbaceous planting composition in the Interactive Experimental Garden is available on website www.interaktivnazahrada.sk/en.

The second goal is an adjustment of the above planting composition to the low-cost planting design, considering also principles for herbaceous planting in dry conditions (Hillová, 2016; Hillová et al., 2016; Šajbidorová et al., 2019). This determination serves to state the "ecological value" of each planting composition in the garden, that means how it significantly impacts the environment – amount and frequency of irrigation, mulching, fertilization and other maintenance interventions as well as hiding and feeding opportunity for insects, reptiles, amphibians and small mammals.

Spontaneously spreading weeds monitoring

Experiences with spontaneously spreading weeds in planned planting and their potential further ornamental use is often perceived as a treat of planted design by experts and laymen. Despite the fact, some of spontaneously spreading weeds exhibit a kind of beauty which is ´authentic´ and can remind residents of the memory or history in a site and demonstrate the changing dynamic for the naturally proceeding succession (Dunnett, 2004; Kuhn, 2006). Planning the multi-layer planting (Rainer and West, 2015) is a design approach by which we can control weeds with dense planting of the functional ground cover layer. Weeds that cover the soil early in the spring, do not restrict deliberately planted plants in growth, and do not interfere in higher design layers may by accepted as potential settlers.

Specifying and monitoring features of spontaneous spreading weeds with potential further ornamental use in ecological approach of multi-layered planting design is one of the research goals in the Interactive Experimental Garden. Selected taxa of spontaneously spreading weeds, which belong to three groups:

1. fill gaps before engaging space with later sprouting, but purposely planted perennials,
2. are later dormant or do not tend to climb or grow over purposely planted perennials in height,
3. reduce the occurrence of weeds growing in/over design layers, were monitored.

The spontaneous vegetation can enhance biodiversity and establish oases for habitats, wildlife, and people. Inventory and survey of existing vegetation of a site is the first step of designing innovative low maintenance communities. Essentially, there are four ways of dealing with existing (spontaneous) vegetation:

- maintaining the current state (status quo) through appropriate measures (for example, maintaining a meadow by mowing);
- allowing succession to proceed naturally (no intervention takes place: a new kind of wilderness will be created);
- effecting changes in succession through interventions (for example, creating an open grove-like effect by removing branches and shrubs in a mature stand);
- improving of the aesthetic value by changing the species composition (Kühn, 2006).

The spontaneously spreading weeds in the Interactive Experimental Garden without threatening impact on the surrounding planting were *Prunella vulgaris* L., *Ficaria verna* Huds., *Fragaria vesca* L. and partially *Glechoma hederacea* L.

Phenology monitoring – timing and abundance of flowering

Knowledge about the onset of aesthetically significant phenophases as well as knowledge of the local succession of usual vegetation cycles in larger groups of plants is increasingly important for the use of plants in landscaping (Bulíř, 2011). Flowering of perennials is the most important aspect when talking about the herbaceous planting design. The aim of this part of research is to evaluate the phenology of perennials – timing and abundance. The beginning of flowering was determined by the opening of the first flower in monitored specimens. Full flowering of a plant is when 50% or more of the flowers in a plant open. The end of flowering is when less than 50% of the flowers are flowering and the majority of flowers show signs of decay. In our study we used the methodology of Leverenz (2006). The most important data is the total sum of days of full flowering.

Phenology monitoring in the garden starts on 15th February with the first flowering plant, *Galanthus elwesii*. The monitoring has been done three times a week during the whole season and it has still not been over (in October). During phenology monitoring changes in the beginning of flowering in the same taxa at different light condition in the garden were observed (the beginning of flowering of *Rudbeckia fulgida* in the IEG 9 starts on 3th June compared to the same taxa in IEG 10 with more shade starts on 12th June).

The focus on high seasonal dynamics of plants composition and wide offer for insect, when designing herbaceous composition, is necessary.

Pollinators monitoring

Monitoring of pollinators is carried out with the main focus on species from the families *Apidae* and *Syrphidae*. Species composition and feeding preference of pollinators in the Interactive Experimental Garden were evaluated. Wild bees are well known pollinators and there is plenty of information about their distribution and feeding preferences. Hoverflies (Diptera: *Syrphidae*) are among the most important pollinators, although they attract less attention than bees. They are usually thought to be rather opportunistic flower visitors, although previous studies demonstrated that they show colour preferences and their nectar feeding is affected by morphological constraints related to flower morphology. Despite the growing appreciation of hoverflies and other non-bee insects as pollinators, there is a lack of community-wide studies of flower visitation by syrphids (Klecka et al., 2018).

Appearance of wide range of pollinators with different feeding preferences is possible to increase by high diversity of plants composition.

The selection of research topics and research solutions is an integral part of education at the Horticulture and Landscape Engineering Faculty of the Slovak University of Agriculture in Nitra.

Experiential education opportunity of the Interactive Experimental Garden

The Interactive Experimental Garden provides the experimental environment in the field of the herbaceous planting design at the Horticulture and Landscape Engineering Faculty, applying new forms of creative and experiential education.

Experiential learning can be defined as studying by experience or by performing an activity (learning by doing) (Lewis and Williams, 1994). The first theories about experiential learning date back to the 19th century when the main goal was to enrich conventional learning methods. This learning method is based upon the principle of interdisciplinary and constructive education. A constructive principle means that the outcomes of the educational processes are variable and often unpredictable, and students are in the role of critics of their own learning processes. The way one student can solve a problem differs from another one. The experience or knowledge from experiential education may vary considerably within one group of students (Wurdinger, 2005). Thanks to experiential learning (e.g. a practical educational project), participants create their own knowledge through active learning in the framework of interactions with their teachers and classmates or teammates (Frank et al., 2003). A teacher plays the role of a students´ tutor and teaches them how to study. A teacher does not play the role of "a provider of knowledge or facts", he/she is rather a mentor, a facilitator, an assistant or an intermediary in education. From the students´ viewpoint, experiential education brings various advantages such as: gaining presentation skills, improved reasoning, better learning abilities, increased motivation, self-confidence and student´s independence (Orevi and Danon, 1999). In the course of experiential education, students acquire in-depth comprehension of content and processes, adopt new team-working skills or learn to work with people with different backgrounds, attitudes and qualifications in order to solve problems jointly and mutually (sharing opinions for the purpose of finding answers to questions).

Student´s participation in the project of the Interactive Experimental Garden had a positive impact on acquiring new skills and abilities. The Interactive Experimental Garden has become an original educational tool. Real participation of students in projecting and performing the complete landscape works has turned a traditional approach to education into an experiential and interactive form, bringing new competences of a student and a teacher. A web questionnaire was used to collect the opinions of students with the aim to confirm positive impacts on their acquiring of new skills and abilities. The respondents were sent the questionnaire online. They had to answer 10 open and multiple-choice questions. In total, 82 students were included from the bachelor´s study program Landscape and Garden Architecture and of the engineer´s study program Landscape and Garden Architecture and Biotechnics of Parks and Landscape Arrangements at the Horticulture and Landscape Engineering Faculty at the Slovak University of Agriculture in Nitra. The feedback provided by the online questionnaire was 27%, i.e. 22 students from 82 in total. However, the informative value of the research sufficed. The average feedback of the answers is 33% compared to paper-based questionnaires with the feedback rate of appr. 56% (Nulty, 2008). The outcomes of the questionnaire survey have proved practical contributions of experimental education to the study and the profession of a landscape architect.

The respondents who built the garden appreciated having acquired practical skills and experience motivating them in the work or in further studies at the faculty. Other benefits regarded by the students were development of managerial skills, team-working abilities, sharing joint experience between teachers and students and new viewpoints of the relationship between them. Students' views indicate positive acceptance of the Interactive Experimental Garden in the university educational process.

After completion, the garden has become an educational platform for various subjects in the study program at the Horticulture and Landscape Engineering Faculty, thus ensuring its long-term sustainability. As for the subject of Landscape floriculture, students may apply the knowledge as a textbook of morphological, habitual, growing, ecological and aesthetic features of plants. Observing and evaluations of plant combinations, perceiving seasonal dynamicity of plants as well as assessing maintenance management and the process of planting reconstruction is the core of the subject of Designing in Landscape floriculture. In the subject of Landscape design and maintenance, students may acquire skills in maintenance of woody plants, construction of irrigation systems or methods of flower bed mulching. At the same time the garden will provide an opportunity for allocating proper deadlines and financial costs of completion and maintenance of flower beds in the subject of Budgeting of landscape design.

Social and cultural opportunities of the Interactive Experimental Garden

The Interactive Experimental Garden is the platform for discussions in the field of herbaceous planting design for the public and experts and has an impact on awareness increasing of planting design and on the faculty ranking between experts and public.

Thematic trainings and events in the garden aim at:

- showing attractive faculty education area to the public and foreign visits to the faculty,
- offering workshops and courses to the public,
- being professional partner to experts.
- The students of the course Design in Landscape Floriculture participated in guided tours in the garden and thematic lectures during
- spring debates on bulbs,
- the 11th edition of the Open Park and Garden Weekend Event in summer, with debates on Perennials Seasonal Dynamics,
- autumn debates on designing flower beds.

4 Conclusion

The Interactive Experimental Garden set up an innovative experiential learning approach in bachelor and master study programs Landscape and Garden Architecture and Biotechnics of Park and Landscape arrangements. The students participating on several practical courses gain:

- working experience within installation and subsequent maintenance of the garden;
- creative mindset due to participating in looking for and selection of solutions to problems or research topics (evaluations of low-cost planting designs, monitoring flowering phenology, pollinator species and spontaneously spreading weeds);
- communication skills within organizational and professional support of thematic trainings and events in the garden.

The garden has created the brainstorming and communication platform allowing exchange of skills, knowledge and ideas between different professions, generations, experts and the public since its inception.

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CONTENTS

PLANTS
IN URBAN AREAS AND LANDSCAPE

ADVANCED TREES ASSESSMENT TECHNIQUES – POSSIBILITIES AND LIMITATIONS

Marzena Suchocka

Warsaw University of Live Sciences, Warsaw, Poland

It is the responsibility of land managers to ensure safety of users. This obligation also applies to public administrators responsible for urban forests. People professionally dealing with trees have often conflicting opinions about the use of modern technology for responsible safety recommendations. Knowledge of its applicability is crucial especially for making decisions about mature, ancient and veteran trees. The most popular devices have their strengths and weaknesses. The ability to use it without proper interpretation of the obtained results may lead to wrong conclusions and thus the decisions made. The work was based on analyses of the applicability of selected methods and was supported by two case study examples from practice. The use of diagnostic equipment has been discussed. Instrumental diagnosis supports the correct assessment of trees, but requires a sufficient knowledge and experience in selection of the needed information and interpretation of obtained results.

Keywords: risk assessment, Visual Tree Assessment, Resistograph, Tomograpf, Pulling test (SIM), Dyna Root

1 Introduction

For the purposes of the VTA method, a number of tests were carried out to determine the thresholds for the dangerous loss of mechanical strength of the trunk (Niklas 1992). In connection to the above, more complex equipment and software are used in the diagnostics of trees as a support for safety recommendation (Hayes, 2002). The characteristics of the most frequently used equipment and limitations are presented below.

One of the most popular devices is a tomograph, which allows the assessment of the location and extent of defects in a trunk (Chomicz, 2007; Nicolotti and Miglietta, 1998). Acoustic tomography is a test that uses sound waves to obtain a digital map of wood density (tomogram) in living trees. Similarly, ultrasonic tomography allows reconstructing the structure of the trunk by the distribution of the velocity of ultrasonic propagation within the investigated section even in early stages of wood degradation (Bucur, 1985; Wilcox, 1988; Bauer et al., 1991). In research, a decay characterized by a mass loss of only 15% was clearly detected (Nicolotti et al., 2003). In all cases, computer simulation allows the image of the interior of the tree to be obtained. Moreover, depending on the speed of sound or ultrasonic velocity passing through wood, it is possible to determine the internal structure of the trunk without the necessity to disturb the sound wood (Chomicz, 2007; Nicolotti and Miglietta, 1998). The sensors should be inserted into the bark of a tree so that they reach wood. Then, the test is carried out by striking the sensors several times with a hammer (Arborsonic 3D: User's Manual, 2017). Electric tomography allows the user to obtain an image of the resistivity distribution on a section of a tree (Shortle, 1982).

The result of the test is a tomogram – a graphical representation of the measurement result. It presents the internal structure of the trunk and allows determining the degree of wood distribution at a given height (Chomicz, 2007). ArborSonic 3D software has the ability to calculate the probability of breaking a tree in the trunk (safety factor) at the place of measurement. The program calculates the safety factor for each trunk cross-section examined and shows which winds are most dangerous for the stability of a given tree. The safety factor in acoustic tomography is calculated as a percentage. Higher percentage means lower risk. Above 150% the risk of fracture is low, between 100% and 150% the risk is medium, and between 100%

Marzena Suchocka, Warsaw University of Live Sciences, Landscape Architecture Department, Nowoursynowska 161, 02-787, Warsaw, Poland
e-mail: marzena.suchocka@interia.pl

and 50% the risk is high, and below 50% the threat is extreme (Arborsonic 3D: User's Manual, 2017).

The standard device used in the VTA procedure is a resistograph (Denise and Jacobi, 2002). Measurements consist in measuring the resistance created during drilling; the data is then generated giving the picture on the real scale. The resistor allows us to study the degree of wood degradation inside a tree trunk. Data from the resistograph are developed in specialized software and, combined with knowledge about the CODIT model, allow for an accurate interpretation of the degree of wood distribution, location and distribution range as well as the presence or absence of a compartment barrier (Johnstone et al., 2002; Shigo, 1979). In the case of the decayed area, characterized by a low mass loss, the result was less accurately detected (Nicolotti et al., 2003).

Another popular method is the integrated measurement of statics, called SIM (Static Integrated Measurement), and popularly called Elasto-Inclino, too. The method was patented in 1989 by Wessolly, and is considered a group of non-invasive methods. It determines the stability of a tree in the ground and the strength of a tree trunk to break. The basis of this method is subjecting the tree to a load simulating the effects of winds, however, not exceeding 3% of the hurricane strength. The dataset specifying the static properties of a tree species, also referred to as the Stuttgart Stability Catalog, and the computer program used to interpret the results, are constantly updated (Wessolly and Erb, 1998). SIM uses sensors, and elastometers, dynamometers and inclinometers to assess the mechanical resistance of trees.

The important approach based on the reaction of roots and the slash on the actual wind load is the Dyna ROOT method. The result is the safety coefficient of the examined tree. The method uses the actual wind and on that basis calculates reactions of the tree. The lowest wind speed, which is needed for successful investigation, is 25 km/h (8 m/s) (Divos and Szalai, 2002). The inclinometer measures the degree of deflection of the tree in the clutch part during movement. The software calculates safety factor on the basis of information collected from inclinometer installed close to the ground and anemometer. It is possible to obtain a safety factor calculated on the basis of wind speed and the degree of tree deviation in the ground (Dynaroot..., 2017). When the safety factor is above 1.5, the safety level is high, between 1 and 1.5 – medium, below 1 – low (Dynaroot..., 2017).

The above presented set of devices potentially gives information allowing for safety recommendation formulation. The question is wheter all methods should be used for that reason or not – which method is highly recommended to solve problem of risk in particular situations. The aim of the study is to demonstrate the tree risk assessment specificity in the context of specialized equipment use on the example of two case studies.

2 Material and methods

In the risk assessment, the most important issue is correct and incorrect interpretation of obtained data. The paper demonstrates the validity of using advanced tools and diagnostic methods for tree risk assessment, in relation to real cases of trees. The use of devices such as: resistograph, tomograph, Integrated Static Integrated Measurement (SIM) – pulling test and DynaRoot system is discussed.

In the study there were used twelve sensors ArborSonic 3D equipment from Fakopp Bt, and Picus.

Moreover, the Elasto method was used which examines the resistance of trunks to fracture, and the Inclino method testing tree stability in the ground. Then, the following parameters were determined: Sg – basic strength, Sb – current breaking strength and Sk – stability of the tree in the ground.

The DynaRoot test consisting of an anemometer and an inclinometer was used to determine the dynamic stability of roots. Using the anemometer, measurements of wind speed and its direction were made. In order for the measurement to be correct and the results reliable, the device was located 10 meters above the ground and in the vicinity of examined trees (no more than 1.5 kilometers).

Before final safety recommendation formulation, analyses of tree specifics was made to determine the optimal set of instrumental methods needed to obtain reasonable results.

3 Results and discussion

3.1 Assessment of the usefulness of instrumental methods

In the paper, limitations and suitability were analysed for risk assessment purposes.

Resistograph is a fast method and gives the basis for monitoring the statics of trees. The method presents results (dendrogram with line presenting integrity of trunks) on a real scale. The hole created by the drill is sealed with packed chips. It has been proved that due to the elevated temperature prevailing during drilling, it is not possible to transfer the pathogen (e.g. hyphae of a parasitic fungus) to other trees (Schwarze et al., 1997; Kersten and Schwarze, 2008). In the immediate vicinity of the wounds, discoloration was observed, but it is assumed that it was probably caused by disturbances of water and oxygen movement. No fungal infection was found caused by the resistograph examination (Kersten and Schwarze, 2008).

Acoustic tomography, using ArborSonic 3D, presents accuracy of results of about 84%. This test has its limitations, e.g. cannot be used in the presence of large metal components integrated with the trunk. As was reported in a field work, small trunk diameter (below 40 cm) and ambient temperature below zero are a contraindication to the test – such results are misleading. The test shows the location and size of cavities and decay without disturbing and destroying living wood (Ostrovský et al., 2017). However, decay and cracks in trunks, the two defects of various significance for loss of stability, are presented as a cavity. Moreover, the tomogram may indicate that cavity is bigger than in reality (Ostrovský et al., 2017; Chomicz, 2007; Wang and Bruce, 2008; Smiley and Freadrich, 2004).

Another approach is to determine the root dynamic stability by Dyna Root or static pulling test. In the classical pulling test the necessary force should cause the same pressure on the crown of the tree as the wind with a speed of 118 km/h (33 m/s) and is obtained by pulling the rope attached to the trunk. A 10–40 kN force is required to perform the static load test. The static load test needs a heavy anchor point, e.g. a different tree or a heavy car. The Dyna Root test needs to be accompanied with 10 m high pole with anemometer on the top, no further than 1.65 km from the checked tree. Both methods, however, use very accurate inclinometers (Wang and Bruce, 2004).

The result of the test is the reaction of the entire tree to load. The Dyna Root method reflects the fact that the entire tree is examined in its natural surroundings. The safety factor is calculated based on the wind speed and the degree of tree deviation at the top. The use of natural wind eliminates the need for height adjustment of arborist ropes during the test. However, a wind speed of at least 25 km/h (8 m/s) is needed, which occurs on average once a week, and requires dependence from weather forecasts. Labeling requires more time to do it properly, although testing alone is easier than the classical pulling test. The disadvantage of the method is that it needs several hours of wind at the right speed to complete the test. Insufficient investigation produces unreliable results.

Coming back to the question which method is the best it seems that the essence of the matter is the solution of the problem or diagnosis of the risk assessment or condition of the tree. In the case of old trees, determining the degree of risk may require the use of several methods, adapted to the existing situation and the tree structure. The cases analysed in order to better understand the decision process are given below.

■ **Figure 1:** Two codominant stems of a large *Quercus robur*
Source: Suchocka 2019

Case study 1

For example, the oak (*Quercus robur*) in Figure 1 grows on the area of a private garden. The tree has two codominant trunks with bark included, connection of trunks is 2 m high (Figure 1). The use of the tomograph will not deliver reasonable data, because of the trunk construction – codominant trunks with a bark included – the result will be unreliable (the bark included, similarly like a crack causes that tomography will detect an excessive cavity inside the trunk, that does not exist in reality). Moreover, the trunk is partly connected with the metal fence – wood grows through metal pieces. In this case it is not possible to apply a test like the pulling test or tomograph. The only effective device in this case is resistograph – the result of the examination is the thickness of the sound wood wall. Moreover, that approach allows the monitoring of the tree. Repetition of the test in the next year or in two years will show whether the wall thickness decreases or increases, and allows diagnosis and decision regarding the range of treatments and future safety decisions concerning the investigated tree.

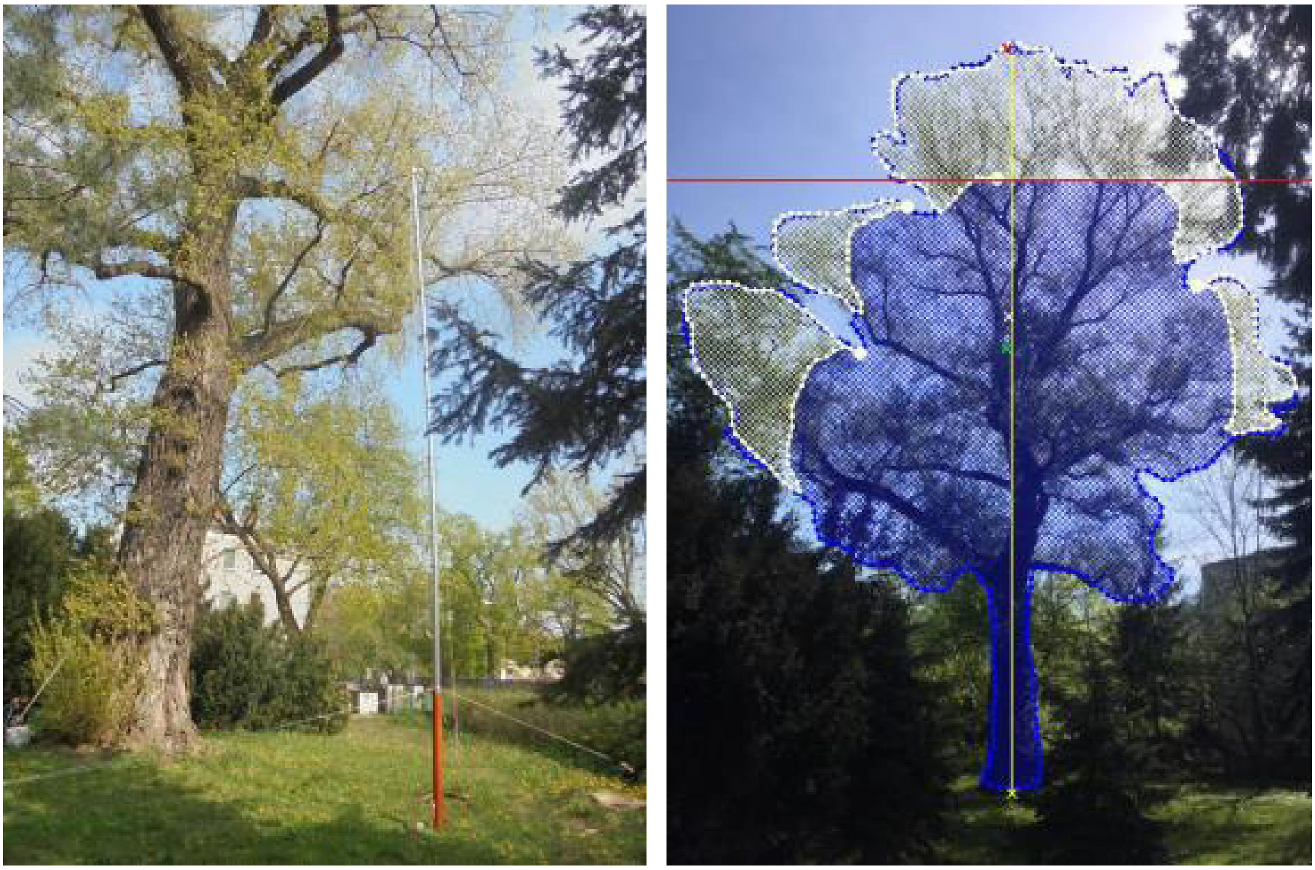
Case study 2

The next tree is a poplar (*Populus nigra*), in which the formulation of recommendations required testing by devices like tomograph, the Dyna Root study, the pulling test and investigation of the buttresses with a resistograph.

The tomography scan was performed at the height of 2 m, a test on the lower level failed due to deep empty spaces between buttresses in the trunk collar and lack of contact between the sensors. At the height of 2 m, the study showed a trunk cavity and caries of 78%. The calculated safety factor was 758%, which gives a low risk of breaking the trunk at the tested height.

The Dyna-ROOT study was performed on three sides – sensors were installed in the root collar from the west, north and east (Figure 2A). The study showed a low risk of falling from the west (safety factor 1.54), moderate risk from the east (1.06) and high risk from the north (0.9). To verify these results, the pulling test was performed. This complementary investigation indicated that in the present state the tree has insufficient value of safety factors, both for breaking and for stability in the ground. The stability factor in soil *Sk* = 1.1 is less than the required value equal to 1.5. The safety factor for a fracture (*Sb*) is 0.9 and its value is also insufficient. The values of safety factors for individual measuring points (measuring instruments) are shown in Table 1. The lowest, insufficient test results are marked in red.

In order to improve the tree's safety parameters, the program indicated the necessity of 40% reduction of its crown in the range shown in the picture below (Figure



A B

■ **Figure 2:** Dyna-ROOT test – visible anemometer (A) and simulation of crown reduction as a result of the pulling test software recommendation (B)

Table 1 Results from the Elasto-inclino test sensors

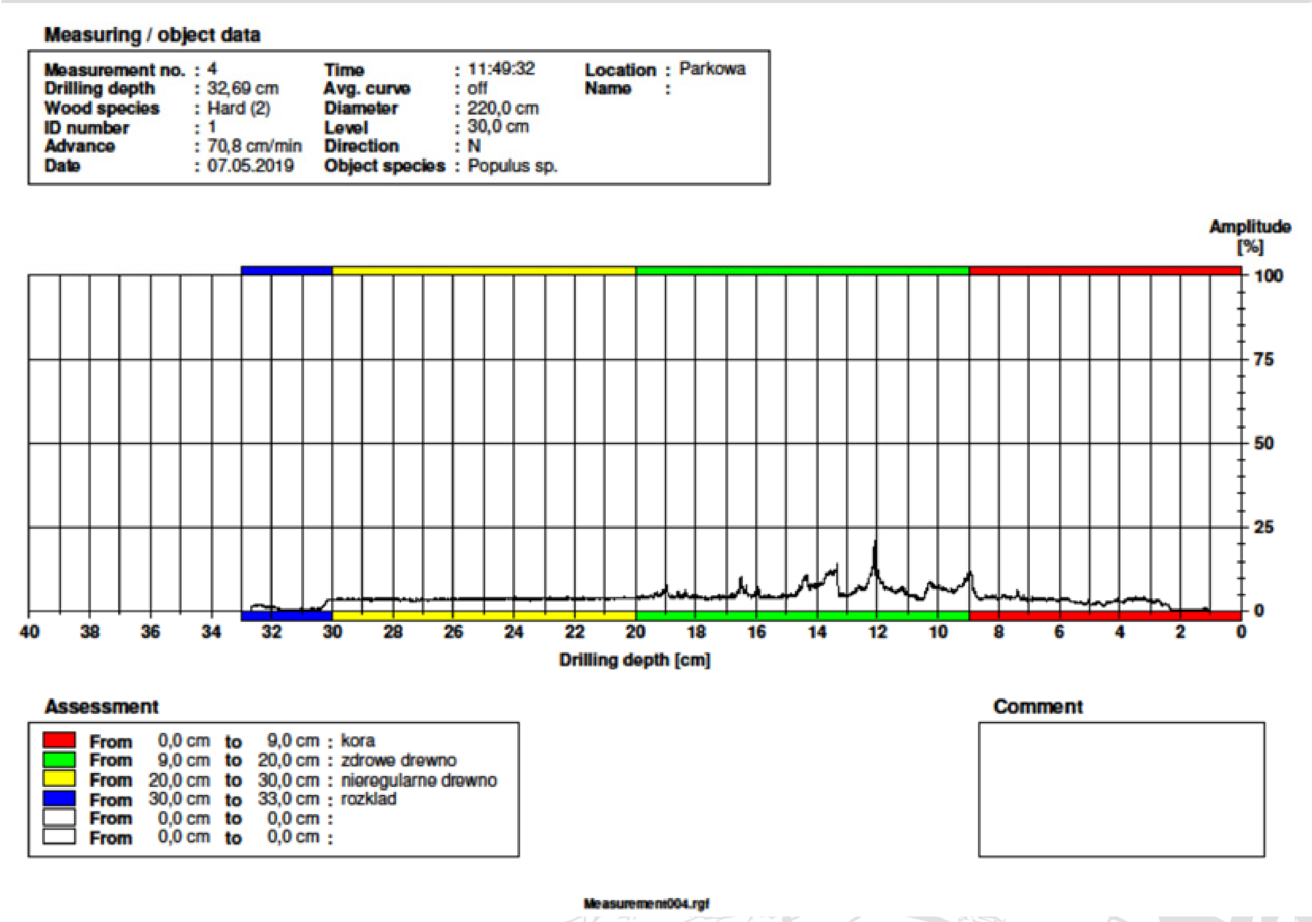
Number of the device	Safety factor
Inclinometer I 1	5.3
Inclinometer I 2	1.1
Elastometer S 1	0.9
Elastometer S 2	1.5
Elastometer S 3	5.2

Source: author's calculations

Table 2 Recomendation for the tree crown reduction

	Before reduction	After reduction
Tree height	34 m	28 m
Crown area	461 m^2	322 m^2
Height of the central point of the crown	20.3 m	17.8 m
Height of the central wind pressure point	21.8 m	19.1 m
Force of wind pressure on the crown	85kN	55 kN
Moment acting on the base of the trunk	1,858 kNm	1,054 kNm

Source: author's calculations



■ **Figure 3:** Drill 4 North-up test – the weakest result from 8 tree buttresses
Source: author's calculations

2B). This procedure would increase the value of safety parameters to *Sb* = 1.6 and *Sk* = 1.9, but such a large intervention would cause the destruction of the tree.

Due to the inconclusive results of both load tests suggesting risk of root collar failure and fear of destroying a valuable tree by excessive cuts to improve the statics, a resistograph was performed on all 6 buttresses of the tree. The study showed the presence of sound wood without decomposition from the east and north-east (more than 35 and 33 cm of sound wood wall) and 22 cm of remote wood on the second on the east side.

The study of both buttresses (No. 5 and 6) from the west also did not show caries over the entire length of the measurement (38 cm). Only one of the six tested buttresses – from the north (Figure 3) showed traces of weakness – 11 cm of healthy wood and 10 cm of irregular wood. The positive results obtained in the root collar resulted in the recommendation of retrenchment cutting to remodel the crown of the tree (a natural reduction of its centre of gravity), which is still possible, and its regular monitoring.

Risks in urban areas cannot be accepted; on the other hand, valuable trees cannot be cut based on incorrect results, therefore, the methods described above are used in practice for comprehensive assessment of trees that may pose a risk. The study of Wang and Allison (2007) demonstrated that the representation of a lateral crack inside of investigated oaks provided by the tomography was similar to cavity inside the trunk and in that case resistance microdrilling tests made the result of the test realistic. The difference between decayed wood and crack-induced acoustic shadows was not a representation of the internal condition, which is crucial for appropriate failure risk classification. Similar conclusions come from the conducted studies. To reduce the number of necessary tests, the assessment should be carried out by a competent person with relevant experience (Suchocka et al., 2019). In case of difficult trees all methods could be recommended to get relevant results of investigation. The proper set of devices for tree risk assessment depends on the situation. For example, the SIM method, due to the multifaceted nature of the information received, seems to be a very good tool, but as shown above, the results of the survey may require verification in order to make a responsible decision. A test with a resistograph or a CT scanner may be insufficient to obtain complete information of tree stability. Studies report that tomography is able to point accurately revealed general location and magnitude of defects, but often in tree investigation, drilling is required to locate the defects and differentiate between decayed wood and crack-induced acoustic shadows (e.g. Wang and Allison 2007). In some cases more testing could be needed, such as results obtained during the pulling test (performed in windless weather) or the Dyna ROOT, which in turn must be done with the right wind. The decision about the way of investigation should be taken after a careful inspection of a tree.

4 Conclusion

Each tree presents a different phytostatic situation and therefore, requires an individual approach. It is not possible to adopt the only proper procedure, the application of which will provide enough information to make a decision in terms of risk mitigation.

The selection of the right method depends on the experience of the person conducting the study, aware of the limitations that are associated with each of them in terms of data interpretation by the device, and limitations associated with the construction of the tree. An example of limitation is CT examination that shows a general picture of the distribution within the trunk, but in case of cracks or bark included the distribution of cavity it is incorrectly shown. In case of result interpretation doubts there can be used a resistograph that demonstrates the sound wood thickness and allows for monitoring of the cavity. The ability to precisely check the wall thickness of healthy wood using a resistograph is crucial for the monitoring of the tree risk.

Each tree presents a different phytostatic situation and therefore, requires an individual approach of an expert. The only correct procedure in the field of testing with use of specialist equipment cannot be assumed in advance. Visual investigation leads to a decision on the selection of a proper device to provide enough information to make a risk mitigation decision.

For many trees, visual assessment is sufficient for risk assessment. However, valuable and at the same time difficult trees (e.g. ancient or aged trees) may require the use of many methods, or even all available ones, that allows us to take reasonable decisions and monitoring, resulting in their preservation for a long period of time, without incurring unnecessary risk by the assessor.

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CONTENTS

PLANTS
IN URBAN AREAS AND LANDSCAPE

ASSESSMENT OF THE RECREATIONAL POTENTIAL OF SELECTED POLISH AND SLOVAK TOWNS DUE TO THEIR NATURAL VALUES

Beata Fornal-Pieniak[1]*, Maria Bihunova[2], Ewa Zaraś-Januszkiewicz[1]

[1]Warsaw University of Life Sciences, Warsaw, Poland
[2]Slovak University of Agriculture in Nitra, Slovak Republic

There are many research methods used in landscape evaluation, but attention should be paid to the fact that most of them concern non-urbanized areas. There is a lack of many elements closely integrated with urban space, in particular concerning the recreational potential of open urban green areas. The goal of the project is: to present the methodical approach to natural assessment of selected Polish and Slovak towns and to formulate guidelines in the field of landscape design for the recreational aspect. The research will be conducted in Slovak and Polish towns. The landscape structure will be analyzed in three dimensions, i.e. qualitative analysis, quantitative analysis and spatial analysis. The qualitative analysis concerns elements that built the landscape of the studied area, e.g. forest ecosystems, water, arable land, meadows, built-up areas, etc. The quantitative aspect shows the contribution of each type of structural elements in the total area. On the basis of spatial-landscape units, landscape assessment will be made, taking into account natural elements. In order to assess the quality of landscape, a list containing all relevant assessment criteria and their possible bonitation results from 3 points to 1 point was compiled. In the next stage of research there will be distinguished areas with very high natural values, areas with high natural values, areas with medium natural values, and areas with low values.

Keywords: natural evaluation, vegetation, recreation, Nitra, Brzesko, towns

1 Introduction

Natural evaluation is a very important method for analysis of landscape values (Kil and Kowalczyk, 2011; Łukowiak et al., 2017). There are many landscape evaluation methods such as: Bajerowski's value matrix method, Janecki's straight lines method (Janecki 1981), Wojciechowski method (1986), Gacka-Grześkiewicz et al. method (1994), Żarska method (2014). It is necessary to collect much information about nature before the landscape evaluation (Litwin et al., 2009). Landscapes are much diversified, so sometimes it is needed to do modifications of two or three evaluation methods. After that, it is possible to achieve good results with valuable information about values of the studied areas (Litwin et al., 2009). Most of evaluation methods are based on bonitation points consisting in assigning point values to individual elements. However, the very important criterion for choosing a particular method of landscape evaluation is the aim of this assessment (Bajerowski, 2001; Myga-Piątek, 2007; Żarska, 2014). The application of this method may be the basis for determining the valuable natural resources of Polish and Slovak municipalities. Application of this evaluation method may be helpful in defining future directions of development recreation services of urban municipalities, as well as being a determinant of a new trend in spatial landscape planning. Proper management of systems of green areas, including legally protected sites, gives a real chance to keep relatively high biological diversity in towns. Birds are a good bioindicator of whether environmental conditions in urbanized areas are good for human population (Shanahan et al., 2011; Threlfall et al., 2016). These towns will also be more attractive for users, including the recreational aspect. It is necessary to add that the "green infrastructure" concept has emerged in the USA in the end of the 20th century and concerned mainly good environmental life conditions for humans (Benedict and McMachon, 2006), later used in Europe. Today, you can no longer afford town planning without a system of natural areas, without pro-ecological space and solutions. Many researches give evidence that the increase of green areas in the total area of towns

Beata Fornal-Pieniak, Warsaw University of Life Sciences, Institution of Horticulture Sciences, Department of Environmental Protection and Dendrology, Nowoursynowska Str. 166, 02-787 Warsaw, Poland
e-mail: beata_fornal_pieniak@sggw.pl

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influence the improvement of climate conditions, such as decreasing temperatures and increasing the ability to collect rainwater, to a large extent (Gill et al., 2007, Emanuel and Loconsole, 2015). It is really important for the recreational aspect in towns, too.

■ **Figure 1:** Localization of Nitra (Slovakia) and Brzesko (Poland)

The aim of the paper is to present a methodical approach to nature evaluation and recommend changes and improvements regarding the landscape planning for the selected Polish and Slovak towns for the purpose of recreation resources and other landscape features beneficial for inhabitants. It is also vital to compare the urban nature values in the selected Polish and Slovak towns, including the recreational aspect. The nature evaluations were performed in Brzesko and Nitra. The total population is about 11,000 in Brzesko and about 80,000 in Nitra.

2 Methods

The landscape structure was analysed in three important aspects: qualitative analysis, quantitative analysis and spatial analysis (Żarska et al., 2014). The qualitative analysis is concerned with the types of land uses in the areas, e.g. forest ecosystems, water, arable lands, meadows, built-up areas etc. The quantitative aspect shows the share of every type of structural elements in the total area. In this work, diverse types

Table 1 Criteria of assesment with bonitation scale

	Criteria	Bonitation
Diversity of green areas	3 types of green areas	3
	2 types of green areas	2
	1 type of green area	1
Degree of vegetation naturalness	natural vegetation dominated (forests, parks)	3
	semi-natural vegetation dominated (grass vegetations)	2
	synanthropic vegetation dominated	1
Water elements occurring	>75% – cover of spatial-landscape unit	3
	50–75% (cover)	2
	<50% – cover of spatial-landscape unit	1
Active biological surface	>75% – cover of spatial-landscape unit	3
	50–75% – cover of spatial-landscape unit	2
	<50% – cover of spatial-landscape unit	1
Density of built-up areas	intensive density of built-up area	0
	medium density of built-up area	1
	low density of built up area	2
	lack of built-up areas	3
Number of ecological connections	above 4 ecological connections	3
	2–3 ecological connections	2
	1 ecological connection	1
Afforestation areas	>75% cover of spatial-landscape unit	3
	50–75% cover of spatial-landscape unit	2
	<50% cover of spatial-landscape unit	1

Four category of spatial-landscape units (areas) are distinguished: First category (A) from 17 to 21 points – areas with very high natural values, second category (B) from 12–16 points – areas with high natural values, third category (C) from 7 to 11 points – areas with medium natural values and fourth category (D) <6 points – areas with low natural values. The differences between structure and nature values of Nitra and Brzesko were determined of coverage were calculated and estimated with help of maps and the field research, which also presents the spatial layout of the landscape and its elements.

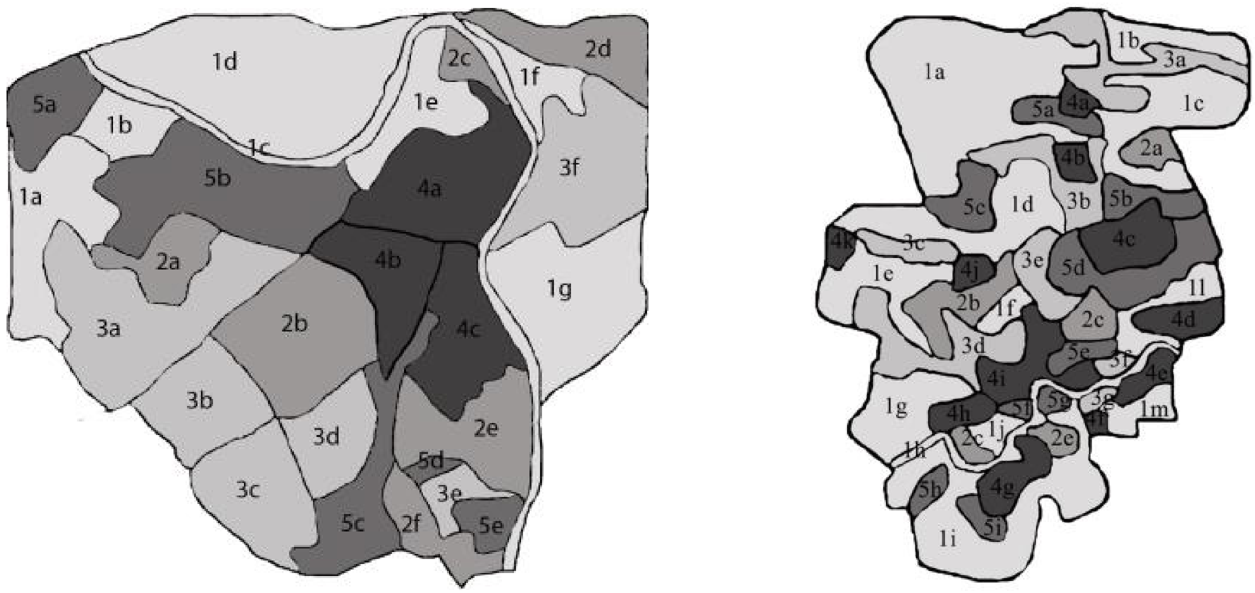
Based on the spatial-landscape units a natural evaluation of landscape was conducted in the next stage of the work. In order to assess the quality of the landscape, a list with all relevant criteria and their possible bonitation scores from 3 to 1 was compiled (Table 1). Every spatial-landscape unit was assessed individually according to this list.

3 Results

According to natural evalution, there were distinguished five types of spatial landscape units in Brzesko and Nitra (Figure 2). The types of spatial landscape units were represented by: areas with dominant natural and semi-natural vegetation, areas with dominant green areas, areas with housing estates and green areas, areas with dominant built up areas, and areas with different types of built up areas with vegetation. Areas with natural and seminatural vegetation and built up areas were dominant in Brzesko. It was observed that areas with natural, seminatural vegetation, different types of green areas and housing estates with green areas were characteristic for Nitra. The total numer of spatial landscape units was 27 for Nitra and 45 for Brzesko (Table 2). Nature evaluation was performed using seven criteria of assesment such as diversity of green areas, degree of naturalness of vegetation, water elements occurring, active biological surface, density of built-up areas, number of ecological connections, and afforestation areas (Table 3). Both towns have potential in the recreational aspect because of valuable vegetation and different types of green areas such as parks, urban forests, and water elements occurring. The evaluation proved that areas with medium natural values were dominant in both towns. There were spatial-landscape units with different density of built up areas and also industrial areas with accompanying vegetation.

Table 2 Categorization of areas in Nitra and Brzesko

Category/town	Nitra (27 spatial-landscape units)	Brzesko (45 spatial-landscape units)
A – areas with very high natural values	3	7
B – areas with high natural values	7	6
C – areas with medium natural values	12	14
D – areas with low natural values	4	11



A B

■ **Figure 2:** Types of spatial-landscape units in Nitra (A) and Brzesko (B) (scheme)
1 (a, b, c…) – spatial-landscape units with dominant natural and semi-natural vegetation; 2 (a, b, c…) – spatial-landscape units with dominant green areas; 3 (a, b, c...) – spatial-landscape units with housing estates and green areas; 4 (a, b, c…) – spatial-landscape units with dominant built up areas; 5 (a, b, c..) – spatial-landscape units with different types of built up areas with vegetation

Table 3 Results of natural evaluation in Nitra (a) and Brzesko (b)

a) Nitra

No of criteria/types of units	1							2						3						4			5				
	a	b	c	d	e	f	g	a	b	c	d	e	f	a	b	c	d	e	f	a	b	c	a	b	c	d	e
I	2	1	2	2	3	2	2	2	3	1	3	3	1	2	1	2	2	1	2	1	1	1	1	1	1	1	1
II	2	2	3	2	3	2	3	2	3	1	3	3	1	2	2	2	2	2	2	1	2	2	1	2	2	1	1
III	1	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IV	2	3	3	3	3	3	3	2	2	3	2	3	3	2	2	2	2	1	2	1	2	1	1	2	1	1	1
V	2	2	3	2	2	3	2	2	1	2	1	2	2	1	1	2	1	1	2	0	0	0	0	1	0	1	0
VI	2	0	3	3	2	2	3	1	2	2	2	3	0	2	0	1	0	1	2	0	1	2	1	1	1	1	3
VII	2	2	1	1	3	3	3	2	3	1	2	2	1	1	1	2	1	1	2	0	1	1	1	2	1	0	1
Sum	13	10	18	13	18	15	17	11	14	10	13	16	8	10	7	11	8	7	12	3	7	7	5	9	6	5	7
Category of natural values	B	C	A	B	A	B	A	C	B	C	B	B	C	C	C	C	C	C	B	D	C	C	D	C	D	D	D

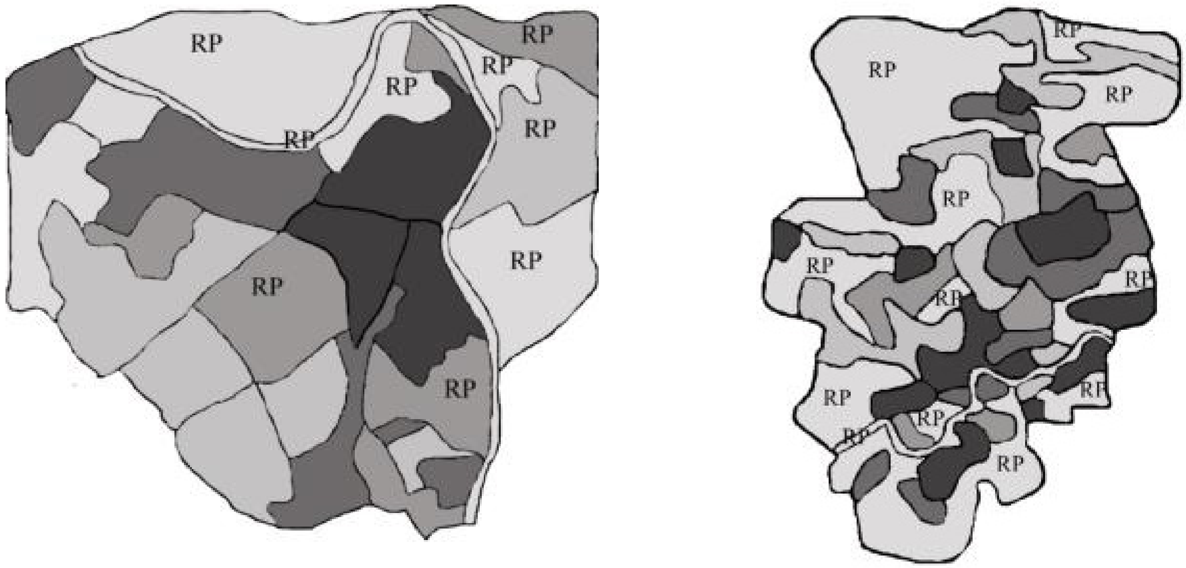
* I – diversity of green areas, II – degree of naturalness of vegetation III – water elements occurring, IV – active biological surface, V – density of built-up areas VI – number of ecological connections VII – size of afforestration areas

b) Brzesko

No of criteria/types of units	1													2				
	a	b	c	d	e	f	g	h	i	j	k	l	m	a	b	c	d	e
I	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	1
II	3	3	2	3	2	2	3	3	2	2	3	2	2	2	2	2	2	2
III	3	0	2	0	0	0	2	0	2	3	0	0	0	0	0	0	0	0
IV	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2
V	3	3	3	3	3	3	3	3	3	3	3	3	3	2	2	2	2	2
VI	2	2	3	2	2	2	2	2	3	2	3	3	3	2	2	2	2	2
VII	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1	1	1
Sum	19	18	16	16	15	15	18	16	18	18	17	16	15	11	11	11	11	10
Category of natural values	A	A	B	B	B	B	A	B	A	A	A	B	A	C	C	C	C	C

No of criteria/types of units	3							4										
	a	b	c	d	e	f	g	a	b	c	d	e	f	g	h	i	j	k
I	2	2	2	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0
II	2	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1
III	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
IV	2	2	2	2	2	2	2	2	2	1	2	1	2	1	1	2	2	2
V	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
VI	2	1	1	1	1	2	2	1	1	1	1	1	1	1	1	1	1	1
VII	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum	9	8	8	10	8	9	9	5	5	4	5	4	5	4	4	5	5	5
Category of natural values	C	C	C	C	C	C	C	D	D	D	D	D	D	D	D	D	D	D

* I – diversity of green areas, II – degree of naturalness of vegetation III – water elements occurring, IV – active biological surface, V – density of built-up areas VI – number of ecological connections VII – size of afforestration areas
Categorization of spatial-landscape units: A – areas with very high natural values (from 17 to 21 points); B – areas with high natural values (from 12 to 16 points); C – areas with medium natural values (from 7 to 11 points); D – areas with low natural values (<6 points)



A – Nitra

B – Brzesko

■ **Figure 3:** Areas with the highest potential for recreation (RP) in Nitra and Brzesko (scheme)
RP – areas with the recreational potential (spatial-landscape units with very high and high natural values)

4 Conclusions

The main benefit of the research for both towns was distinguishing the areas with high potential for recreation using the proper method of nature evaluation (Figure 3).

Benefits for the future: developing a model for shaping the natural system of Slovak and Polish towns for recreational purposes. It is planned to continue these researches in other towns in order to cooperate with local governments of the towns.

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PLANTS
IN URBAN AREAS AND LANDSCAPE

RESPONSE OF STOMATAL CONDUCTANCE OF *ACER CAMPESTRE* L. TO GRADUAL DRYING OF THE SUBSTRATUM

Marcel Raček*, Helena Lichtnerová, Miroslava Záchenská

Slovak University of Agriculture in Nitra, Slovak Republic

The goal of the presented study was to clarify stomatal closure and water content changes in the leaves of *Acer campestre* L. in relation to drying of substratum. We supposed that field maple would preserve water in the leaves by stomatal closure after substratum drought detection. Relative water content in the leaves, water content of the soil and stomatal conductance was measured. Duration of the experiment was forteen days. Three years old plants originating from dry sites of south Slovakia were used in the experiment. According to the obtained results, *A. campestre* L. was able to preserve standard water content in the leaves seven days after water scarcity introduction. Water content in the leaves rapidly decreased after seven days in drought conditions. Stomatal closure was observed after three days in drought conditions. Decrease in stomatal conductance on next days was rapid.

Keywords: *Acer campestre* L., stomatal conductance, relative water content, drought

1 Introduction

Changes of environmental conditions in urban areas restrict the growth of many species (Gillner et al., 2013). Growth and vitality are considerably influenced by microclimatic conditions, especially changes in air humidity and air temperature caused by reradiation effects, higher surface temperatures, and higher winds pells (tunel effects) in streets (Sieghardt et al., 2005; Huang et al., 2008). Lack and irregular distribution of water cause periods of drought. Drought is the most important environmental stress, severely impairing plant growth and development (Anjum et al., 2011). It is known that drought significantly influences photosynthesis by changes in metabolism and regulation of stomatal conductance (Bota et al., 2004). Stomatal responses to changes in environment are assential for the plants acclimation to environmental conditions (Heterington and Woodward, 2003; Berry et al., 2010). Stomatal closure is a protective strategy against waterloss and xylem hydraulic failure (Choat et al., 2007; Chen et al., 2010). In relation to plant strategy of stomatal control used to eliminate consequences of water losses, there are two known types of plants. Isohydric plants under drought conditions close their stomata gradually to reduce gas exchange and waterloss (Kumagai and Porporato, 2012; Sade et al., 2012). Anisohydric plants tolerate a decline in water potential by keeping stomata open to enable continuous gas exchange within certain levels of water stress (Tardieu and Simonneau, 1998). Stomatal closure is generally considered a protective mechanism against drought stress (Tyree et al., 1998).

Stomata have two main functions in plants. They participate in photosynthesis course and optimise water balance. Stomata open after sunrise (when there is light for photosynthesis) and close after sunset (Procházka et al., 1998). Stomata play key role in retaining water in plant. Plants are able create tolerance against water deficit by creation of tolerance to conditions of water deficit or by prevention of water loose (Bray, 2001). Transpiration is related to water content in leaves. Relative water content (*RWC*) indicates metabolic changes in plants. *RWC* represents the total amount of water needed by a plant at full saturation. The *RWC* expresses the water content in per cent at a given time as related to the water content at full turgor (González and González Vilar, 2001). Decrease of the *RWC* is accompanied with changes in physiological functions of plants, synthesis of growth and stock substances and metabolical changes. Relationship between the *RWC*, water content in soil and stomatal conductance could be an indicator of plants reactions to water stress.

Marcel Raček, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Planting Design and Maintenance, Trieda Andreja Hlinku, 2, 949 76, Nitra, Slovakia
e-mail: marcel.racek@uniag.sk

The objective of the presented study was to clarify the interaction between stomatal closure and water content changes in the leaves in relation to dryness of soil substratum. *A. campestre* L, native maple from dry sites of Slovakia, was chosen as the subject of the study. We supposed that the relative water content and stomatal closure would be in direct relation and *A. campestre* L. would preserve water in leaves by stomatal closure after detection of water scarcity in the substratum.

2 Materials and methods

Plant material was produced from seeds. The plants were three-years old; a year grown in 2 litres containers. The height of plants was 700–800 mm, with trunk diameter 7–9 mm (measured 150 mm above ground). Donor parent trees were grown in the Arborétum Mlyňany in southern Slovakia. TS 3 standard substratum (pH 5.5 to 6.0 + fertilizer 1 kg/m^3) enriched by clay fraction (0–25 mm/m clay 20 kg/m^3) with 10% of additional sand was used. Up to end of June, the humidity of substratum was on the level of 70% of soil water content. From the mid-July (at the beginning of experiments), irrigation was stopped and the process of continual substratum desiccation began. Irrigation was stopped up to the end of the experiment (for next 13 days). Water content in the substratum was 25% in the end of the experiment. During the experiment the plants were stored in a greenhouse, protected from rain and direct sunlight.

Stomatal conductance, as an index of plant stress and indicator of photosynthetic activity, was measured with an AP4 Leaf Porometer. Measurements were taken in three days intervals on two fully expanded leaves of five plants between 7 and 10 a.m. Ten replications were made for each measurement.

During measurements (once in three days) there were defined soil water contents and relative water contents in the leaves. There were used two plants for analyses each weak. Water contents were set gravimetrically. The *RWC* was set as follows:

All leaves per plant were detached to determine their relative water content (*RWC*). After cuttings, the petiole was immediately immersed in distilled water inside of a glass tube, which was immediately sealed. The tubes were then taken to the laboratory where the increased weight of the tubes was used to determine leaf fresh weight (*FW*). After 4h, the leaves were weighed to obtain the turgid weight (*TW*). The dry weight (*DW*) was then measured after oven drying at 80 °C for 48 h, and the *RWC* was calculated as follows: $RWC = 100\,(FW - DW)/TW - DW$. After the end of the experiment, the analysis of variance and the multiple range test were used for data evaluation. The software Statgraphics Centurion XVI was used for statistical evaluation.

3 Results and discussion

Substratum desiccation caused immediate decrease of stomatal conductance in the leaves of *A. campestre* L. Changes in the relative water content (*RWC*) in the leaves were observed after seven days without water. In relation to substratum desiccation, *A. campestre* L. plants reacted by linear decrease of stomatal conductance. After the first days, when water content of the substratum decreased from 70% to 62%, stomatal conductance decreased slowly by 8% (from 0.65 mm/s to 0.57 mm/s). After the next three days, when water content of the substratum decreased on 53%, stomatal conductance decreased by 14% (from 0.57 mm/s to 0.43 mm/s). The decrease in stomatal conductance was observed in all next days. After thirteen days, stomatal conductance decreased to 0.23 mm/s (Table 1).

During the first seven days of the experiment, the observed *RWC* value in the leaves was about 84%. The decrease of the *RWC* was observed after seven days without irrigation when the *RWC* began to change rapidly. The *RWC* decreased to 30.7% at the end of the experiment.

According to the study by Li et al. (2016) *A. campestre* L. belongs to anisohydric plants. It was found to tolerate a declining water potential with a slow reduction of

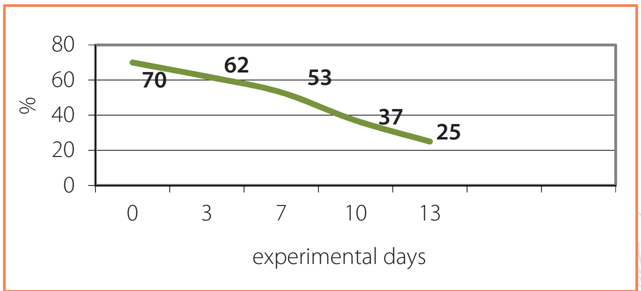
Table 1 Multiple range test of stomatal conductance in *A. campestre* L. leaves under water scarcity (*P* value <0.05) during experiment

Experimental days	Count	Mean	Differences in groups
0	10	0.65	*
3	10	0.57	*
7	10	0.43	*
10	10	0.30	* *
13	10	0.23	*

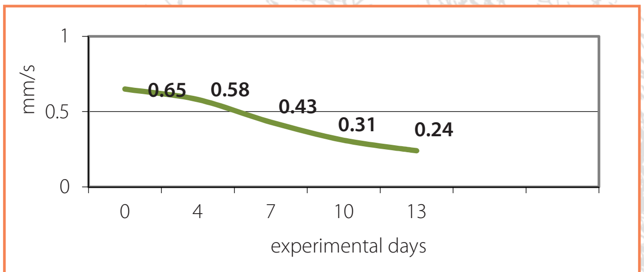
gas exchange. Stomatal closure and leaf turgor were coordinated.

The results show that field maple reacted to the decrease of soil water content by stomatal closure. That reaction indicates sensitivity of species to drought and efforts to minimise water losses in plants during transpiration. There were not observed more significant changes in the *RWC* up to the decrease of soil water content to 53%.

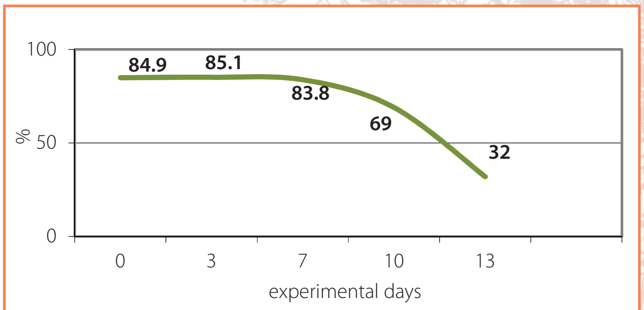
It is known that the rate of the *RWC* in plants with high resistance to drought is higher than in others (Arjenaki et al., 2012). Based on this knowledge and our results we can define *A. campestre* L. as a species with tolerance to drought in the first stages of soil dessication and the soil water content between 55% to 60%.



Decrease of soil water capacity



Decrease of stomatal conductance of *Acer campestre* L. leaves during soil dessication



RWC development in the leaves of *Acer campestre* L. during soil dessication

■ **Figurere 1:** Development of water content in the substratum, stomatal conductance, *RWC* content in the leaves of *A. campestre* L. under conditions of water scarcity

In the first week without water, plants maintained balanced *RWC*. During the second week, the *RWC* dramatically decreased. The *RWC* is closely related to photosynthesis limitation. A border of photosynthesis limitation in relation to the *RWC* could be very variable and reactions of plants are specific due to species differences (Bota et al., 2004; Flexas et al., 2006). Chaves et al. (2002) consider decrease of the *RWC* to 70–75% a limit for photosynthesis. Plants of field maple reached this limit after seven days of drought, and the use of stomatal closure was not more able to preserve water in the leaves.

4 Conclusions

As we supoposed, relative water content and stomatal closure of *A. campestre* were in direct relation. The ecrease of the *RWC* began three days after stomatal closure induction, when the water content in substratum decreased to 53% of soil water capacity.

The preservation of water in the leaves of young plants by stomatal closure after detection of water scarcity in the substratum lasted 7 days. After decrease of water content in substratum under 50% of soil water capacity, the *RWC* decreased dramatically.

Acknowledgement

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CONTENTS

PLANTS
IN URBAN AREAS AND LANDSCAPE

IMPACT OF AIRBORNE SALINITY DEPOSITION ON SHOOT GROWTH AND LEAF PHENOLOGY OF LONDON PLANE (*PLATANUS × HISPANICA* MILL. EX MÜNCHH. 'ACERIFOLIA')

Tatiana Swoczyna*, Jacek Borowski

Warsaw University of Life Sciences, Warszawa, Poland

Street environmental conditions are characterised by heavy pollution which is detrimental for street trees. Especially, application of de-icing salt in streets in Central and Northern Europe causes serious damages of urban trees. Along with salt deposition in soils some amount of de-icing salt is also sprayed in the air and may be deposited on street trees' shoots. The aim of this study was to determine how the close vicinity to roads affects shoot increment and leaf phenology of London plane. Annual shoot elongation and the estimated sum of shoot length (using photographic method) of each 5 trees growing in 4 different streets was measured and leaf phenology was observed in 2008 and 2009. Additionally, the soil salinity and the shoot surface salinity was measured in spring. The results indicate that soil and shoot surface salinity depends on traffic intensity and distance of the road. Trees growing in the close vicinity to the road of low traffic and trees growing 15 m away from the road showed similar pattern in shoot salt deposition. Salt deposition on shoots in trees growing in the close proximity to a road of heavy traffic was three-fold higher. Those trees revealed very late bud swelling and late leaf shedding. Leaf yellowing did not occur, leaves turned brown and dry and were shed in late November. Moreover, trees growing in the close vicinity to the road of heavy traffic were developing late long shoots, but their estimated sum of shoot length did not increase much. This response is expected to be the consequence of buds' injuries caused by salt spray produced in roads of high vehicle speed.

Keywords: de-icing salt, electrical conductivity, salt spray, street trees, urban trees

1 Introduction

Application of de-icing salts, particularly sodium chloride (NaCl), in streets in Central and Northern Europe is a very common and efficient way to keep the appropriate traffic flow in winter. This contributes to salt deposition in street soils and affects trees growing along streets (Equiza, Calvo-Polanco, Cirelli, Señorans, Wartenbe, Saunders and Zwiazek, 2017; Ordóñez-Barona, Sabetski, Millward and Steenberg, 2018). Salt deposition in soils is the highest in the end of winter and diminishes during the growing season (Ordóñez-Barona et al., 2018). On the contrary, salt deposition in trunk, twigs, and leaves increases progressively due to abundant water up-take in the spring for new shoot formation and accompanying Na and Cl ion up-take from the soil (Cekstere, Nikodemus and Osvalde, 2008). Most of scientific papers report leaf injuries such as chlorosis and necrosis as a result of road-side salinity (Gałuszka, Migaszewski, Podlaski, Dołęgowska and Michalik, 2011), lower chlorophyll content (Equiza et al., 2017), disturbed nutrient uptake (Ordóñez-Barona et al., 2018), and decreased photosynthetic apparatus efficiency (Swoczyna, Kalaji, Pietkiewicz, Borowsk, and Zaraś-Januszkiewicz, 2010). Changed leaf anatomy (Hura, Szewczyk-Taranek Hura, Nowak and Pawłowska, 2017), diminished photosynthetic rate (Loreto, Centritto and Chartzoulakis, 2003; Hura et al., 2017) and impeded growth (Patykowski, Kołodziejek and Wala, 2018) were also observed in pot experiments.

Along with salt deposition in soils, some amount of de-icing salt is also sprayed in the air in winter (Majewski, Rogula-Kozłowska, Rozbicka, Rogula-Kopiec, Mathews and Brandyk, 2018; Rogula-Kozłowska, Majewski, Widziewicz, Rogula-Kopiec, Tytła, Mathews and Ciuka-Witrylak, 2019) and may be deposited in roadside trees' shoots (Borowski and Pstrągowska, 2010; Borowski, Pstrągowska and Swoczyna, 2014). Here, the symptoms may be different than those caused by salt up-take from the soil (Borowski et al., 2014) including dieback of shoots and buds formed in the previous

Tatiana Swoczyna, Warsaw University of Life Sciences, Institute of Horticulture Sciences, Department of Environmental Protection and Dendrology, ul. Nowoursynowska 159, 02-776 Warszawa, Poland
e-mail: tatiana_swoczyna@sggw.pl; jacek_borowski@sggw.pl

season (Hofstra and Lumis, 1975), suppression of flowering (Hofstra and Lumis, 1975; Berkheimer and Hanson, 2006), additional buds' emergence, and tree crown deformations (Hofstra, Hall and Lumis, 1979). It was reported that airborne salinity affects foliage of evergreen gymnosperms such as Norway spruce (Zítková, Hegrová and Anděl, 2018) and may affect phenological phases (Paludan-Müller, Saxe, Pedersen and Randrup, 2002).

Street trees play essential role in mitigation of the urban heat island effect (Shashua-Bar and Hoffman, 2000), therefore, their appropriate performance in street habitats is of high importance. Good health conditions enable effective photosynthetic activity. The size of crown volume and leaf biomass are also important due to shading properties (Gillner, Korn and Roloff, 2015). Therefore, numerous researches are engaged in selection of tree species suitable for harsh urban environment. Some studies indicate that London plane is one of the best-performing tree species in urban environment in Central Europe (Dmuchowski and Badurek, 2004; Swoczyna et al., 2010). Since 2002, London plane is often planted in Warsaw as a street tree and is considered to be tolerant to urban drought and soil salinity (Dmuchowski, Baczewska, Gozdowski and Brągoszewska, 2014; Swoczyna, Kalaji, Pietkiewicz and Borowski, 2015)

The aim of this study was to determine:

1. how the magnitude of vehicle traffic and proximity to a road influences salt deposition on street trees' shoots;
2. how the salt contamination of tree crowns affects shoot increment and leaf phenology in London plane.

2 Material and methods

2.1 Plant material and location

The examined London plane trees were planted in 2003 along streets in Warsaw (52° 7′ N–52° 16′ N, 20° 55′ E–21° 2′ E), Poland. The trees were situated in 4 locations with differing proximity to a road. Rodowicza, Dolinka, and Wolska are arterial streets of heavy road traffic (2,748, 6,166 and 4,962 vehicles per hour at the morning rush hour, respectively; source: http://www.zdm.waw.pl/fileadmin/user_upload/informacje/analizy_na_drogach/Analiza_ruchu_na_drogach_2007.pdf, retrieved 2009.02.18) and high vehicle speed, and trees here were planted in the distance of 15, 8, and 3.5 m from roads, respectively. In Podskarbińska, a local street of low traffic (443 vehicles per hour, source: as above) and low car speed, trees were planted in the distance of 2.5–3 m from the road. Rodowicza and Dolinka are situated in peripheral districts, Wolska and Podskarbińska in pericentral ones. All trees grow in lawn strips. Five trees of good health condition in each site were examined.

2.2 Salinity measurements

In July 2008, soil samples at 0–20 cm depth from tree surroundings were taken for laboratory analyses and their electrical conductivity was measured using the CX-551 multifunction meter (ELMETRON Sp.j., Zabrze, Poland).

In the end of March 2011, i.e. before bud swelling, 5 living shoots from a road-side part of a tree crown and 5 shoots from an opposite side of the crown were collected from each tree (2 samples from each tree). Additionally, for shoot salinity measurements, 25 shoots from 2 trees growing in the park of the Warsaw University of Life Sciences were collected in order to assess the magnitude of overall road salt deposition. A diameter of each shoot was measured 4 cm below the apical bud. A standarised surface of every shoot was calculated as a right circular cylinder surface by multiplication of a circumference of a shoot (calculated from the measured shoot diameter) by length of 5 cm (as the cylinder height). Apical parts of every 5 shoots being a sample of the examined tree crown part were immersed in distilled water at 20 °C for the depth of 5 cm in separate beakers. After 1 hour shoots were removed and the electrical conductivity of the solutions was measured using the CX-551 multifunction meter (ELMETRON Sp.j., Zabrze, Poland). Shoot salinity was calculated as a standarised salinity index Z:

$$Z = EC/P \quad (1)$$

where:

EC – was electrical conductivity of the single solution (μS/cm)

P – is the sum of standarised surfaces of 5 shoots being the single sample (cm^2)

2.3 Annual shoot elongation and estimated sum of shoot length

A photographic method described by Borowski, Pstrągowska, Sikorski, Orzechowski, and Mąkowski (2005) was used to obtain estimated sum of shoot length in each year. Five trees in every location were photographed at night-time using a digital camera and a flashgun of high light power. The obtained images showed bright and clear tree silhouettes on a dark background. The DENDRO software was used in order to calculate the estimated sum of shoot length (Borowski et al., 2005). The length of annual shoots of each 5 trees was measured after the termination of the growing season in 2008 and 2009, 20 randomly chosen shoots from around the crown from the height of 2–2.5 m above ground were selected for the measurements.

2.4 Leaf phenology

Leaf phenology was observed in 2008 and 2009. The following stages were noted when in 10% of buds occured the beginning of bud swelling, BBCH 01, and beginning of bud breaking, BBCH 07, in 90% of buds leaf expansion was completed, BBCH 19, 50% of leaves were shed, BBCH 95, and the end of leaf fall when 90% of leaves were shed, BBCH 97 (Finn, Straszewski and Peterson, 2007). The length of the growing season (LGS) was calculated as the subtraction of BBCH 97 and BBCH 01 (Matsumoto, Ohta, Irasawa and Nakamura, 2007).

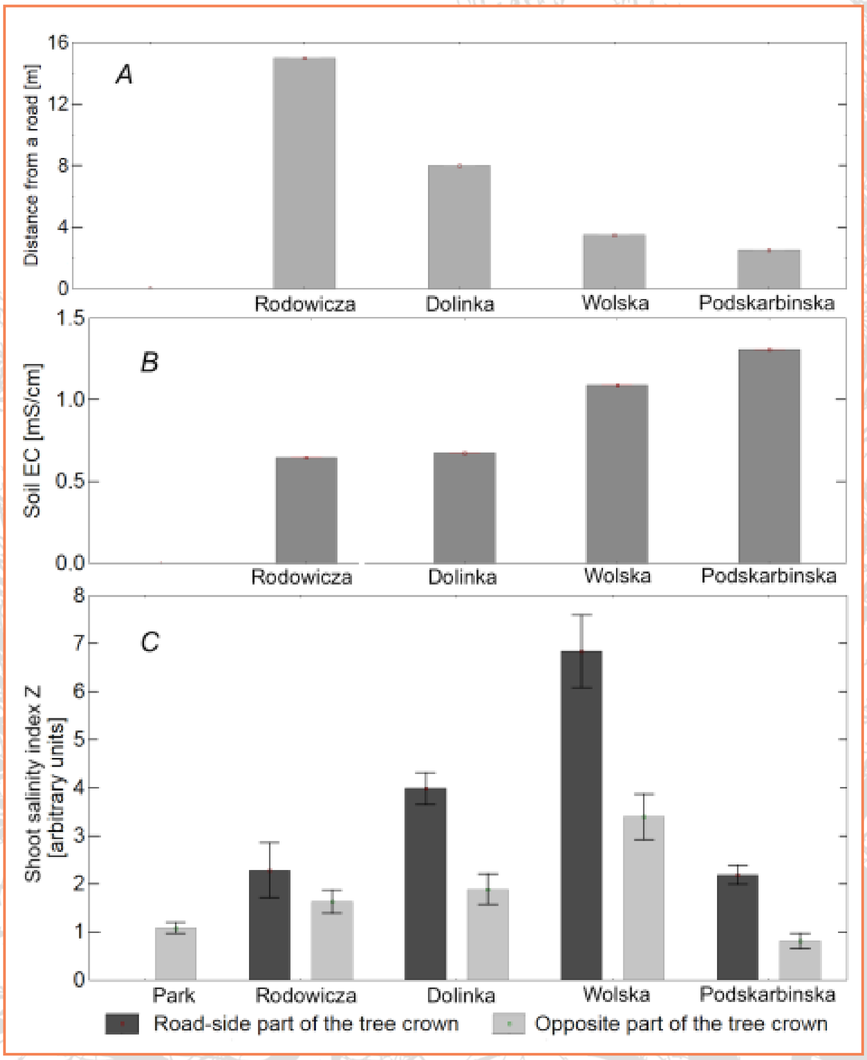
2.5 Statistical Analysis

One-way ANOVA was used to compare leaf phenology and shoot increments between 4 locations, as well as for shoot salinity comparison. For all comparisons STATISTICA version 13.0 software (TIBCO Software Inc. (2017), http://statistica.io., USA) was used.

3 Results and discussion

Salt deposition in road-side soils depends on the distance from a road, but also on the magnitude of road traffic (Blomqvist and Johansson, 1999). In our research, salt deposition in street soils depended on the distance of the road (Figure 1A and B). The farther the samples were collected the lower soil salinity was measured. The soil in Dolinka (8 m from a road) had similar EC to the soil in Rodowicza. This is consistent to Marosz (2011) who found that contamination with de-icing salt reaches up to 7 m or rarely 8 m far from a landscape road characterised by heavy road traffic.

Soil samples from Wolska and Podskarbińska were collected nearly from the same distance from a road edge adequately to the position of tree trunks. Lower EC in Wolska (a street of high road traffic) than in Podskarbińska (a street of low road traffic) suggests the different way of salt deposition in soil. In fact, streets of high road traffic were simultaneously of higher vehicle speed due to longer distances between neighbouring crossings, and Podskarbińska, the street of low road traffic, was of lower vehicle speed. In the streets of higher vehicle speed diluted de-icing salts are moved with the traffic-raised wind as aerosol farther and deposited in soil at distant locations (Hofstra



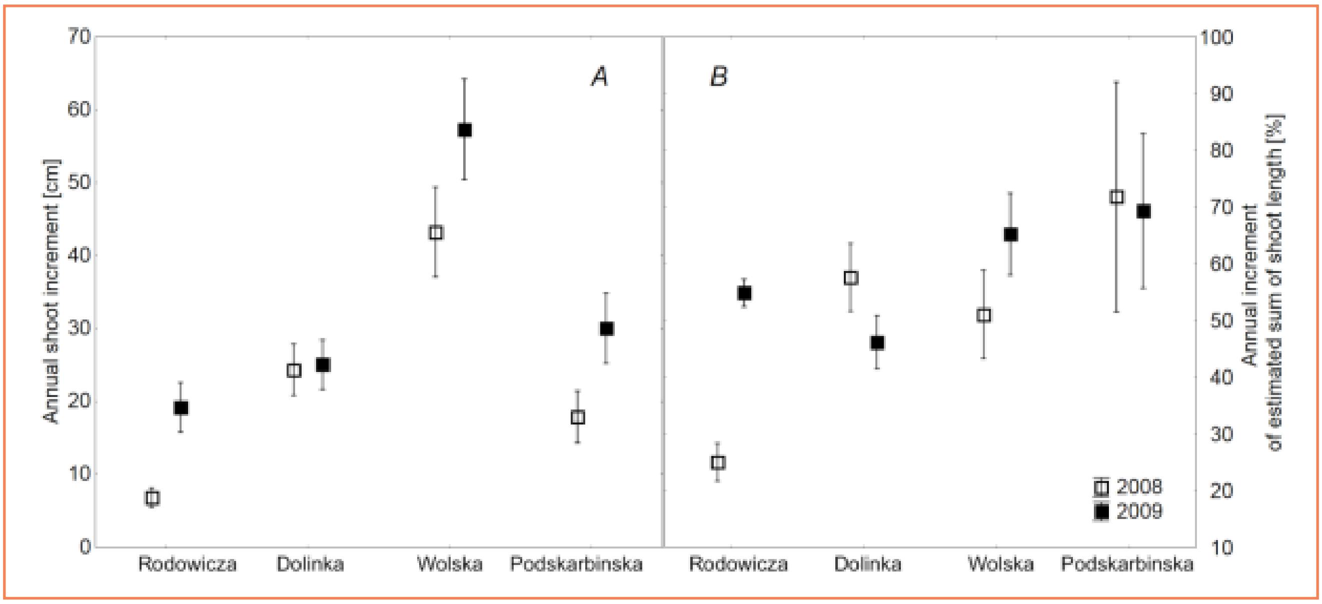
Figurere 1: Distance from a road where examined trees were planted (A), soil *EC* in examined locations (B), and standardised shoot salinity index *Z* calculated as a ratio of *EC* of diluted salt spray from shoots divided by standarised area of shoot surface (C)
Source: author's own work

et al., 1979). Therefore, their concentration in the soil adjacent to the road may be lower compared to roads where splashing or spraying of diluted salts do not penetrate far.

On the contrary, salt deposition on shoots of trees growing along two high-speed roads, Wolska and Dolinka, was higher than in Podskarbińska (Figure 1C). Road-side part of the crowns in Podskarbińska revealed higher EC while the opposite part of the crowns showed EC similar to park trees. This confirms the above mentioned suggestion that in quiet streets de-icing salt dispersion is low. In Rodowicza, at the distance of 15 m, salt deposition on road-side shoots was as high as in Podskarbińska. Moreover, salt deposition in the opposite part of the crowns in Rodowicza was still higher than in the opposite part of the crowns in Podskarbińska and in park trees. Some authors underline that wind exposure and prevailing direction may shift salt deposition on road-side trees and shrubs (Hofstra et al., 1979; Berkheimer and Hanson, 2006). In Central Poland, west, southwest and northwest winds predominate and trees in Rodowicza planted on the east side of the street were the most exposed ones to winds. Trees in Wolska and Dolinka grew on the south and north side, respectively. Nevertheless, in each examined site salt deposition on the opposite side of tree crowns was approximately twice as low as on the road-side shoots. This indicates that not only simply a distance from a road affects salt deposition, but also filtering capacity of numerous twigs and branches in the crown as ascertained by Beckett, Freer-Smith, and Taylor (2001). Weerakkody, Dover, Mitchell and Reiling (2018) found that particular matter deposition depends on density of plant organs so it is obvious that crowns themselves acted as filters to some extent and farther situated shoots captured less salt microparticles.

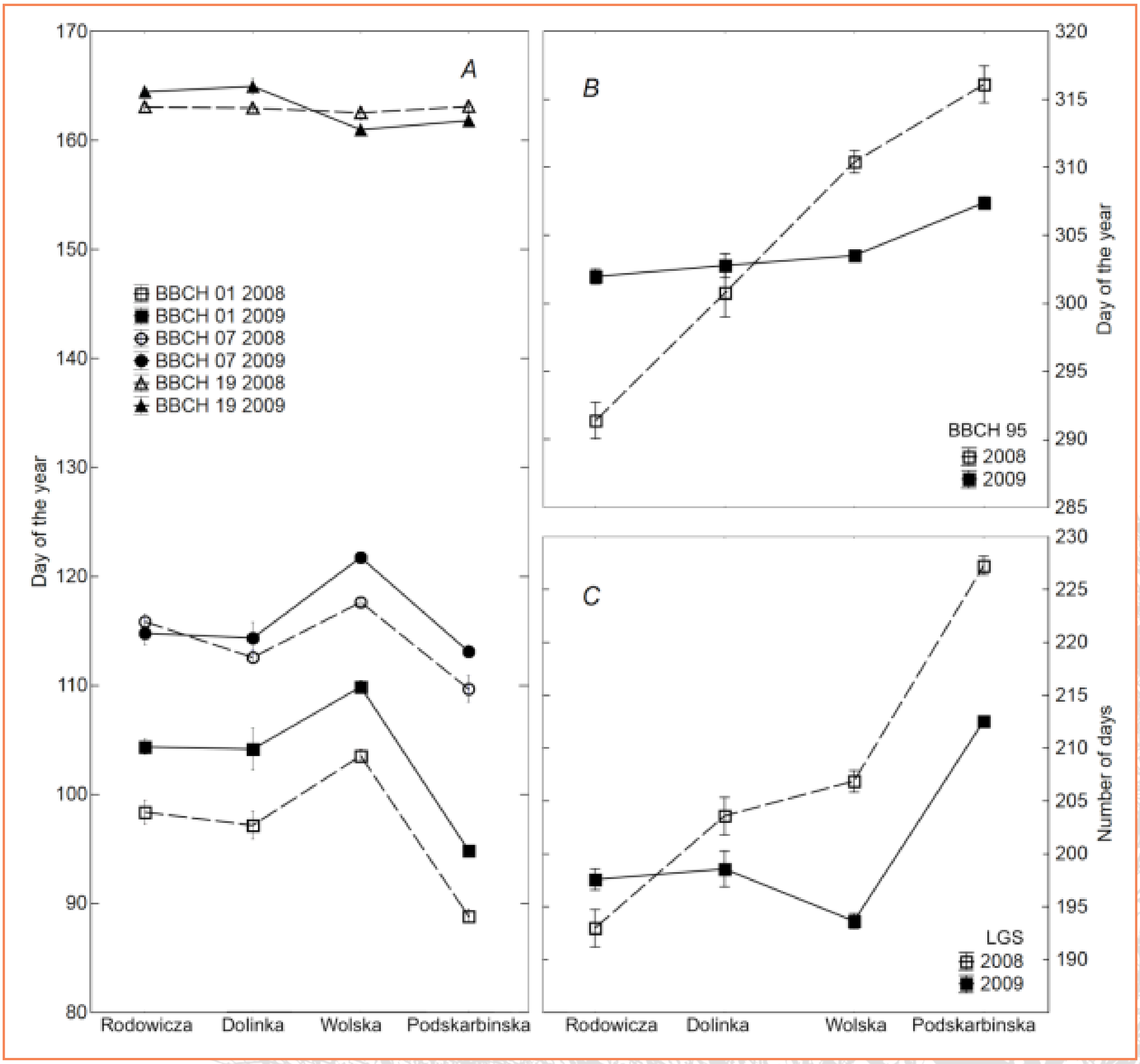
Salt deposition on shoots and buds is harmful for trees and shrubs growing along roads (Hofstra et al., 1979; Borowski et al., 2014; Swoczyna and Latocha, 2016). According to visual assessment of examined trees, the most severe injuries were observed in Wolska and Dolinka. Numerous buds did not develop and shoots partially died down. Affected branches developed new shoots and leaves later from dormant or adventitious buds. There were no evident differences between road-side and opposite parts of tree crowns according to visual assessment, however, lost shoots were not counted and such comparison was not performed. Reaction of trees to abundant shoot dieback was illustrated by annual shoots' measurements. In severely affected planes in Wolska, new shoots developing from adventitious buds revealed high vitality and their length was untypically great (Figure 2A). This is consistent with Puijalon, Piola, and Bornette (2008) reporting shifted regeneration ability in stressed plants.

Formation of long shoots did not cause the increase of digitally estimated sum of shoot length (Figure 2B). Dead dry shoots were partially dropped down and thus the increase of shoot number in Wolska did not differ from other locations. In many species, died shoots



Figurere 2: Annual shoot increments [cm] in London plane growing in 4 locations (A), means, whiskers indicate confidence level at $p = 0.05$, $N = 100$; annual increment of estimated sum of shoots (B), means, whiskers indicate *SD*, $N = 5$

Source: author's own work



■ **Figurere 3:** Phenological stages of bud and leaf development, beginning of bud swelling, BBCH 01, bud breaking, BBCH 07, leaf expansion completed, BBCH 19 (A); 50% of leaves shed, BBCH 95 (B); length of growing season, LGS (C); means, whiskers indicate *SE*
Source: author's own work

are not removed by the tree itself. Then, formation of bundles of old and new shoots developing at the base of older branches is observed (Hofstra et al., 1979; Borowski and Pstrągowska, 2010).

Previous research indicates late bud breaking as a typical consequence of salt injuries in trees and shrubs (Hofstra et al., 1979). Reports describing injuries due to salt deposition on shoots are rather sparse and discuss both marine aerosol (in seashore habitats) and de-icing salts (in the proximity to roads) effects. Paludan-Müller et al. (2002) showed that salt solution application to bark evoked 4–6 day delay in bud breaking in *Tilia cordata* and 8 day delay in *Acer pseudoplatanus* and *Fagus sylvatica*, however, salt application to buds did not influenced bud break timing. Jonsson (2006) in *in situ* research indicated that the delay in bud development is connected with high chloride concentration in leaf primordia in buds. This impeded water accumulation and then primordia remained stagnant till mid-May. Shifted chloride concentration and unsuccessful water accumulation in leaf primordia led to bud necrosis.

In our research, the latest bud swelling and breaking was observed in Wolska, but the last stage of spring development was nearly of the same timing as in other locations in 2008 and slightly earlier in 2009 (Figure 3A). This indicates that after the delay in bud development in April, leaf development was vigorous and terminated on time. Contrary to Paludan-Müller et al. (2002) and Jonsson (2006), no visible symptoms of leaf injuries were observed in Wolska. Both new shoots and leaves were of good conditions. Leaf shedding phase in Wolska appeared simultaneously with leaf shedding in Dolinka and Rodowicza in 2008 and 8 days later in 2009 (Figure 3B). In all streets, leaf shedding was preceded by leaf yellowing, except of Wolska where only green leaves were shed. Although trees in Wolska started vegetation with ca. 5 day delay, the length of the growing season there was not shortened (Figure 3C).

According to former research, London plane seems to be very tolerant to urban environments (Dmuchowski et al., 2014; Swoczyna et al., 2015) in Poland. The results of this research reveal that road-side salinity in the city affects growth and physiological processes in young London plane trees leading to disturbances in phenological behaviour. Salt contamination of shoots and buds may result in dieback of particular organs. But in general, trees maintain good vitality and are able to acclimate to urban conditions. The pattern of habitat conditions in urban streets is more complex and depends on street characteristics (wide or narrow), built environment (dense or scattered), magnitude of road traffic (high or low), soil conditions (tree pits or lawns), wind exposure and many other factors. Evaluating species only based on e.g. their ability to accumulation of sodium and chloride ions or on growth pattern does not give the complex information. In order to evaluate woody species ability to cope with urban environmental conditions, the examined species should experience different sites and their behaviour should be evaluated comprehensively.

4 Conclusions

1. In urban habitats, salt contamination at harmful levels may concentrate mostly in soil, but also on tree shoots and branches, depending on street characteristics.
2. Higher de-icing salt deposition on road-side shoots than on opposite-side shoots indicates both the depletion of salt aerosol deposition along with the distance from a road and filtering capacity of twigs and branches in tree crowns.
3. High salt deposition on shoots in trees growing along arterial streets indicates the important effect of vehicle speed on salt dispersion and tree crowns' contamination.
4. Shoot deposition of de-icing salt may lead to shoot and bud dieback and secondary growth from dormant or adventitious buds may not compensate for the lost of injured organs.
5. Extended length of the growing season in trees in a local street despite the highest soil salinity should be explained as an effect of the urban heat island because of its location in proximity to the downtown area. Simultaneously, this confirms relatively high resistance of London plane to soil salinity.
6. London plane seems to be a species of high vitality and ability to cope also with salt deposition on shoots.

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PLANTS
IN URBAN AREAS AND LANDSCAPE

EFFECT OF SUBSTRATE SALINITY ON GROWTH OF JUVENILE PLANTS *PYRUS PYRASTER* (L.) BURGSD.

Viera Paganová*, Marek Hus, Helena Lichtnerová

Slovak University of Agriculture in Nitra, Slovak Republic

The responses of *Pyrus pyraster* L. Burgsd. to salinity stress in the juvenile stage of growth were studied, particularly the influence of different salt concentrations on seedlings growth, content of assimilation pigments and sodium ion distribution. Two years old seedlings were subjected to the salt treatment by addition of 60 and 120 mM NaCl solution to the substrate for 92 days. Control plants were saturated by water. The WinRhizo REG 2009 system was used for the analytical processing of the plant root system. The stem increment, leaf area, content of assimilatory pigments and allocation of the dry matter in the plant organs were also determined. The obtained data documented significant reduction in dry weight of the leaves (-36%) stems (-32%) and roots (-22%) in the treatment with higher concentration of NaCl (120 mM). Under low salinity treatment (60 mM NaCl) *P. pyraster* invested more dry matter to roots and maintained a balanced total dry weight per plant. In the response to salt treatments seedlings created coarser roots, maintained higher water content in the leaves and roots and changed ion balance in the plant organs.

Keywords: adaptability, salt stress, seedlings, roots, woody plants

1 Introduction

The application of de-icing salts in urban areas affects the chemical composition of urban soils and has a complex effect on trees. Salinity of soil and water is caused by the presence of excessive amounts of salts. Most commonly, high Na^+ and Cl^- cause salt stress.

Salt stress reduces water potential and causes ion imbalance or disturbances in ion homeostasis and toxicity (Parida and Das, 2005; Galvani-Ampudia and Testerink, 2011). Salinity affects woody plants by inducing injury, inhibiting growth, and altering plant morphology and anatomy (Kozlowski, 1997). Negative impact of salinity stress is observed at the whole-plant level as death of plants or decrease in productivity.

Suppression of growth occurs in all plants, but there is quite large variability among species in their tolerance levels and rates of growth reduction at lethal concentrations of (Flowers et al., 1977; Greenway and Munns, 1980; Hernandez et al., 1995; Cherian et al., 1999; Takemura et al., 2000).

The variations in salt tolerance of species and genotypes of woody plants are well documented (Holmes, 1961; Monk and Peterson, 1962; Braun et al., 1978; Dirr, 1978; Francois and Clark, 1978; Tal, 1986). Only some tree species originated in central Europe tolerate salt stress. Generally, conifers, fruit trees (stone fruits) and any young trees are more prone to be damaged by salt than deciduous trees and trees older than 3–5 years (Šerá, 2017). Most fruit trees are sensitive to salinity, including *Malus domestica*, *Pyrus* ssp., *Prunus domestica*, *Prunus persica* and *Citrus* ssp. (Mc Kersie and Leshem, 1994). Most of the forest tree species growing close to roads are described as salt sensitive (Thornton et al., 1988; Sehmer et al., 1995; Alaoui-Sossé et al., 1998; Epron et al., 1999).

Tolerance of woody plants to salinity is changing in the course of life as they are relatively tolerant during seed germination, more sensitive during the emergence and young seedling stages and become progressively more tolerant with increasing age (Shannon et al., 1994). The variation in salinity tolerance may also depend on salinity level, or phenological stage of a plant (Tatar et al., 2010).

Munns and Tester (2008) reported 3 adaptation mechanisms of plants exposed to salinity stress: osmotic stress tolerance, Na^+ or Cl^- exclusion and tissue tolerance to accumulated Na^+ or Cl^-. In the literature, the

Viera Paganová, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Planting Design and Maintenance, Trieda Andreja Hlinku 2, 949 76, Nitra, Slovakia
e-mail: viera.paganova@uniag.sk

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impact of salinity on plants and their responses to salt stress, as well as biochemical pathways of salt tolerance are widely discussed (Parida and Das, 2005; Tuteja, 2007; Munns and Tester, 2008; Craig and Moller, 2010). However, adaptations of roots and their relevance to salt tolerance especially in woody plant species are less recognized.

The aim of the present research was to assess the adaptive responses of *Pyrus pyraster* to salinity stress in the juvenile stage of growth. There is evaluated the influence of different salt concentrations in the substrate on seedlings growth, content of assimilation pigments and sodium ion distribution.

P. pyraster is a light-demanding tree tolerant to fluctuations in the soil water content (Paganová, 2003). The lifespan and aesthetic properties of *P. pyraster* are comparable with other urban tree species. This woody plant can increase the species diversity in urban conditions, and evaluation of the plasticity to abiotic stresses, including soil salinity is an important precondition of its wider utilization.

2 Material and methods

2.1 Plant material and growth conditions

Two-year old plants of *Pyrus pyraster* were grown from seeds collected in the location Tŕnie in Slovakia (for location characteristics see Table 1). The seeds were extracted manually after harvest and were subjected to a cold stratification treatment with temperatures ranging from -10 °C to +5 °C.

During the phenological growth stage "beginning of bud swelling", the seedlings were placed in plastic pots (90 mm in diameter, volume 0.47 l) with a fertilized peat-based growth substrate (20% black peat and 80% white peat moss, 0–5 mm fraction, pH of 5.5–6.5, enriched with nutrients 1.0 kg/m^3 NPK 14 : 16 : 18).

There were applied two salt treatments by addition of 60 or 120 mM NaCl solution to the substrate. In the salt treatments, the experimental plants were regularly saturated by the salt solution in the amount 3.5 ml per plant and day. Within the experiment a total amount 320 ml of the saline solution was applied per plant. Control plants were saturated by water. There were 20 replications for each treatment. The proposed sample size maintained sufficient data homogeneity.

The water content in the growth substrate was calculated based on wet weight (Trautmann and Richard, 1996) and maintained at 60% water as per the weight of the fully saturated substrate. The water regime was maintained by regularly weighing the pots on a Kern SD digital scale (max. = 8,000 g, standard deviation = 0.05 g) at 2-day intervals.

Potted plants were placed in the growth chamber PolEko KK 1450. The photoperiod of the growth chamber was set to a long light period of 14 h and a dark period of 10 h; the irradiation density on the surface of the uppermost leaves was 99.54 µmol/m^2/s. Air humidity was 65%; the temperature was maintained at 24 °C during the light period and 14 °C during the dark period. After 29 days of acclimatization, the plants were maintained under salt treatment for 90 days from March to June.

2.2 Measurement and analysis of plant parameters

The WinRhizo REG 2009 system (Regent Instruments, Canada, SK0410192) was used for the analytical processing of the plant root system. The following root parameters were measured: root length (mm), root surface (mm^2), root volume (mm^3), average root diameter (mm), number of root tips, and volume of particular root fractions (mm^3). The length of the primary stem of the experimental plants was also measured, and the total leaf area (*LA*) was determined by scanning fresh leaves using the ImageJ software.

The dry weight (DW_R) of the roots was determined after the plant material was dried at 105 °C until it has reached a constant weight. Other parameters calculated were the leaf water content (*LWC*), the specific root length (*SRL*), the specific leaf area (*SLA*), the root to shoot ratio (*R* : *S*), and the fine-to-coarse root volume ratio (*F*/*C*). Fine roots were defined as roots with ϕ <2 mm and coarse roots with ϕ >2 mm. The chlorophyll content (*CC*) in the leaves was measured with a spectrophotometer (model Lange DR 3900), following the procedures described by Lichtenthaler and Buschmann (2001). The chlorophyll content was expressed in relation to leaf

Table 1 Climatic-geographic description of the original stand of mother plants

Taxon	Location	Altitude (m)	Exposure	TI. (°C)	TVII. (°C)	Precipitation (mm)	Type	Subtype
Pyrus pyraster	Tŕnie	540	S	-3	18	750	MW	W6

Source: Lapin et al., 2002
TI.– the average temperature in January; TVII. – the average temperature in July; MW – moderately warm region; W6 – moderately warm, humid, highland climate

area, as plants usually respond to salt stress by reducing the size of leaf area.

2.3 Statistical analysis

Mathematical and statistical data analysis was performed using the Statgraphics Centurion XVII software (StatPoint Technologies, USA, XVIII, license number: B480-E10A-00EA-P00S-60PO). The data were checked for normality (Shapiro-Wilk's test at significance level α = 0.001) and homogeneity (Leven's test at a significance level α = 0.05). All analyzed data showed a normal data distribution and met the assumption of homogeneity.

3 Results and discussion

According to the literature, *Pyrus* is regarded a plant with weak tolerance to salinity. The results presented here document a significant impact of salt treatment on growth of *P. pyraster* samplings and allocation of dry mater in plant organs (Table 2). The null hypothesis was adopted for the stem increment, *SLA*, Chl *b*, Chl *a*/*b* ratio, the root to shoot ratio and the fine-to-coarse root ratio.

The salt stress of plants often results in a considerable decrease in the fresh and dry weights of leaves, stems, and roots (Hernandez et al., 1995; Ali-Dinar et al., 1999; Chartzoulakis and Klapaki, 2000). In the presented experiment with *P. pyraster* seedlings, the total dry weight per plant was significantly reduced only under the treatment with 120 mM NaCl solution (-27%) compared to the Control. The reduction of dry weight was -32% for stem and -36% for leaves compared to the Control. In this treatment there were observed burned leaves and leaf tips on several seedlings and recorded plant mortality up to 35% due to excessive accumulation of salts, which can lead to death of tissues, organs and whole plants (Munns and Termaat, 1986; Munns, 1993).

P. pyraster invested more dry matter to roots (R : S = 1.02) and maintained a balanced total dry weight per plant at the low salinity treatment (60 mM NaCl). A similar growth reaction to salinity is referred by Kurban et al. (1999) for halophytic plant *Alhagi seudoalhagi* exposed to different treatments of NaCl solution, when total plant weight increased at low salinity (50 mM NaCl), but decreased at high salinity (100 and 200 mM NaCl) treatments. In agreement with the findings of Flowers et al. (1977), Greenway and Munns (1980) the growth suppression of *P. pyraster* seedlings was directly related to concentration of soluble salts in the substrate.

There were reduced the leaf area (-36%) and total chlorophyll content (-14%) of the *P. pyraster* seedlings under the higher salinity treatment (120 mM NaCl). Especially the Chl *a* content was negatively affected, while the Chl *b* and Chl *a*/*b* ratio remained stable even under the

Table 2 One way ANOVA for selected aboveground and root parameters of two-year old seedlings of *P. pyraster* grown after 90 days of treatment in control and NaCl treatments (60 and 120 mM)

Parameter	Treatment	
	F value	*p*-value
Stem increment (mm)	1.70	0.1927
Leaf area (mm^2)	12.75	0.0000
Specific leaf area (mm^2/mg)	2.34	0.1064
Dry weight of stem (mg)	6.35	0.0034
Dry weight of leaves (mg)	9.42	0.0003
Dry weight (mg)	6.50	0.0031
Leaf water content (%)	17.46	0.0000
Chl *a*, *b* (mg/mm^2)	4.44	0.0166
Chl *a* (mg/mm^2)	5.37	0.0076
Chl *b* (mg/mm^2)	2.60	0.0843
Chl *a*/*b* ratio	2.19	0.1219
Total carotenoids (mg/mm^2)	7.25	0.0017
Root length (mm)	16.68	0.0000
Specific root length (mm/mg)	6.12	0.0042
Root surface (mm^2)	16.94	0.0000
Root volume (mm^3)	7.59	0.0013
Average root diameter (mm)	1.99	0.1476
Number of root tips	5.70	0.0060
Dry weight of root (mg)	8.83	0.0005
Root water content (%)	6.63	0.0027
R : *S* (root to shoot ratio)	2.29	0.1116
Volume of fine roots (mm^3)	15.28	0.0000
Volume of coarse roots (mm^3)	4.92	0.0112
F/C (fine to coarse root ratio)	1.87	0.1654

treatment with higher concentration (120 mM) of the salt solution. The reduction in the rate of leaf surface expansion is considered an immediate response to salt stress leading to cessation of expansion as salt concentration increases (Wang and Nii, 2000; Munns and Tester, 2008; Zörb et al., 2015). The reduction of leaf area has also been recorded by other authors. The decrease of total chlorophyll, Chl *a* and β carotene content by NaCl stress in the leaves of tomato is referred by Khavari-Nejad and Mostofi (1998). According to Parida and Das (2005) the chlorophyll content and total carotenoid contents of leaves decrease in general under salt stress. The development of chlorosis and fall of the oldest leaves with prolonged period of salt stress are referred by several authors (Hernandez et al., 1995; 1999; Gadallah, 1999; Agastian et al., 2000).

The salt treatment in both concentrations (60 mM and 120 mM) of the NaCl solution had a significantly negative effect on root length and root surface of the pear seedlings. The decrease in the root length was (-33%) and (-45%) with the application of 60 and 120 mM NaCl solution compared to the control. The root surface was reduced (-19%) and (-41%) by application of 60 and 120 mM NaCl solution compared to the control. Salt treatments inhibited the root elongation and growth of the lateral roots. It is documented by a significant decrease of the specific root length (-26%, -31%) of the seedlings grown under salt treatments, as well as a significant decrease in the number of root tips (-25%, 28%) compared to the control.

Under the salt treatment, the volume of the root system of *Pyrus* seedlings (Table 3) was negatively affected, especially in the fine root fraction. The volume of fine root fraction was significantly reduced by 25% and 45% with 60 and 120 mM NaCl, respectively. The seedlings created coarser roots, what is documented by a weak,

Table 3 Plant parameters of *P. pyraster* seedlings after 90 days of salt treatment in the Control and NaCl treatments (60 and 120 mM). Presented data are means ±SE (n = 20). Values followed by different letters differ significantly (p <0.05)

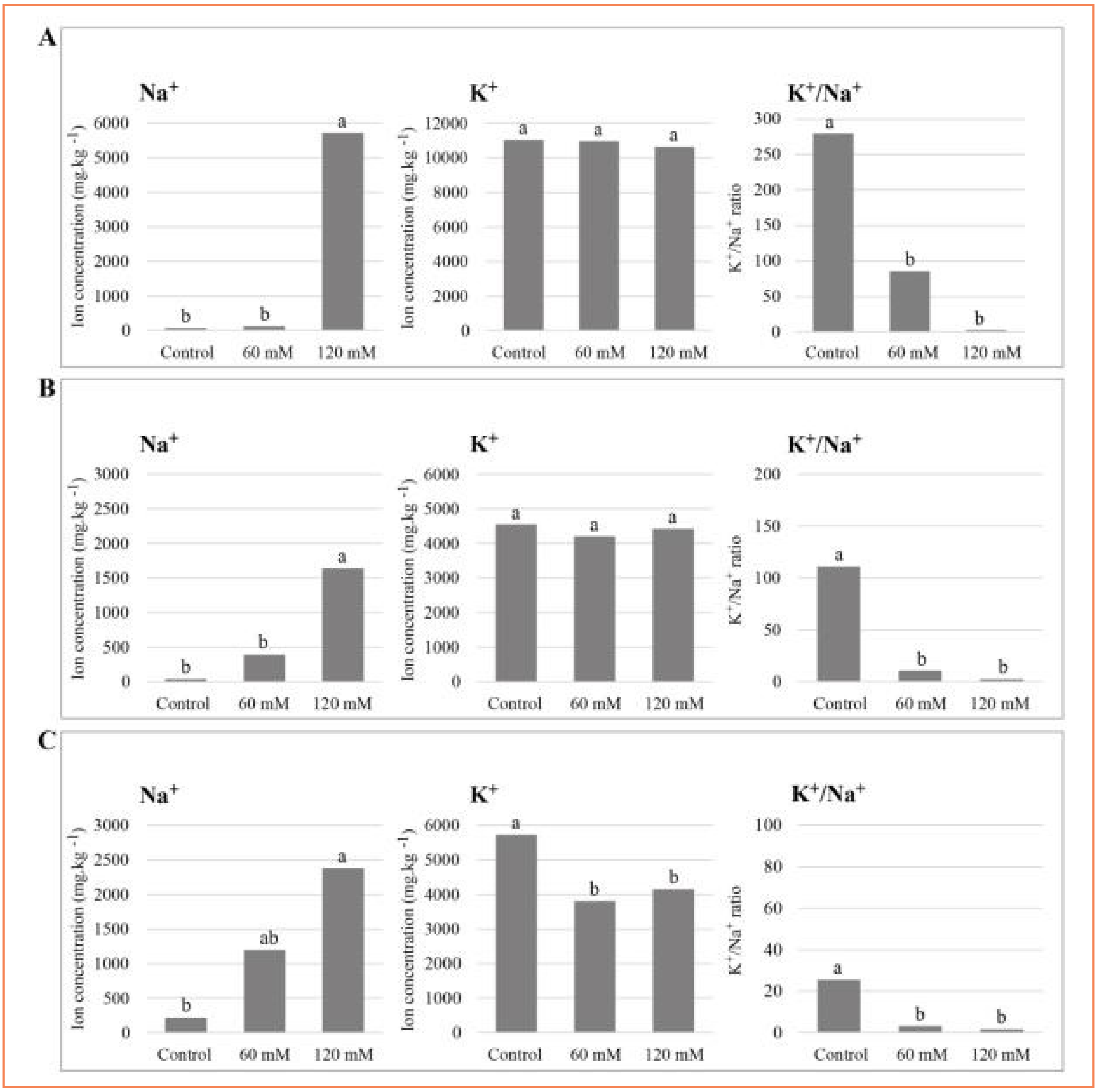
Parameter	Control	60 mM NaCl	120 mM NaCl
Stem increment (mm)	107.55 ±35.22 a	101.65 ±30.72 a	85.46 ±36.96 a
Leaf area (mm^2)	12,854.00 ±2,603.99 a	10,868.50 ±2,734.66 a	8165.97 ±2,421.67 b
Specific leaf area (mm^2/mg)	16.13 ±1.49 a	14.03 ±4.88 a	15.67 ±1.03 a
Dry weight of stem (mg)	1,259.85 ±363.52 a	1,219.10 ±420.82 a	856.86 ±228.55 b
Dry weight of leaves (mg)	810.66 ±202.54 a	703.99 ±200.17 a	519.21 ±140.81 b
Dry weight (mg)	2,070.52 ±551.47 a	1,923.09 ±592.19 a	1,407.06 ±356.10 b
Leaf water content (%)	41.76 ±1.90 b	43.39 ±1.43 b	46.42 ±3.39 a
Chl *a* . *b* (mg/mm^2)	681.19 ±77.52 a	665.03 ±101.59 ab	584.39 ±121.85 b
Chl *a* (mg/mm^2)	504.68 ±55.23 a	487.00 ±71.94 a	429.29 ±81.46 b
Chl *b* (mg/mm^2)	176.66 ±24.55 a	178.19 ±30.12 a	155.24 ±42.53 a
Chl *a*/*b* ratio	2.87 ±0.21 a	2.74 ±0.11 a	2.81 ±0.25 a
Total carotenoids (mg/mm^2)	141.43 ±15.13 a	129.96 ±13.97 ab	121.77 ±17.40 b
Root length (mm)	4,614.68 ±1,041.58 a	3,609.08 ±1,019.65 b	2,531.69 ±978.70 c
Specific root length (mm/mg)	2.72 ±0.77 a	2.02 ±0.74 b	1.89 ±0.77 b
Root surface (mm^2)	11,033.40 ±2,079.68 a	8,897.25 ±2,186.23 b	6,549.64 ±2,295.67 c
Root volume (mm^3)	6,239.55 ±1,696.34 a	5,794.70 ±1,787.16 a	3,991.47 ±1,409.78 b
Average root diameter (mm)	0.85 ±0.12 a	0.91 ±0.13 a	0.96 ±0.19 a
Number of root tips	749.20 ±198.10 a	562.83 ±211.52 b	537.00 ±205.27 b
Dry weight of root (mg)	1,753.00 ±347.86 a	1,887.35 ±449.55 a	1,360.87 ±289.39 b
Root water content (%)	48.37 ±2.69 ab	46.12 ±3.09 b	50.87 ±5.59 a
***R* : *S* (root to shoot ratio)**	0.88 ±0.19 a	1.02 ±0.23 a	0.99 ±0.21 a
Volume of fine roots (mm^3)	1,533.25 ±359.10 a	1,146.10 ±329.68 b	838.86 ±404.28 b
Volume of coarse roots (mm^3)	4,706.30 ±1,568.81 a	4,648.61 ±1,664.85 a	3,152.60 ±1,178.69 b
***F*/*C* (fine to coarse root ratio)**	0.35 ±0.12 a	0.28 ±0.13 a	0.27 ±0.15 a

but gradual increase of the average root diameter from 0.85 mm (control) to 0.96 mm (120 mM NaCl).

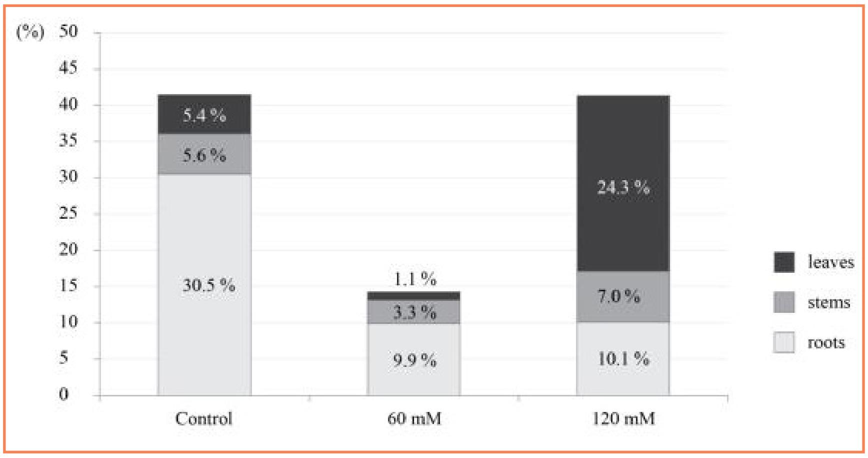
Despite the mentioned reduction of the absorptive surface of the roots, under salt stress, *P. pyraster* significantly increased the water content in roots and leaves (Table 2), what is probably related to the need maintain the physiological processes in the plant body.

Under the low salt treatment (60 mM), the accumulation of dry mass in the root did not change significantly compared to the control, but at a higher concentration (120 mM) the decrease of the DW_R parameter was significant (-22%), the $R : S$ ratio did not change significantly under different treatments (Table 3).

The presented data for root and shoot dry matter of *P. pyraster* are in agreement with findings of Laffray et al. (2018), who reported stronger reduction in aerial biomass than in root system of *Q. robur* seedlings under different salt treatments. However, *P. pyraster* significantly reduced the absorptive root surface, root length and volume of fine root fraction even under



■ **Figurere 1:** The ion content (Na^+, K^+, K^+/Na^+) in the leaves (A), stems (B) and roots (C) of two-year old seedlings of *P. pyraster* after 90 days of treatment with $NaCl^-$ solutions (60 and 120 mM) and in the control. Values followed by different letters differ significantly ($p < 0.05$)



Figurere 2: Distribution of the ion content Na^+ in plant organs (roots, stems and leaves) of *P. pyraster* seedlings calculated from the total amount of Na^+ that was delivered in the substrate within 90 days of the treatment by NaCl solution (60 and 120 mM)

low salt concentrations. These data indicate quite high sensitivity of the fine root structures of *P. pyraster* seedlings to salt stress.

After 90 days of salt treatment, the accumulation of Na^+ the roots *P. pyraster* seedlings grown with 60 and 120 mM NaCl was 5 and 10 times higher than the control content (Figure 1). The statistically significant difference in the ion content was found in the stem between the control plants and salt treatment with 120 mM NaCl. A significant difference in Na^+ content in the leaves was found only in treatment with 120 mM NaCl. The significant increase in K^+ content was recorded in both salt treatments. The values of K^+/Na^+ ratio decreased in the root growing zone from 25.49 in control to 3.19 and 1.74 in 60 and 120 m M NaCl treated roots respectively.

In a study by Huffaker and Wallace (1959) it was found that Na^+ appears to be excluded at or below the shoot-root transition zone and this may account for the relatively later appearance of Na^+-induced salinity symptoms.

The distribution of Na^+ in the plant organs (Figure 2) clearly indicates retention of the salt ions in the roots and stems of *P. pyraster* seedlings. The relative distribution of the salt ions was calculated from the total amount of Na^+, that was delivered in the substrate within 90 days of the treatment of *P. pyraster* seedlings by NaCl solution (60 and 120 mM). In both salt treatments, the functional retention of Na^+ ions is evident in the roots and stems. The control plants did not retain Na^+ ions in the root and stem tissues (Figure 2). The mentioned retention was effective under treatment with low concentration (60 mM) NaCl, when only 1.1% of the total amount of Na^+ delivered in the substrate was transported to the leaves. These data support the opinion that differences between leaf and woody tissues in Na^+ concentrations suggest a functional role of wood in preventing Na^+ accumulation in leaves (Ziska et al., 1991). However, the retention of Na^+ ions in wood is effective only up to the certain level of the salt concentration in the substrate. This barrier is finally overcome in salt stressed species, and the Na^+ accumulation in leaves which later ensues is typified by either mottling or by tipburn in stone fruit trees (McKersie and Leshem, 1994).

4 Conclusion

The obtained data documented the ability of *P. pyraster* to cope with moderate salt stress (60 mM NaCl) via morphological adaptations of the root system (created coarser roots at the expense of the root elongation and fine root fractions). Despite reduction of the absorptive surface of the roots under salt stress, seedlings significantly increased the water content in roots and leaves, and maintained balanced growth of the aboveground organs and chlorophyll content in the leaf tissues.

The mentioned root adaptive responses, as well as retention of sodium ions in the wood tissues (roots and stems) were insufficient to maintain adequate water uptake and prevent transport of the sodium to leaves in conditions of sever salinity treatment (120 mM NaCl). Therefore, salt stress induced a strong reduction in growth of *P. pyraster* seedlings.

This study should be completed within a more detailed evaluation of the responses of *P. pyraster* to salinity. The topic has to be explored in more detail before utilization of this woody species in urban areas where it is often exposed to the stress from application of de-icing salts.

Acknowledgements

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CONTENTS

PLANTS
IN URBAN AREAS AND LANDSCAPE

SPREAD RATE OF *ACERIA PYRACANTHI* IN SLOVAKIA IN THE PERIOD 2006–2018

Ladislav Bakay

Slovak University of Agriculture in Nitra, Slovak Republic

Scarlet firethorn (*Pyracantha coccinea* M. Roem) is an ornamental shrub, non-native in the conditions of Slovakia. It can endure urban environment, which is why it is used intensively in landscaping. In 2006, *Aceria pyracanthi*, a spider mite damaging firethorns, was discovered in the Botanical Garden of the Slovak Agricultural University in Nitra. After 12 years from its first record we tried to summarize its distribution and spread rate in Slovakia. Data were gained through a field work and through citizen scientists. In total, *A. pyracanthi* was observed in 9 localities. It can be concluded that *A. pyracanthi* can damage firethorn plants in all climatic regions where firethorns can thrive. A commercial plant sale can be considered the main vector for the spread of *A. pyracanthi*.

Keywords: *Aceria pyracanthi*, insect pest, invasive species, urban greenery

1 Introduction

The eriophyids are among the most important plant-feeding mites, causing damage to wild and cultivated plants. Although they are the most numerous of the plant-feeding mites, only 1859 species are known at present (Davis et al., 1982) Eriophyoid mites are obligatory phytophagous organisms and are well adapted to living on plants. Since eriophyoid mites are of great economic importance, both as pests and candidates for biological control of weeds, the need for understanding the ecological and evolutionary patterns of their host specialization is obvious (Lindquist et Oldfield 1996). The galling eriophyoids constitute a highly specialized phytophagous group capable of inducing modifications in plant tissues by cellular hyperplasia and hypertrophy (Nasareen and Ramani, 2014). Csóka (1997) mentioned 500 species of mites which cause galls. Previous studies (Keifer et al., 1982; Lindquist and Oldfield, 1996; Skoracka, 2006; Nasareen and Ramani, 2014; Araújo and Kollár, 2019) demonstrated a high specialization of eriophyoids on host plants. Araújo and Kollár (2019) observed that 74% of mite species were recorded on a single host plant species (i.e. monophagous species), which is also the case of *Aceria pyracanti* (G. Canestrini, 1891). A total of 900 species are known from the genus *Aceria* Keifer, 1944 (Fam. Eriophyidae) (Amrine et al., 2003). *A. pyracanthi* is a spider mite and there is only a few data about its distribution and ecology (Amrine et al., 1994; Kollár, 2011; Kollár and Donoval, 2013). *A. pyracanthi* is present in Hungary (Ripka, 2010), Croatia, Bosnia and Herzegovina, Italy (Amrine et al., 1994) and Slovakia (Kollár, 2011; Kollár and Donoval, 2013). *A. pyracanthi* causes carmine erineum especially on the underside of the leaves of *Pyracantha coccinea* (Ripka, 2010), but it can also appear on the upper side of the leaves (Kollár and Donoval, 2013). *Pyracantha coccinea* is distributed especially in North, Central and South Anatolia in Turkey and South Europe, Crimea, Caucasia, North-West Iran in the world; Wild in Turkey, especially near the Black Sea Coast; also cultivated for its ornamental berries (Akguc et al., 2010). *P. coccinea* is a naturalised neophyte in the conditions of Slovakia and its current status is a frequently spreading neophyte (Reháčková, 2009).

In our research we cooperated with citizen scientists. The use of citizen scientists in entomology has a long tradition in Hungary (Vig and Szél, 2010) and in many other places in the world as well (e.g. Gaedike, 1955; Allen, 1959; Eliáš, 2014). In recent years, Internet platforms and social media are playing larger roles in studies of insects (e.g. Walther and Kampen, 2017; Le Feon et al., 2016; Bakay and Kollár, 2018). In contrast, the role of the citizen scientist in acarological studies is relatively *minor*. Mites are small and not easy to notice

Ladislav Bakay, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of planting design and maintenance, Tulipánová 7, Nitra 949 01, Slovakia
e-mail: lazlo.bakay@gmail.com

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on plants, in the soil or on animal hosts (Kontschán et al., 2019). In the case of *A. pyracanthi* it is different, because they create visible plant galls on the leaves of the firethorn, which are hard to misidentify (Kollár and Donoval, 2013).

Our aim was to analyse the distribution of this non-native insect pest in Slovakia and identify possible vectors, which lead to the spreading of this species.

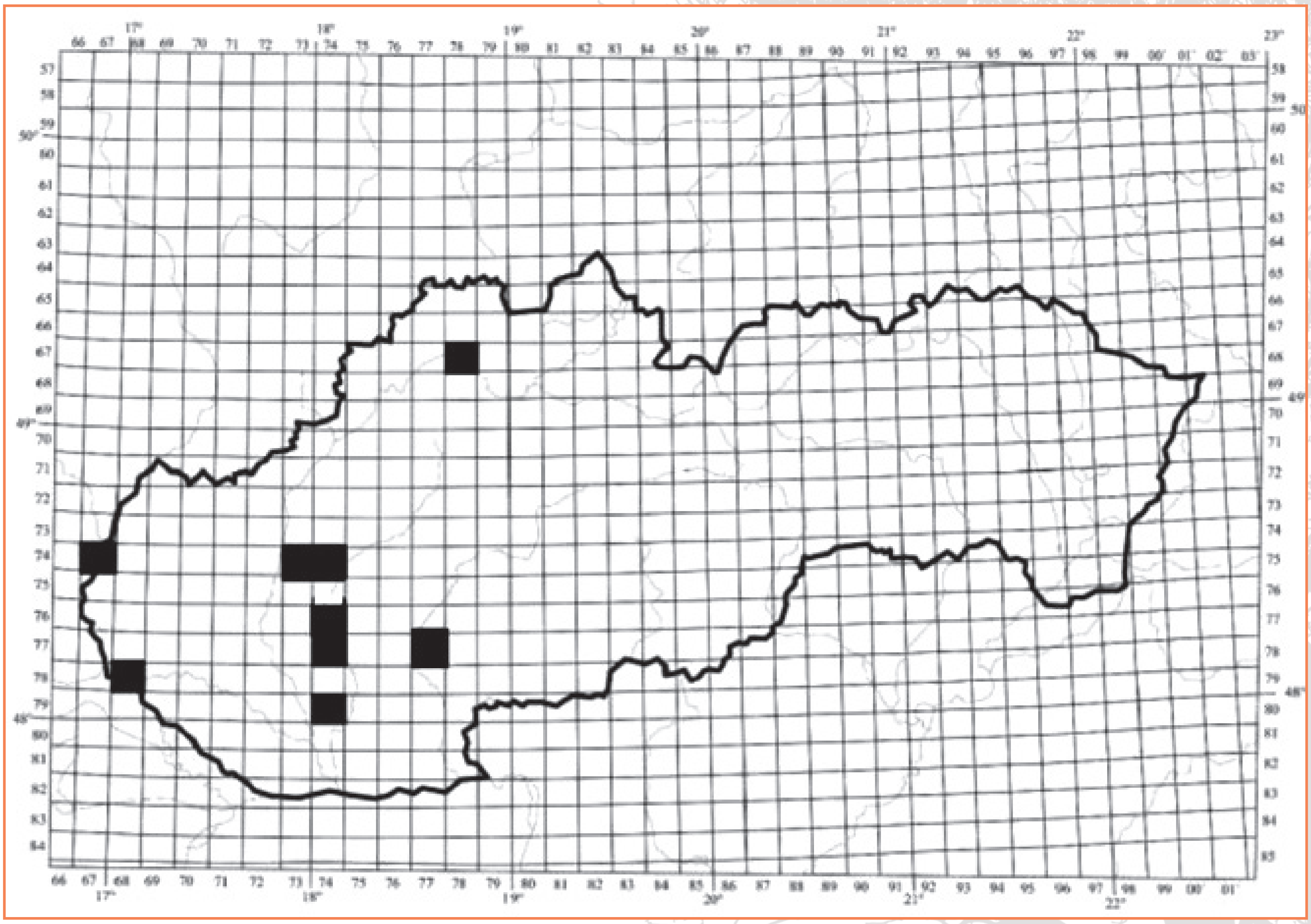
2 Material and methods

The monitoring of *A. pyracanthi* distribution in Slovakia was carried out with the help of questionnaires addressed to landscape architects and horticulturists (mostly Alumni students from the Slovak University of Agriculture), citizen scientists and through field observations in the years 2006–2018. The questionnaire contained detailed descriptions and photos of *A. pyracanthi* and its symptoms on *P. coccinea*. For the dissemination of the questionnaire we used Facebook. The questionnaire was posted on the page Zelovoc Laca Bakaya, which is a page for plant enthusiasts (1,002 likes, 1,050 followers, and max. organic reach around 10,000 profiles). The respondents confirmed the presence or absence on the locality and attached pictures, where it was possible to clearly identify *A. pyracanthi*. Doubtful data were not considered and such localities were visited to ensure the presence of this insect pest.

3 Results and discussion

In total, *A. pyracanthi* was detected in 9 localities in Slovakia (Figure 1) The first occurrence of *A. pyracanthi* in Slovakia was recorded in the locality of Nitra (faunistic square (dfs): 7674d, 7674c; 48.3058972 N, 18.0962242 E) in the Botanical Garden of the Slovak University of Agriculture in 2006 (Kollár and Donoval, 2013). All the plants in the Botanical Garden were infested. Now, *A. pyracanthi* can be found in all city parts. It can be assumed that *A. pyracanthi* spread from this place into the other parts of Nitra.

In Žilina (dfs: 6778c; 49.2261622 N, 18.7460217 E), infested plants of *P. coccinea* were present in an



Figurere 1: Distribution of *Aceria pyracanthi* in Slovakia marked with black squares

ornamental plant nursery in 2018. The infested plants were imported from the Czech Republic.

At the locality of Banka (dfs: 7473a; 48.5758694 N, 17.8394644 E), we found infestation of *A. pyracanthi* on older plants of *P. coccinea* in 2016. *A. pyracanthi* was observed on a firethorn hedge in a private garden by a citizen scientist, who sent us pictures of the monitored insect pest. The determination was correct. We visited the locality every year and *A. pyracanthi* was still present even though the owner applied acaricides several times.

In Bratislava (dfs: 7868d; 48.1332442N, 17.1085628E), we found infestation on a newly planted *P. coccinea* near the shopping centre Aupark in 2018.

Heavily infested plants of *P. coccinea* with *A. pyracanthi* were found in Levice (dfs: 7777d; 48.2157717 N, 18.6036822 E) in 2016. Firethorns grow in the city park in the understorey of trees.

During the survey of the Tovarníky park near Topoľčany (dfs: 7474b; 48.5674056N, 18.1469983E) we detected *A. pyracanthi* all around the park on firethorns in 2017.

In Malé Leváre (dfs: 7467d, 48.5032406N, 16.9694336E), we identified *A. pyracanthi* on a firethorn hedge in a private garden of a citizen scientist in 2018, who sent us pictures of the monitored insect pest. The determination was correct.

In Palárikovo (dfs: 7974c; 48.0401944N, 18.0746111E), we identified *A. pyracanthi* on a single firethorn plant in a private garden of a citizen scientist in 2018, who sent us pictures of the monitored insect pest.

The data did not show a pattern in the distribution of *A. pyracanthi* in Slovakia according to climatic regions. As Némethy (2019) mentions in her article, *A. pyracanthi* could spread with the help of commercial plant sale, which is also the case in Slovakia. The questionnaire on Facebook had 75 shares and an organic reach of 10,300 profiles. We received 6 messages with correct identification of the monitored insect pest with new data in localities. With the help of citizen scientists we confirmed the presence of *A. pyracanthi* at the following localities: Bratislava, Malé Leváre and Palárikovo. Our results were similar to the findings by Kontschán et al. (2019).

4 Conclusion

A. pyracanthi is a non-native insect pest on a non-native ornamental shrub *P. coccinea*, which is widely used in landscaping in the conditions of Slovakia. This spider mite is very data deficient, and there is a lack of information on its biology, origin and distribution. *A. pyracanthi* causes carmine erineum on leaves and lowers the overall aesthetical value of the plant. It is present in Slovakia in 9 localities: Nitra, Topoľčany, Levice, Žilina, Malé Leváre. *A. pyracanthi* has been present in Slovakia since 2006 and its main vector is probably a plant trade. *A. pyracanthi* can survive in Slovakia wherever firethorns can withstand the climate conditions. A part of the data (33%) was gained with the help of citizen scientists. This result highlights the possibilities of social media in the field of entomology, especially in monitoring of non-native or invasive insect species.

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CONTENTS

PLANTS
IN URBAN AREAS AND LANDSCAPE

REVITALIZATION OF HISTORIC CEMETERIES – POSSIBLE APPROACHES IN THE CASE STUDY OF CEMETERY IN HLOHOVEC, SLOVAKIA

Denisa Halajová

Slovak University of Agriculture in Nitra, Slovak Republic

In this work we point out the main problems of the current state of historic cemeteries and also the possibilities for their restoration. Historic cemeteries are important parts of cities' lives, for their historical, art or ecological value and their potential as recreational or tourist attractions. The article draws attention to the values, but also the negatives of historic cemeteries as shown by the example of the historic cemetery in Hlohovec in Slovakia. The Old Cemetery in Hlohovec is linked with the formation of calvary in 1734. Historic sacral buildings of calvary, chapels and a collection of neo-Gothic and neo-Romanesque tombs makes the cemetery very valuable from the architectural point of view and creates a specific cemetery atmosphere. Based on the analyses, great density of graves, inappropriate grave design, decline of the number of trees in alleys, inappropriate spreading of nature seeding trees, lack of park furniture elements and elements of orientation and information system etc. were identified as problems. In the case study we point out the possible approaches to revitalization, especially from the perspective of greenery and cemetery amenities.

Keywords: cemeteries, calvary, urbanity, Slovakia, trees

1 Introduction

In addition to the main function of burials, historic cemeteries have other functions. Historic cemeteries have a role in displaying historical developments, and as historic landmarks they may contribute to the territorial identity (local, regional) memory and identity (Swensen, Nordh and Brendalsmo, 2016; Kráľová, 2018; Finka and Jamečný, 2018). Cemeteries are places of tourism, whether for architectural monuments, sculptural art, or for any important personalities buried there. According to Finka and Jamečný (2018), cemetery tourism is associated with an active form of tourism focused on the issue of cultural heritage. No less important are cemeteries as green areas, with microclimatic and recreational functions, which are particularly important in heavily urbanized areas of historic cities (Halajová, 2018). Many historically and architecturally valuable cemeteries in Slovakia are in bad condition for several reasons. In the case of historic cemeteries, there is a problem with the maintenance of tombstones and the growth of natural seeding woody plants. On the contrary, there are many historic cemeteries that are still very intensively used for burying, therefore graves and trees are damaged by the construction of new graves. According to Vaščák (2018), the necropolic architecture in Slovakia does not receive sufficient professional attention, due to the lack of methodology in identifying and evaluating these elements and because they do not have the status of national cultural monuments and their ownership is often unclear. In addition to the lack of professional care, there is also no public attention given to historic cemeteries. According to Vaščák (2018), the main reason for the lack of public interest in cemetery architecture is the reduced sensitivity of perception and ignorance of the cultural-social values of necropolic and sepulchral architecture as part of cultural heritage. The starting point for the protection of historic cemeteries is their assessment in terms of cultural – historical value, biological-aesthetic value and possible use based on evaluation of suitable activities (Gécová and Putrová, 2018). The cultural-historical value is based on the age of the complex, architectural or artistic value of small buildings or tombstones and graves of prominent personalities. The bio-aesthetic value of the cemetery is characterized by the species composition of vegetation and its landscape composition.

Denisa Halajová, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Garden and Landscape Architecture, Tulipánová 7, Nitra, Slovakia
e-mail: denisa.halajova@uniag.sk

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2 Material and methods

The cemetery area is located in the town Hlohovec, a district town in Slovakia in the Trnava region. Hlohovec is a historically important town, situated on the bank of the river Váh, the longest river in Slovakia. The first written reference of the town was found in the Zobor Charter of 1113. The most important and dominant historic monument of the town is the chateau, originally a medieval castle. The cemetery is a complex consisting of three parts – the Old Town Cemetery with calvary, the Jewish Cemetery and the New Cemetery. The aim of this study was to design the revitalization of the Old Cemetery, to design the greenery in the New Cemetery, but also to design the street spaces in front of the cemetery. Data from the evidence of town greenery was used for the study of cemetery revitalisation. The study was elaborated at The Department of Garden and Landscape Architecture in The Course of the Restoration of Historic Greenery in the winter semester 2018/2019 by the 2nd-year students of Landscape Architecture.

3 Results and discussion

3.1 Historical and architectural analysis

The Old Cemetery in Hlohovec is linked with the formation of calvary in 1734. The calvary was created as a thank you for the end of the plague epidemic in 1705–1708. The calvary was built on the site of an older chapel with a hermitage and a small cemetery on the slope above the town. The whole calvary complex originally consisted of seven Stations of the Cross and the top sculpture with the trio of the Crucified from 1734. The site was closed by the original Chapel of Our Lady of Sorrows (Urminský, 2019).

The chapel underwent two reconstructions, in 1730 it was rebuilt and in 1802 it was extended to the burial chapel of the Erdödy and Hardegg families. Sculptures of the Deposition of Christ from the Cross and sculptures of Mary Magdalene, Virgin Mary and St. John were added to the calvary in 1742. To this day, six stone reliefs with scenes from Christ's journey to Golgotha have been preserved from the original way of the cross. Reliefs and sculptures are the oldest preserved and complete sets of The Way of the Cross from Slovakia.

After 1892, the original reliefs of The Way of the Cross were relocated and mounted onto the terrace next to the Our Lady of Lourdes cave, where they are to this day. The original Stations of the Cross were replaced by the new Chapel of the Cross, built by the citizens of the town as private tombs in the developing cemetery. The current form of the cemetery was completed with a collection of about 60 family tombs in the form of a chapel from the end of the 19th century, which is unique in Slovakia. A separate space with an altar,

■ **Figurere 1:** The calvary in Hlohovec – comparison of maps of the first military mapping (1782–1785) and second military mapping (1819–1869). Even in the first picture there is a visible chapel on the top of the hill and also the Stations of the Cross, in the pictures from the second military mapping the Stations of the Cross are already more detailed
Source: http://geoportal.gov.sk

■ **Figurere 2:** The fact that the Way of the Cross in Hlohovec had originally only seven stops, as was a custom in the 18th century, is also evident in the town's veduta of 1807
Source: Archive of the Monuments Board of the Slovak Republic

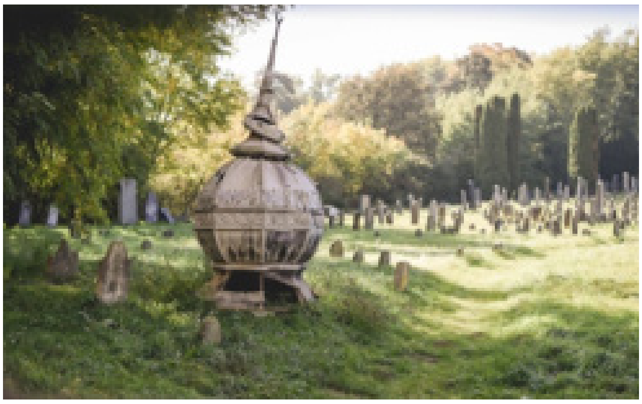
■ **Figurere 3:** The oldest building in the cemetery in Hlohovec, Chapel of Our Lady of Sorrows, in 1802 extended to the burial chapel of the Erdödy family by Count Jozef Erdödy

a pulpit and benches surrounded by chapels was created near the cave chapel of Our Lady of Lourdes.

A part of the cemetery complex is a Jewish cemetery bounded by a high stone-brick wall from the 19th century. In the cemetery we can find graves of important personalities, such as Sarah Ley van Geldern, grandmother of Heinrich Heine, or scholar Mordechai Deutsch from 1773. Baroque tombstones are situated in the older part of the cemetery.

The statue of St. John of Nepomuk with a pedestal at the Our Lady of Lourdes Cave and the Jewish cemetery area are the only heritage protected objects in the

■ **Figurere 4:** Complex of neo-Romanesque and neo-Gothic family tombs from the end of the 19th century in the cemetery in Hlohovec



■ **Figurere 5:** A turret from a demolished synagogue at the Jewish cemetery in Hlohovec

cemetery. Because of this, the heritage protection of the cemetery as a complex, architectural elements or trees is problematic.

3.2 Analysis of current state, functions and operation

The historic cemetery is located on an area of more than 7 hectares. The cemetery complex can be divided into several functional units. The largest one is The Old Cemetery with traditional burial, which provides 6,600 grave sites. The graves are regularly arranged, raised, with a hard surface. There are over 200 funerals a year in the town, of which three quarters are held in already existing graves in The Old Cemetery. A part of the cemetery is represented by the historic sacral buildings of calvary and the chapel of Our Lady of Lourdes and a collection of neo-Gothic and neo-Romanesque tombs. The cemetery complex includes facilities such as a ceremonial hall with an entrance area and a parking lot. Another separate part is the Jewish cemetery, which is inaccessible to visitors. Behind the Jewish cemetery there is a New Cemetery with a traditional grave field and an urn grave field.

3.3 Vegetation analysis

The basis for the vegetation analysis was the evidence of the trees of the town of Hlohovec, which records the species composition of the trees and their condition. The greenery evidence also includes proposals for treatments and felling of the trees, which are divided into three time stages. Within the area of The Old Cemetery there are 311 trees represented by 31 tree species. Coniferous tree species predominate, they are represented by 18 species and 185 individuals, and

■ **Figurere 6:** Comparison of cemetery state in 1950 and 2010. In 1950, the trees of the Old Cemetery are visible along the Calvary and roads defining the grave fields. In 2010 there is a visible expansion of the cemetery complex area of the New Cemetery with urn grave field, new grave fields and ceremonial hall and parking area. From the greenery point of view, in 2010 there are visible natural seeding woody plants in the Jewish cemetery, as well as around the Chapel of Our Lady of Sorrows. On the contrary there is visible a decrease in the number of trees in the alleys, along the Calvary and in the grave fields. In 2010 there is visible a high intensity of burial on The Old Cemetery and filling of the area with hard surfaces graves. Legend: red – Old cemetery in 1950, yellow – Jewish cemetery, green – cemetery complex in 2010
Source: https://mapy.tuzvo.sk/

deciduous trees are represented by 13 species with 126 individuals. The most abundant species is the conifer *Platycladus orientalis* (L.) with 77 individuals, *Aesculus hippocastanum* L. with 29 individuals is the most abundant deciduous tree. From the compositional point of view, the remains of tree alleys of the species *Acer pseudoplatanus* L. and *Aesculus hippocastanum* L. and solitary trees *Tilia cordata* Mil and *Tilia platyphylos* Scop are visible in the old part of the cemetery. Coniferous trees are located without any evident compositional intent; they are planted mainly individually near graves. The vegetation analysis shows that in The Old Cemetery, there are trees in different conditions, and 42 of them are to be cut down in three phases. In the cemetery there are still visible the remains of old alleys, unfortunately, they are not restored by planting new trees.

3.4 SWOT analysis

Based on the analysis of the cemetery area from the point of view of its operation, facilities, architectural and artistic value, history and current use, the state of greenery or promotion and attendance, a SWOT analysis was prepared.

3.5 The basis for revitalization

According to Swensen and Skår (2018) two societal tendencies are present in cemeteries: a tendency towards secularism meaning that people are paying more attention to personal desires, including recreational needs, and on other hand, a renewed interest in personal religiousness and life-philosophies. The analysis shows that the cemetery in Hlohovec has, thanks to the presence of Calvary, a great value as a historic monument, but also as a sacred place. There is therefore a presumption of a clash between the two opposing tendencies, both of which must be consistent with the operation of the cemetery at the time of funerals. Thus, the revitalization of the cemetery is intended to reinforce all the three dominant functions of this space, namely funeral, sacral and recreational functions, in particular by adding greenery and amenities.

Based on the results of the analysis, a proposal for the restoration of the cemetery was established, which divides the restoration of the cemetery complex from the spatial point of view into the following functional and compositional units:

- revitalization of The Old Cemetery,
- design of the public space around the ceremonial hall,
- design of the cemetery entrance area,
- landscape design for The New Cemetery,

Within the framework of spatial units, priority was given to the following elements:

- greenery,
- park furniture,
- an information system.

The concept of greenery revitalization of The Old Cemetery is based on:

- finding suitable places for planting deciduous trees among the graves in the field,
- restoration of deciduous trees alleys,

Table 1 SWOT analysis of the historic cemetery in Hlohovec

Strengths	Weaknesses	Opportunities	Threats
– unique cultural value – historical, architectural, artistic, spiritual	– great density of graves, Inappropriate grave design	– identity	– high burial intensity
– memory, identity, story of the city	– decline in number of trees in alleys, lack of green elements (flowers, lianas, trees)	– education	– stone industry
– ecological value of greenery	– inappropriate spreading of nature seeding trees	– tourism	– lack of funding
– sacral place	– inappropriate design of entrance areas	– recreation	– no preservation of monuments
	– lack of park furniture elements	– contemplation	
	– missing orientation and information system		
	– inappropriate design of equipment elements (water, lighting, waste containers)		
	– unsorted waste		
	– barriers		
	– no promotion		

- removal of unsuitable plantings, especially coniferous species of trees and natural seeding trees near the calvary and chapels,
- above the benches and along the roads, where trees cannot be planted, it is necessary to supplement the area with other forms of greenery for shading, such as climbing plants on frames,
- in terms of tree species selected for planting, species of deciduous trees that are growing in cemetery such as *Acer pseudoplatanus* L., *Aesculus hippocastanum* L. and *Tilia cordata* Mill. were selected.

When revitalizing older cemeteries with a high burial density, the most substantial problem is finding a place for planting trees, whether in grave fields or in alleyways. Especially in places where tree planting is not possible, shielding of resting areas is particularly important. Shade is important both for regulars and occasional visitors, but especially for visitors who experience a period of mourning shortly after losing a loved one when their cemetery visits are very intense. In Slovakia, wearing a black suit as a sign of a mourning period is fairly common, thus increasing the need for shade in cemeteries, especially for the elderly and indisposed.

Figurere 8: Example of designing a trellis with climbing roses to cover up a waste container

The design of the green space in front of the ceremonial hall is based on:

- creating a meeting area with plenty of rest areas and benches,
- supplying hedges, perennial beds and roses, or climbing roses,
- the selection of perennials is focused on the year-round effect of flowering, but especially on the time of the highest cemetery visitation in the fall, when different grass species will act on the beds, but also *Aster ericoides* 'Pink cloud' and *Anemone hupehensis*,
- covering up negative elements such as waste containers or the ceremonial hall operating premises by greenery.

In particular, the space around the ceremonial hall fulfils the role of a meeting and rest area, so its design should be representative and quiet.

The design of the entrance area of the cemetery, in this case in the area of a busy street is based on:

Figurere 7: An example of a design of a trellis with planted roses above benches for shielding of rest areas. Shade is an important element where no trees are available

■ **Figurere 9:** The design of the street space in front of the cemetery fulfils a representative and a meeting function, with added greenery and resting places

- visual separation of pedestrians from the road,
- creating a representative space with greenery and resting places,
- completion of the information and orientation system of the cemetery in the entrance area of the cemetery.

The design of The New Cemetery was limited by the existing network of paths and roads, so the solution was focused on:

- the concept of the possible arrangement of graves, their types and design,
- building a central resting area,
- adding the area of grave fields with elements of green – trees, hedges, perennial beds or grass areas.

Park furniture and the information system

The cemetery, such as any other public space, is completed by elements of park furniture and elements of orientation and information systems. These elements must also be understood as design elements that improve the aesthetic quality of the space. In the cemetery in Hlohovec, these elements are missing or they are in unfavourable technical conditions or very diverse in design. That is why we have focused on uniting the design of these elements. Various elements were designed for the cemetery, namely a bench, a waste bin, an information board, as well as containers with trellises for climbing plants or water sampling points. These elements are located at the burial field so that they are accessible in as small

■ **Figurere 10:** The design of the new cemetery was focused mainly on enriching the area of grave fields with elements of greenery, and designing the graves and the furniture

■ **Figurere 11:** United design of benches, waste bins, mobile green with trellis and information boards for the cemetery in Hlohovec

as possible walking distance. The elements of the information system, providing information about the historical, artistic and architectural value of cemetery are important.

4 Conclusion

The main problems we identified in the cemetery complex in Hlohovec are e.g. high density of graves in grave fields, decline in the number of trees, the lack of elements of park furniture and orientation boards, and the lack of an information system, etc. In the case study of the cemetery complex in Hlohovec, we proposed measures to improve these conditions, especially in terms of greenery and small architecture elements such as planting of deciduous trees, designing the entrance and resting areas, and addition of park furniture and equipment elements. In case it is not possible to replace the original trees in the burial ground for spatial reasons, other forms of greenery can be added, e.g. mobile containers and trellis with climbing plants. The design elements used in the case study design can be applied generally to the revitalization of historic cemeteries in order to make them more attractive to visitors and preserve their historical value.

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PLANTS
IN URBAN AREAS AND LANDSCAPE

THE CHANGES OF PHENOLOGICAL PHASES ON THE EXAMPLE OF SELECTED INVASIVE SPECIES OF TREES

Ewa M. Zaraś-Januszkiewicz*, Edyta Rosłon-Szeryńska, Barbara Żarska, Beata Fornal-Pieniak

Szkoła Główna Gospodarstwa Wiejskiego – SGGW w Warszawie (Warsaw University of Life Science – WULS), Warszawa, Poland

'New' species of trees are sought for cities. These species must cope with difficult urban conditions. Unfortunately, it happens that such new plants well-feeling in the city, they begin to grow uncontrollably. These species of plants desired change in invasive plants and displacement of other plant species from urban spaces and substantially affect the rate of biodiversity loss. There is also the possibility of passing such invasive plants from the cities of natural spaces (e.g. *Acer negundo* L. and *Robinia pseudoacacia* L.). *Ailanthus altissima* (Mill.) Swingle is such a new and potentially dangerous species. It is typically a thermophilic species, because in many Polish cities it occurs in more and more areas. *Ailanthus* is one of the dominant trees in urban centres, such as Wroclaw. *Ailanthus altissima* (Mill.) Swingle, *Caragana arborescens* Lam., *Syringa vulgaris* L., *Acer negundo* L., *Gleditsia triacanthos* L. and other species may also appear in unusual places for its ecological optimum in the example of Warsaw. *Ailanthus* is a species of thermophiles and therefore urban conditions (a heat island effect) favour the development of trees and increase its population. Nevertheless, several-years locations of Ailathus outside the city are recorded, too. As an example of such a position serve urban forests in the northern border of the city. The observations were carried out from 2000 to 2018. Such a location of plants may be indicative of an adaptation to climatic conditions and a possibility of transition to natural plant formations. The simplified phenological observations are the main research tools. They allow you to conclude that plants growing in the central parts of the city have a long vegetation and stronger growth. However, in the locations situated on the outskirts of the city and in the urban forests, the growing period is shorter and plants often remain in the form of shrubs. These species belong to the thermophilic plants, but in just a few years, in the case of *Ailanthus*, and in a slightly longer time, in the case of other species, plants have managed to adapt to the habitat conditions in the cooler areas outside the municipal buildings. The only modification is that the course of their phenophases sometimes shortens the growing period to a few days.

Keywords: foreign species, invasive species, synantropisation, anthropological changes, urban forests

1 Introduction

Invasive species of plants and animals are a very serious problem today. The entry of invasive species into foreign ecosystems was considered a second direct reason for the reduction of the biodiversity, after the destruction of habitats. It is thought that foreign invasive species could cost the world economy up to 5% of world GDP (Pimental et al., 1999). Statistically, out of 10 species introduced to the crop, one 'escapes' to man. From 10 'escapees', one fruit starts to reproduce. And from 10 such species one becomes invasive. The problem of invasive species is constantly growing due to the expansion of the world trade, transport and tourism that could facilitate the introduction and spread of alien species in the environment. If for a given species the new environment is good enough, this species could survive and reproduce. Invasive species, without encountering natural enemies or other restrictions, could increase the area of their occurrence and displace the native species. The further climate change is highly dangerous for phytocenoses, air and water pollution, loss of habitats and every other anthropogenic change in the environment.

Home gardens and other fragments of vegetation are the most important sources of the biodiversity risk through a penetration of the introduced alien species. The use of ornamental trees and shrubs with a poorly understood response to new habitat conditions is of a particular importance in this respect, because they

Ewa M. Zaraś-Januszkiewicz, Szkoła Główna Gospodarstwa Wiejskiego – SGGW w Warszawie (Warsaw University of Life Science – WULS), Instytut Nauk Ogrodniczych – Institute of Horticulture Sciences, Katedra Ochrony Środowiska i Dendrologii – Department of Environmental Protection and Dendrology, Nowoursynowska 166, 02787 Warszawa, Poland
e-mail: ewa_zaras_januszkiewicz@sggw.pl

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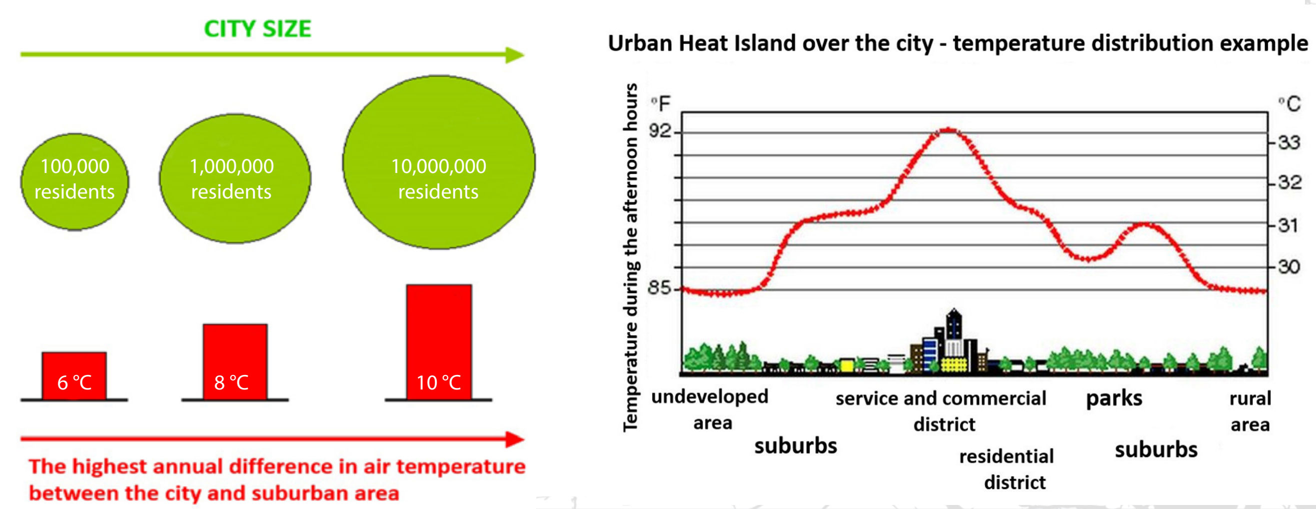
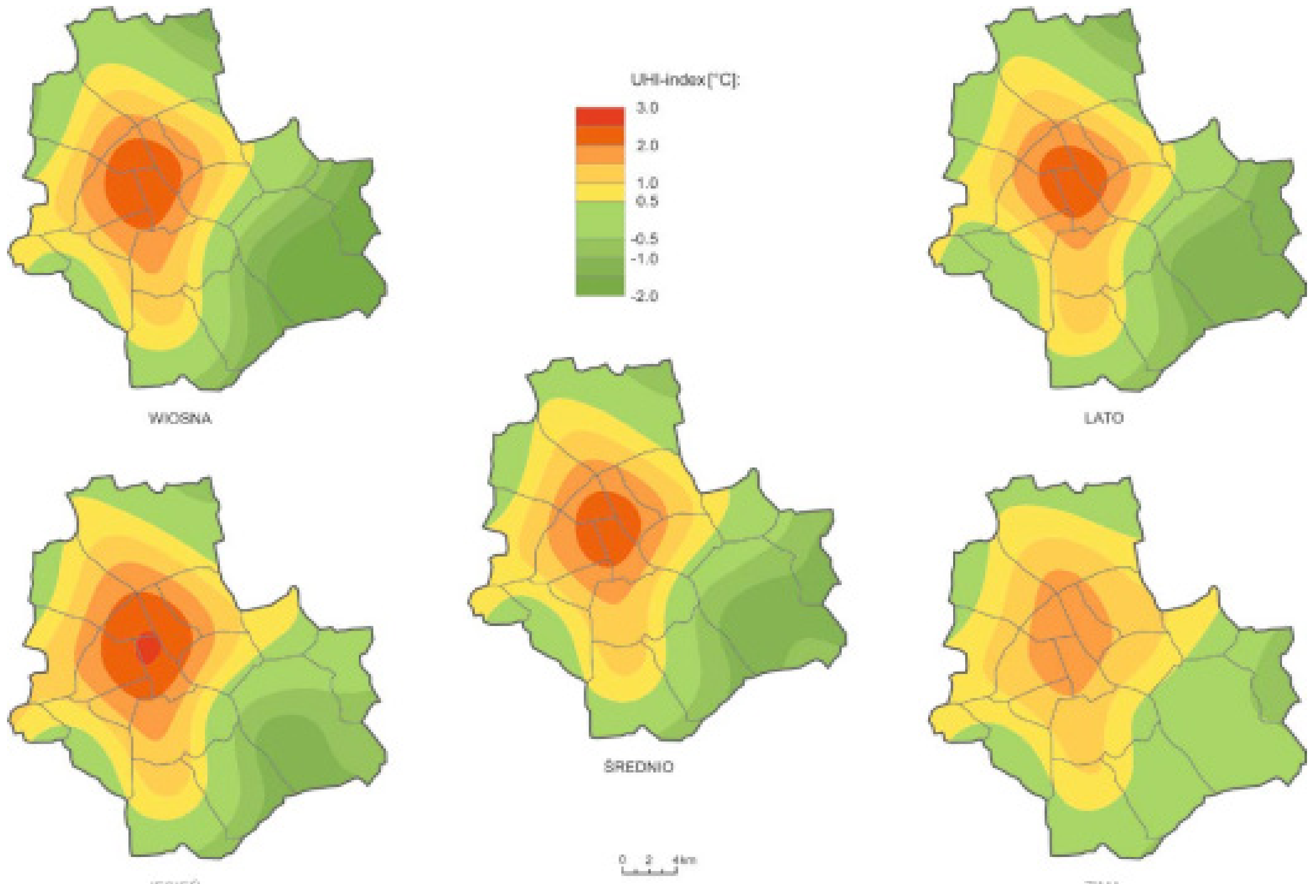
could lead to a long-term transformation of a floristic composition, forest and shrub structure, phytocenosis, especially if cultivated for a longer time and used in large clusters. The number of species of trees and shrubs of an alien origin used in forestry, horticulture and agriculture deliberately introduced by humans to increase a productivity and competitiveness (e.g. *Quercus rubra* L.) or planted as ornamental plants in gardens and parks (e.g. *Acer negundo* L.) has increased very much in the last 100 years. Very often, these species simply get out of control. Their expansiveness is expressed not only in the appropriation of space, but also in the unprecedented possibilities of adapting to the habitat and climate conditions. The examples of such species are *Ailanthus altissima* (Mill.) Swingle, *Caragana arborescens* Lam., *Syringa vulgaris* L., *Robinia pseudoacacia* L., *Gleditsia triacanthos* L., *Acer negundo* L. Although they are plants that largely prefer a gentler thermal environment, characteristic of the central parts of the city, they are increasingly getting into the open areas, where they create compact clusters that prevent the renewal of the natural plant-specific vegetation. The buffer zone of the Park Młociny, the forest complex on the northern part of the external districts of Warsaw, is an example illustrating such processes.

From the biodiversity point of view in the local or regional dimension, the emergence of an alien species is always a serious and a potential threat to native species: it introduces new interactions in ecosystems, habitats, in which it is often difficult to predetermine their degree of aggressiveness and ability of penetration of the alien species in natural or semi-natural ecological systems, often act as a reducing species for the native species (Olaczek 2000). Such a phenomenon was, for example, observed in a gypsy pine. *Ailanthus altissima* (Mill.) Swingle is a very competitive species for a large number of native and domesticated species of trees and shrubs (it produces up to 350,000 seeds per year, as it is a fast growing plant drowning the other plants that grow nearby and it also produces toxins that prevent their development). Its root system is so strong that it could destroy the foundations of buildings and the underground infrastructures like sewerage. *Ailanthus altissima* (Mill.) Swingle could also appear in its ecological optimum also in the atypical places outside the city. Nevertheless, for several years, the trees of heaven locations outside the city have been registered. The urban forests on the northern city border are an example of such a situation.

The aim of this work is to demonstrate the presence of *Ailanthus altissima* (Mill.) Swingle, *Caragana arborescens* Lam., *Robinia pseudoacacia* L., *Gleditsia triacanthos* L., *Syringa vulgaris* L., *Acer negundo* L. in various parts of Warsaw: in the centre (loc. 1), districts located on the periphery (loc. 2) and suburban areas (loc. 3), and the degree of an adaptation of a plant development to a less favourable habitat and thermal conditions. This adjustment is evident in the course of phenophases. The location of the observed dendrological specimens is conditioned by a temperature distribution of an urban heat island (UHI). Many factors contribute to the creation of the UHI. The number of city residents determines the creation of UHI. When it is 500,000–1 million, the inner city air temperature is usually higher by 1.1–1.2 °C than outside the city. The temperature difference increases



■ **Figure 1:** The dependence of the number of city residents and the heat island over the city on the maximum intensity of the urban heat island – an example of the temperature distribution
Source: Wypych and Bokwa, 2015



■ **Figure 2:** The thermal characteristics of the Warsaw heat island
Source: Błażejczyk, 2014

up to 1.2–1.5 °C, when the number of inhabitants exceeds 1 million. However, the highest observed values are much higher as shown in the Figure 1.

2 Material and methods

10 positions for each species in the zones with the UHI Isolation Index values were selected for an observation:

- 1.5–2.0 [loc. 1],
- 0.5–1.5 [loc. 2],
- -1.0–0.5 [loc. 3].

The observed species were: *Ailantus altissima* (Mill.) Swingle (Simaroubaceae), *Caragana arborescens* Lam., *Robinia pseudoacacia* L., *Gleditsia triacanthos* L. (Fabaceae), *Syringa vulgaris* L. (Oleaceae), *Acer negundo* L. (*Aceracea*). 20 specimens from each of the listed species were observed.

The observations covered the period from 2016 to 2017. The phenological observation method was used. The phenological observations were carried out on mature individuals (around 20 years old). The simplified set of

■ **Figure 3:** The intensity of the urban heat island in Warsaw (UHI-index) in the years 2011–2012, the average values
Source: Błażejczyk, 2014

phases was used to observe phenological phenomena (Koźmiński 1998):

1. Vegetative phases:
   - V-phase of a cultivation (V1 – swelling and cracking of buds, V2 – a leaf stage, V3 – a fall of the phase leaves).
2. Generative phases:
   - Fl – a flowering phase,
   - Fr – a fruiting phase (from a fruit harvest to maturity).

For each of the phenophases an average duration was calculated. The presented results show the averages from the observation period. The collected data of the duration of the individual phenophases from all years were analyzed by calculating the arithmetic mean of their duration.

3 Results and discussion

Currently, over 2,500 taxa of trees and shrubs grow in Poland, which is 10 times higher than the number of the indigenous tree species. Many of them may become the plants with an invasive life strategy in the future.

As the observations show, *Ailanthus altissima* (Mill.) Swingle definitely prefers places related to the occurrence of the phenomenon of the 'urban heat island'. The specimens of *Ailanthus altissima* (Mill.) Swingle in Warsaw are developing mainly in the central part of the city. Very often, they appear in the crevices of sidewalks and foundations of buildings, as are the crevices of hardened surfaces (e.g. concrete slabs). The silver birches (*Betula pendula* Roth.) resemble their developmental strategy. They form dense thickets through an intense growth of root systems and a development of rapidly growing root suckers. In the central part of Warsaw, most of the positions of groups, in which some plants were planted deliberately (e.g. parks, squares and adjacent green streets), and groups of plants spontaneously developing from root suckers or seeds could be distinguished.

The situation is slightly different in the case of other species of trees and shrubs. This is mainly due to the fact, that these plants were introduced to Poland much earlier and adapted to the prevailing climatic and habitat conditions. All analyzed species occur individually or in the concentrations with a similar frequency in the city centre to different radii. Concerning the similar frequency, it is possible find them in the suburban area also. In these locations, they constitute the most serious threat to the native plant communities. These phenomena are particularly well visible in the areas of the urban forest complexes.

The frequency of the occurrence of *Ailanthus altissima* (Mill.) Swingle decreases as we move away from the city centre.

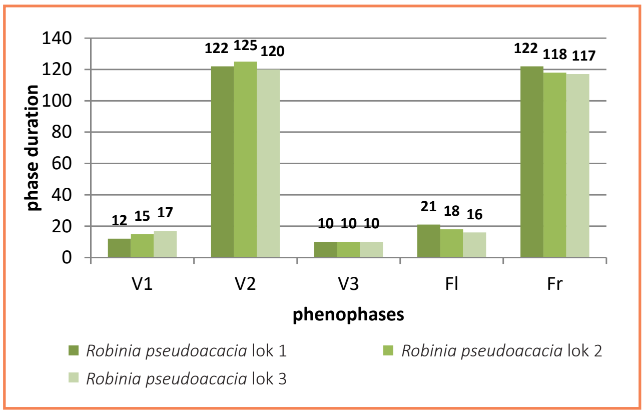
However, the presence of *Ailanthus altissima* (Mill.) Swingle outside the urban area, although found within the urban forests as well, such as the Młociny Park and the northern part of Warsaw, is the most interesting fact. *Ailanthus altissima* (Mill.) Swingle has got a certain limited ability to adapt to a growth under the less favourable thermal conditions.

The average lengths of each phase were used for the comparison. Comparing the average lengths of the individual phenological phases, one could notice that the specimens growing in the central parts of the city are characterized by the longer vegetative and generative phases, compared to other locations. The phase difference V2, between the copies growing in the city centre and the suburban areas, is up to 20 days. Similarly it is seen in the Fr phase, fruits in the city centre mature faster (as well as longer in the trees) than in the suburban areas. On this basis, it could be concluded that the heat island promotes an acceleration of vegetation and extends the duration of the individual phases. Generalizing, it could be said that the UHI promotes the occurrence and development of the thermophilic species.

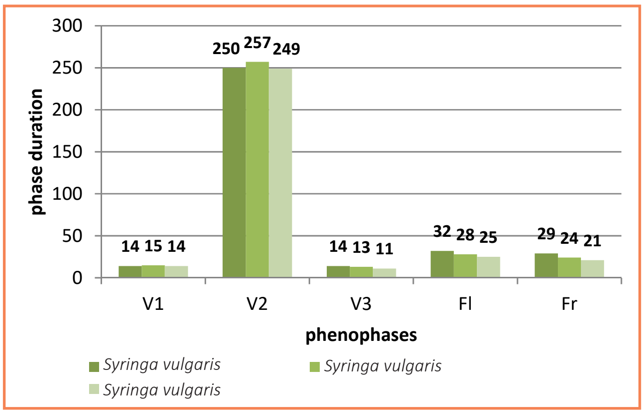
These observations indicate that the conditions in the central part of the city support the processes of synantropisation and confirm the thermal preferences of the species. However, this does not exclude the adaptation of species to less comfortable thermal conditions. In the case of specimens growing in the outer parts of the city, it could be observed that the plants do not form a tree. This happens due to the fact, that *Ailanthus altissima* (Mill.) Swingle is a typically thermophilic species, while in the suburban area the thermal balance is less favourable than in the central part of the city. The early spring and late autumn frosts are particularly destructive for the younger plants of *Ailanthus*. As a result, the plants stop during a bush stage.

However, it should be emphasized, that the unfavourable thermal conditions do not constitute a strong barrier to the development of this species, are not able to eliminate plants and do not prevent their self-renewal and independent spreading in the natural or seminal plant communities. *Ailanthus altissima* (Mill.) Swingle is propagated by seeds, but above all by the root suckers. These are the means by which plants form dense clusters hindering the development of other plants in their vicinity.

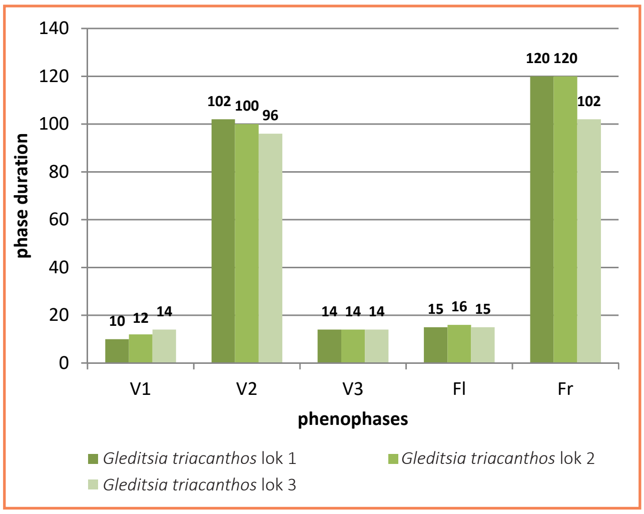
From the length of the individual phenological phases, very important conclusions could be drawn. The copies growing in the city centre start to grow faster (a difference up to 10 days). This occurs similarly in the end of the growing season. The end of the vegetation happens about 14 days earlier in the case of the specimens growing in the suburban zone in comparison to the specimens growing in the city centre.



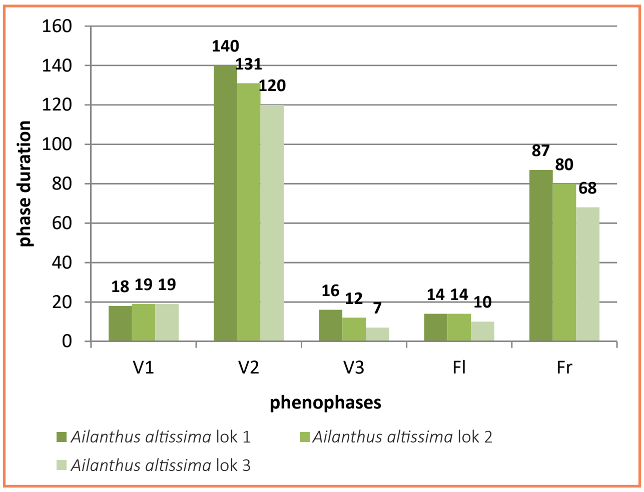
Robinia pseudoacacia



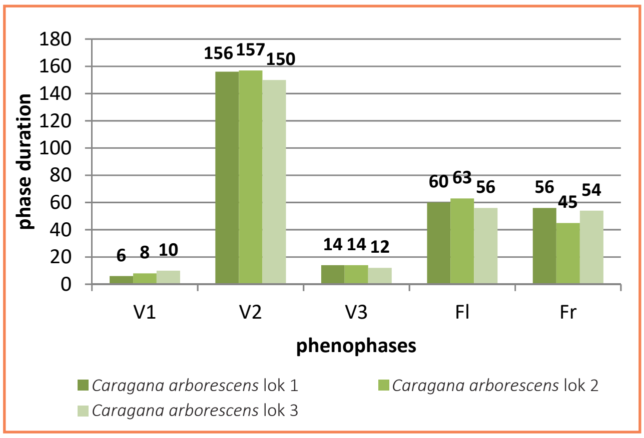
Syringa vulgaris



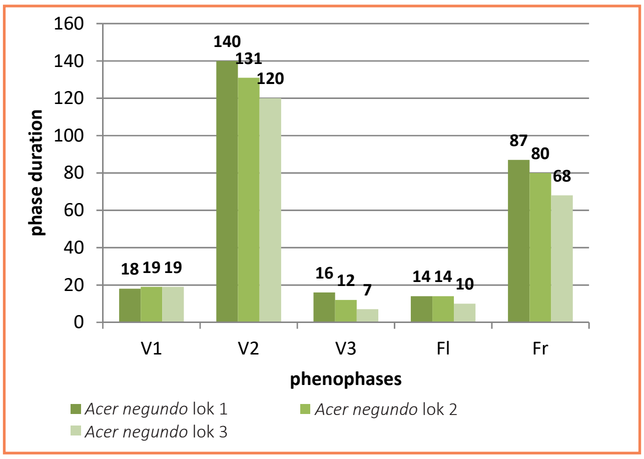
Gleditsia triacanthos



Ailanthus altissima



Caragana arborescens



Acer negundo

■ **Figurere 4:** The average duration of the selected phenophases
In three locations: loc. 1 – the city centre, loc. 2. – districts on the outer part of the city, loc. 3. – suburban areas

Other species of trees and shrubs show minimal and irrelevant differences in the length of the individual phenophases. This may indicate a very deep adaptation of these species to the climatic conditions prevailing in various habitats.

4 Conclusion

The process of synantropisation is particularly intense in the urban areas due to the specific habitat conditions difficult to accept by the native vegetation and the emergence of species of a foreign origin recruiting from the areas similar to the urban habitats, in particular in the field of heat. The great interest in the flora of the urban areas occurred almost 200 years ago (Jackowiak, 1998; Pyšek, 1989; Sudnik-Wójcikowska, 1998a). In particular, the interest concerns the species composition of the urban vegetation and its functions in the urban ecosystem, as well as the role of man in shaping the urban flora. In Warsaw, just like in Wrocław, the number of *Ailanthus altissima* (Mill.) Swingle increased in various habitats. The largest number of the individuals could be noted in the most transformed part of the city, the central part. Since *Ailanthus altissima* (Mill.) Swingle is characterized by a high resistance to the level of the soil salinity, it is often found in the inner-city areas, in the places associated with the greenery of the street areas. The number of idols has also increased in the industrial quarters. However, the tree of heaven particularly develops in the vicinity of parks, where such trees have been deliberately planted. *Ailanthus altissima* (Mill.) Swingle produces similar structures in Warsaw, Poznań and Wrocław, similarly also in Berlin, where trees usually appear in the same habitats (Kowarik and Bocker 1984).

The centre of a big city is warmer than the surrounding area due to the phenomenon of the 'urban heat island'. Its creation is controlled by various factors, such as the effect of building the insulation that results from the absorption of heat during the day and its emission in the evening, additional sources of heat emission generated by the industry, and most importantly, home heating. The occurrence of the thermophilic plant species, i.e. species of a foreign origin, as well as those subjected to the analysis is the result of the heat island existence. These species include also *Clematis* (Czekalski and Kidawska 2003) and *Buddleia davidii* Franch. (Kownas 1958). The distribution of *Ailanthus altissima* (Mill.) Swingle and other species in Warsaw (similarly in Wrocław in 1998–2001) is concentrated in the areas where the air temperature is by several degrees higher. Probably, the heat factor had a decisive influence on such distribution, because the species of synantropic plants, especially those with the invasive life strategies, come from the warmer zones and the thermal index is associated with the warmest areas of the Central European city and highly industrialized regions, e.g. in Duisburg, Berlin, Leipzig, Halle and Zurich, as well as on the French coast of the Mediterranean and the Ruhr area in Germany (1983a, 1983b, Kowarik, Kowarik and Böcker, 1984; Kunick, 1984; Landolt, 1991a, 1991b; Sudnik-Wójcikowska and Moraczewski, 1993; Sudnik-Wójcikowska, 1998a). In Poland, the occurrence of the analyzed species of trees and shrubs, in particular *Ailanthus altissima* (Mill.) Swingle in cities, was presented by Pacyniak (1976) and Sudnik-Wójcikowska (1998b) for Warsaw and Łódź. However, in the last decade, the appearance of *Ailanthus altissima* (Mill.) Swingle and other species outside the 'urban heat island' area may raise concerns about the process of wide changes in the natural plant communities. This may indicate both the climate change, expressed by the increasing thermal equilibrium and the systematic warming of the climate, as well as the adaptation of the species to the less favourable thermal conditions. This phenomenon is very unfavourable, because the species are characterized by a high expansiveness. Thus, they begin to appear in the natural as well as in the semi-natural forest complexes.

The executed phenological observations showed that plants growing in the central parts of the city have got long vegetation and a stronger growth. However, in the places located on the outskirts of the city and in the urban forests, the vegetation period is shorter and the plants often remain in the form of shrubs. The occurrence, and above all the length of the individual phenophases, is an indicator characterizing the urban island of heat. Therefore, the phenological research is a valuable complement to the climate research.

The central part of the city, with the warm island accompanying it, is the most favourable place for the invasive plants, as they could self-reproduce, sow and form thickets by root suckers there. This process is intensified more and more each year.

The vegetation length of *Ailanthus altissima* (Mill.) Swingle in the central part of the city reaches about 180 days and in the case of the suburban, this number is reduced to about 150 days. In the case of other species, the process of shortening of the vegetative phases outside the area of the 'urban heat island' is almost imperceptible.

The same relations of the duration of the individual phenophases and the location of the observed specimens could be seen in the case of the copies of all the analyzed species. In the case of all vegetative specimens, the prolongation of vegetation has been noticed.

In the last 20 years, the change of *Ailanthus altissima* (Mill.) Swingle occurrence zone from the only centre and outer parts greenery parts to the of the city and the suburban areas has become noticeable.

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CONTENTS

PLANTS
IN URBAN AREAS AND LANDSCAPE

BOTANICAL ROSES OF ABANDONED VINEYARDS

Katarína Rovná

Slovak University of Agriculture in Nitra, Slovak Republic

Roses are ancient cultural plants. The Slovak flora is very rich in rose species. As Větvička and Bertová (1992) mentioned, the first rose, which was introduced to the culture, was *Rosa* gallica and its cultivars. This study deals with a list of *Rosa* taxa found in the south-eastern area of The Low Carpathian region. *Rosa* taxa are published with their primary description. The aim of our work was to revise species which were described by rhodologists as Holuby (1912) Klášterský (1901–1979) and others who carried out the botanical research in The Low Carpathian region. Our research was executed in the localities of Líščie stráne, Dolné trávniky in the town of Modra and Vimpergy in the town of Pezinok. The data used in the study were obtained from Flora of Slovakia IV/3. In this paper, *Rosa* species found in abandoned vineyards are listed with their characteristics and uses.

Keywords: abandoned vineyards, biodiversity, utilisation, *Rosa* species

1 Introduction

The history of vine-growing in Slovakia dates back to the Celts, but the role of the founder of the Slovak viticulture is attributed to the Roman Emperor Marcus Aurelius Probus. During his reign in the third century AD, the Roman legions conquered almost whole Europe and established vineyards in the area of the present city of Bratislava (The Low Carpathian region) and in the Tokaj region.

King Andrew II had a great merit in the development of vineyards and viticulture. With the privilege called Golden Bull, he confirmed large freedoms to winegrowers in 1222.

Most of the vineyards were destroyed after the invasion of the Tatars in 1241. However, with the help of colonizers, concerning the Low Carpathian region, they were Germans, the vineyards managed to recover quite quickly (Žudel and Dubovský, 2006).

Since The Middle Ages, the method of a vineyard management has been on a high level. Traditionally, the cultivation of vineyards is associated with a very difficult labour.

The difficulty of the vine-growing as a crop-growing on the northern border of its geographical distribution in Europe was one of the main reasons why some vineyards in Slovakia were not cultivated in the past (Vanya, 2015).

The greatest decline in viticulture in Europe occurred in the second half of the 19th century due to the introduction of previously unknown diseases and vine pests (powdery mildews, but mainly phylloxera, which was imported together with the American vine).

In the beginning of the 20th century, the first abandoned vineyards, so-called pustáky, appeared and spread. Later, the winegrowers partially reclaimed them and started to use other non-renewed parts in a different way.

The area of the abundant vineyards has gradually increased. Some small vineyards were destroyed and transformed into grassland (grassland) or other cultures. However, many vineyards remained privately owned by co-operatives who had no longer been able to maintain them or have lost interest in them.

The real area of pustáky (the abandoned vineyards) in Slovakia is not known. During the first registration of vineyards (The Central Control Institute of Agriculture, 1996), only 9,300 ha were registered, which equals approximately half of their real area.

The areas of the abandoned vineyards are identified by the orthophotographs using GPS system, for which the geostationary satellites are used over the territory of the Slovak Republic. In this way, not only the cultivated, but also the abandoned vineyards could be registered (Eliáš, 2009).

Katarína Rovná, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Planting Design and Maintenance, Tulipánová 7, Nitra, Slovakia
e-mail: katarina.rovna@uniag.sk

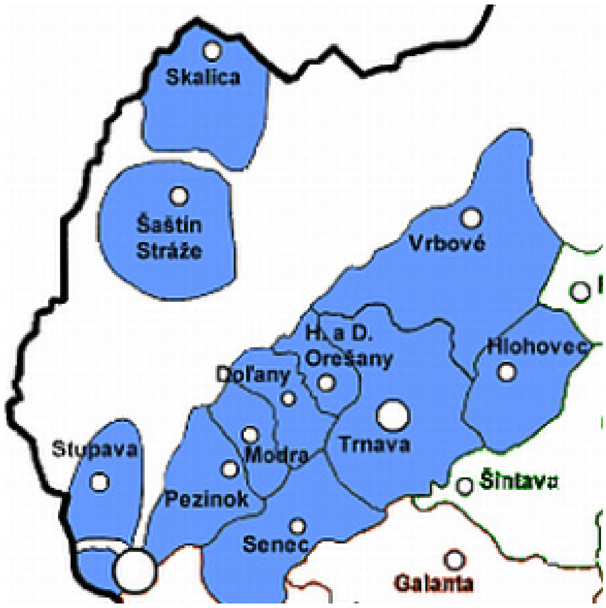
1.1 Succession process of the abandoned vineyards

Eliáš (2009) divides the process of succession in the abandoned vineyards into four stages:

1. The first successive stage (one to three years after the abandonment) consists of annuals, winter and two-year types of weeds and ruderals. The number of weeds and ruderal plants increases, in particular the species *Lactuca serriola*, *Conyza canadensis*, *Convolvulus arvensis*, *Cardaria draba*, *Agropyronrepens*, *Achillea millefolium* and *Arrhenatherum elatius*.
2. The second successive stage in the subsequent years (from three to six, up to ten years), perennial herbs and grasses are increasingly used. High perennial herbs, such as *Artemisia vulgaris* and *Tanacetum vulgare* are used predominantly on loamy soils, *Echium vulgare* and *Melilotus officinalis* predominantly on sandy soils and *Agropyron repens* on heavy clay soils.
3. The third successive stage (after more than 10 years) consists of semi-natural and natural communities of perennial grasses, dominated mainly by *Arrhenatherum elatius* on clay soils and *Calamagrostis epigeios* on sandy soils.
4. The fourth successive stage in the abandoned vineyards consists of stands of trees – shrubs and trees. These are usually deciduous and have a xerothermic character (the class *Quercetea pubescentis-petraea*). The coppices of *Pinus sylvestris* and *Robinia pseudacacia* may develop on sandy soils. On the southern slopes of the Low Carpathians near the city of Bratislava and towns of Pezinok and Modra, oak forests of the *Querco-Fagetea* class grow today.

2 Material and methods

The monitoring of *Rosa* sp. in the abandoned vineyards was carried out by field observations in the years 2009–2017. The Low Carpathian region is a very rich floristic area of Slovakia. The observed areas were in the town of Modra and Pezinok. In the town of Modra, there were localities as Líščie stráne (230 m ASL) and Dolné trávniky (255 m ASL) and in the town of Pezinok, there was the locality of Vimpergy (226 m ASL). Keys for the identification of roses, set by several authors (Klášterský, 1969; Větvička, 1992; Kerényi and Nagy, 2010), were used to determine the individual types of roses and also the findings were confronted with Flora of Slovakia IV/3.



■ **Figurere 1:** The Low Carpathian wine growing region
Source: http://www.vino.sk/encyklopedia-vina/vinohradnicke-oblasti/slovensko-malokarpatska-vinohradnicka-oblast/

The researched areas are situated on the slopes of The Low Carpathian hills, in the town Modra and in the cadastral area of the town of Pezinok. The localities in the town of Modra are exposed to the southeast, as well as the locality in town of Pezinok. According to Pospíšilová et al. (2005), the Low Carpathian vineyards extend on the southwest slopes of the Little Carpathians from the city of Bratislava to the municipality of Horné Orešany. The geological substrates consist mainly of the alluvial cones of the Low Carpathian streams, and there are loamy-sand and medium skeleton soils. In this sub-area, 7 wine growing regions – Bratislava, Pezinok, Modra, Doľany, Orešany, Senec and Trnava are ranked there (see Figure 1).

Table 1 The climatic characteristics of the studied localities

Locality	Geomorphologic unit	Exposure	Elevation (m)	Average temperature (°C)	Average rainfall (mm)
Pezinok	Low Carpathians	SE	226	10	750
Modra	Low Carpathians	SE	230–255	8,21	845

Source: https://zbgis.skgeodesy.sk/mkzbgis/?bm=zbgis&z=11&c=17.259969,48.324955#/detail/ease/igfzIWsBSy_Kk5t4oqfH
http://www.podnemapy.sk/portal/reg_pod_infoservis/klima/klima.aspx

The Low Carpathian wine growing area is the most intensive and one of the in Slovakia. The area of the registered vineyards covers an area of 5,359.2 ha. With its climatic characteristics, it is suitable also for many other species such as *Sorbus domestica*, *Castanea sativa*, *Mespilus germanica*, *Prunus spinosa* and *Rosa* species and many other fruit trees and shrubs.

The typical areas of the European rose sections according to Větvička (2001) are as follows:

- *Cinnamomeae* – forest slopes, forest edges, basin bottoms, inverse positions.
- *Caninae* – forest edges, lighted places.
- *Pimpinellifoiae* and *Rosa* – steppe, rocky scree, rock crevices.
- *Synstylae* – deciduous forests.

3 Results and discussion

This paper reports on the information about all the species, their distribution, potentially useful characteristics and the utilization of *Rosa* species in the abandoned vineyards in the Low Carpathian region.

Rosa species found in the abandoned vineyards:

- *Rosa canina* L.

– grows in forests and at the edge of forests as a liana, or in open spaces, where it creates from 1 to 3 m high shrub with short branches. It grows abundantly throughout Slovakia, from lowlands to hilly areas. Secondary, it grows on banks, pastures, abandoned fields and vineyards. Branches are covered with irregularly distributed sharp and hooked prickles. The leaves are pinnate, with 5–7 leaflets. Flowers are usually single and pale pink, sometimes white. Calyx leaves, first three pinnately clipped, the last one only with a half, fall off before fruits ripen. Hypanthium is variable, elliptic, ovoid, pear-shaped, spherical, compressed-spherical, bland or rare, glandular and orange red to brown red (Větvička and Bertová 1992). The flesh contains a high level of antioxidants, mainly polyphenols and ascorbic acid, carotenoids and the vitamins B and E (Nybom and Werlemark, 2017). Fruits are noted for their high content of the vitamin C and are used in tea or marmalade (Vogl et al., 2013). *Rosa canina* L. and its population are most often used as a rootstock (Větvička and Krejčová, 2001; Větvička and Bertová, 1992). It grows well in the sunny and dry locations (Lindtner et al., 1971), mainly on limestone; its maximum reaches 1,700 m ASL. (Ercisli, 2005). Its frequent occurrence is in the town Modra – Líščie stráne and Dolné trávniky and in the town of Pezinok – Vimpergy.

- *Rosa agrestis* Savi.

– although it is present in the Carpathian and the Pannonian region, it is nowhere particularly abundant. It prefers non forest areas, usually banks, pastures, abandoned fields and vineyards, sunny and dry locations, most frequently on limestone. Its maximum reaches about 1,000 m ASL. Populations consist of a few individuals. It forms a dense, scattered shrub, which is 1.5–2 m high. The shrub creates straight or curved branches. Prickles are strong, banded or hooked. Leaves are pinnate, with 5–7 leaflets and are fragrant (have got an apple fragrance) (Větvička and Bertová, 1992). Small flowers are grouped in sparse white blossoms. Calyx leaves are richly pendant, after flowering bent back. Fruits vary in size and shape. However, they are often small (10 mm), elliptic or wide elliptic, spherical and red. It is a less common rose; the fragrance of its leaves is interesting. Neither economical nor ornamental values are reported (Ercisli, 2005). Small populations were found in the town Modra – Líščie stráne and Dolné trávniky and in the town of Pezinok – Vimpergy.

- *Rosa rubiginosa* L.

– creates a dense shrub 1.2–2 m high, with upright or bent branches. Branches are densely spiny, prickles are hooked, mixed with thin and almost straight prickles. Leaves are pinnate, 5–7 leaflets, with numerous glandular hairs and strong apple fragrance. The flowers are deep-pink with a white base. Calyx leaves, first three pinnately clipped, last one only on one side, remain upright on mature fruits. Fruits are mostly ovoid, spherical, or narrowly elliptical, small (less than 10 mm) or big (over 15 mm), orange red and when mature, they are soft. Fruits endure well the winter. It grows on limestone, on sunny locations. Its maximum reaches about 1,050 m ASL. Hips are very rich of the vitamin C and are used for tea (Větvička and Bertová, 1992; Nybom and Werlemark, 2017). These were found in the town of Modra – Líščie stráne and Dolné trávniky.

- *Rosa inodora* Fries.

– a dense shrub, 1.5–2 m high. Spiked branches are both upright and arched. Leaves are pinnate, 5–7 leaflets, with an intensive apple fragrance. Flowers are grouped in sparse blossoms (approx. 3 flowers), that are light-pink or white and slightly fragrant. Calyx leaves are long and narrow, first three only with few pendants. Fruits are spherical, ovoid, pear-shaped, smooth, shiny, orange red and soft when mature. It often grows on sunny slopes (Eliáš ml., 2016) of limestone, or sand, or pastures and forest edges (Větvička and Bertová, 1992). The occurrence is marked in the town Modra – Líščie stráne and Dolné trávniky.

Table 2 The ethnobotanical features of the rose species found in the abandoned vineyards

	Rosa canina	*Rosa agrestis*	*Rosa jundzillii*	*Rosa micrantha*	*Rosa rubiginosa*	*Rosa inodora*	*Rosa dumalis*
Medicinal uses	+++	-	-	-	+++	-	-
Rootstock	+++	-	-	-	-	-	-
Fresh fruits	+++	-	-	-	+++	-	++
Gardening	++	+++	++	++	+++	+++	+++

Source: Větvička and Bertová, 1992; Lindtner et al., 1971, author's findings
+++ high, ++ medium, - low

■ *Rosa micrantha* Borrer ex Sm.

– an irregular, sparse, 1.5–2.5 m high shrub. Prickles are usually hooked, rarely mixed with acicular prickles. Leaves are pinnate, 5–7 leaflets, on the back with thick hair and glands and with an apple fragrance. Flowers are light-pink, single and with longer peduncle; or three that arranged on a short peduncle. Calyx leaves, first three are with pendants, usually with gland. After flowering, they bent backwards and subside shortly afterwards. Hips are ovoid, narrowly elliptical, small, red and soft when mature. It grows on sunny non-forest areas, pasturelands and abandoned vineyards (Větvička and Bertová, 1992) in the north-western and Central Europe. The occurrence was marked in the town of Modra – Líščie stráne, and in the town of Pezinok – Vimpergy.

■ *Rosa dumalis* Bechst.

– this grows like a shrub, having 1–3 m in height; often a dense, multi-stem shrub, with upright or bent branches. Prickles are uniform, of different size, bent or hooked. Leaves are pinnate, 5–7 (9) leaves. Flowers are rarely single; usually 3–5 are arranged together, rarely white, pink, light-pink or deep-pink. First three calyx leaves with one or more pairs of pendants. Hips are big, orange red or deep red and soft when mature (Větvička and Bertová, 1992). It grows in light forests, forest edges, but also in grasslands and open areas. It could reach the maximal elevation of 1,200 m ASL. The occurrence was marked in the town of Modra – Dolné trávniky and in the town of Pezinok – Vimpergy.

■ *Rosa jundzillii* Besser

– this species creates an erect or hanging shrub, which is 1 m high. Prickles are narrow, straight or bent. Leaves are pinnate, 5–7 leaflets. Flowers arranged in a group of 2–3, petals are large, pink or deep-pink. Calyx leaves are pinnately clipped, pendants are long and narrow. Hips are spherical. It is common on open slopes, sloping hillsides along roads, dry hillsides, pastures and abandoned vineyards. It could reach the maximal elevation of 1,000 m ASL (Věvička and Bertová, 1992; Nilsson 1997).

4 Conclusion

The area of the abundant vineyards has gradually increased. Some small vineyards were destroyed and transformed into grassland (grassland) or into other cultures. However, many vineyards have remained privately owned by owners who have no longer been able to maintain them or have lost interest in them.

Vineyards, together with orchards, evoke a special landscape phenomenon – a vine-growing cultural region, which deserves its borders and protection (Eliáš, 2009). The Low Carpathian vineyards, since they create a secondary natural community, are rarely a natural and economic land, which is why its development and protection is needed.

The vineyards' landscape and its beneficiaries may use the natural trails to acknowledge nature. For example, in the area in the town of Pezinok, Wine Nature Trail was established. The abandoned vineyards could also become an attraction of wine roads that pass through Slovakia, as they are witnesses of the time, either the past, or the present one.

Some *Rosa* species have got important ethnobotanical features (Ercisli et al., 2005; Çinar et al., 2005), concerning e.g. a high content of the vitamin C as is in the species of *Rosa canina*, *Rosa rubiginosa*. Moreover, some are glandulous and release an apple fragrance in humid conditions, as for example *Rosa rubiginosa* and *Rosa agrestis*. These characteristics were found interesting for further landscape uses.

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CONTENTS

PLANTS
IN URBAN AREAS AND LANDSCAPE

IMPACT OF PUBLIC PARKS LOCATION IN CITIES ON RICHNESS AND DIVERSITY OF HERBACEOUS VASCULAR PLANTS ON THE EXAMPLE OF CRACOW (SOUTHERN POLAND)

Łukasz Moszkowicz*, Izabela Krzeptowska-Moszkowicz

Cracow University of Technology, Cracow, Poland

The richness and diversity of greenery in the classic monocentric model of a city increases with the distance from its center. Some elements of greenery in the layout of urban space do not show this principle, that is, their location in a given zone in the city does not affect their richness. This article tested whether the richness and diversity of herbaceous vascular plants of parks depends on their location, on the example of the city of Cracow. The research indicates that in relation to distance from the city center to parks, the herb layer of Cracow's parks has an azonal character, meaning that its richness does not depend on park location. However, as Cracow does not have a typical monocentric character, taking into account several urban centers around which city has developed, the richness and diversity of the herb layer of parks shows a favorable relationship along with the distance from these centers.

Keywords: plant richness, public parks in Cracow, herbaceous plants

1 Introduction

In the classic monocentric city model, the center is the most transformed and poorest in the spontaneous plant species. The closer to the periphery of the city, the richness increases linearly (Kowarik, 1990; Jackowiak, 1998; Fudali, 2005). Some authors (Chojnacki, 1991) believe that the vegetation in the central part of the city is the result of influence of only urban anthropogenic factors, while on the periphery, vegetation is shaped by habitat factors. It is believed that parks are those elements that have an azonic character, i.e. they do not follow this rule (Olaczek, 1996), do not preserve the zonal distribution of urban flora variation (Jackowiak, 1990; Sudnik-Wójcikowska, 1987; Sukopp, 1990; Fudali, 1994; Sukopp and Herbert, 1998; Hohenwallner, 2000; Fojcik and Stebel, 2001). The aim of the following study is to check whether this rule also applies to the park herb layer and it exhibited azonality, or whether the park's location in the city of Cracow affects its richness and floristic diversity

2 Material and methods

2.1 Study Area

Cracow is a geomorphologically diverse city. Different geographic and phytogeographic regions are in contact here (Kondracki and Richling, 2001; Kornaś and Medwecka-Kornaś, 1974). It is crossed by the Vistula valley running from east to west. To the southern part of the city, the Carpathian Foothills reach the flysch type, from the north-west the Krakowsko-Częstochowska Upland with the Jurassic limestone rocks, and from the north-east the Miechowska Upland (Proszowicki Plateau) with a chalk base covered with loess. This affects the large floristic richness of the Cracow area. The flora of vascular plants is estimated at about 1,330 species (Trzcińska-Tacik, 1979), the distribution of most of them is reported by Flora Cracoviensis Secunda (Zając et al., 2006). Around 100 plant communities are known from the area of Cracow (Dubiel, 1991; Dubiel and Szwagrzyk, 2008). The vegetation of the city consists of many different areas of a natural or semi-natural nature, including Sikornik and Sowiniec massif, Tyniecki Forest, Pychowickie Meadows, Nowohuckie Meadows, Skałki Twardowskiego forest, Krzemionki, Bodzów, riparian flora of Vistula, Dłubnia, Rudawa and Wilga river, meadow or scrub communities in undeveloped areas (Dubiel, 1991). The complement of natural, semi-natural and synanthropic vegetation is composed greenery, in which public parks have a significant participation.

The majority of Cracow's public parks are located on flat areas, although some of them contain artificial

Łukasz Moszkowicz, Cracow University of Technology, Institute of Landscape Architecture, Warszawska 24, 31-155 Cracow, Poland
e-mail: lmoszkowicz@pk.edu.pl; ikrzepto@pk.edu.pl

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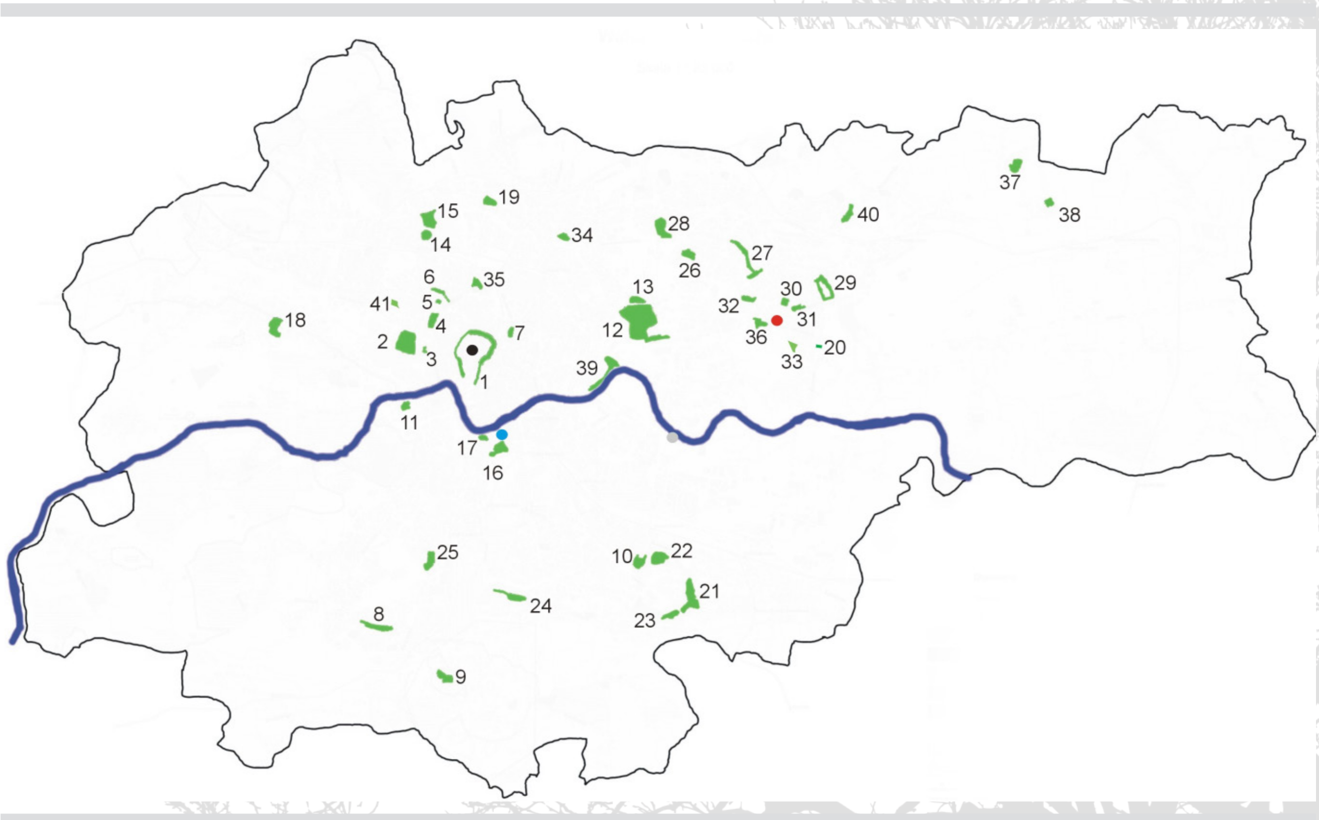
elements of land development, and the habitat and soil conditions are relatively little varied in individual parks. Parks located in the city center occur on anthropogenic soils (Wójcik, 2007) typical for cities, except for the Bednarski Park. The natural character of the habitat has been preserved, for example, in Łuczanowice and partly in Swoszowice. Parks are located in various parts of the city with fewer outlying areas (Figure 1). In most of the parks studied in Cracow, greenery managements are carried out. They are relatively often mowed, although there is variation in the intensity of these activities, sometimes you can observe the most planted bulb plant species, or even the removal of turf and sowing grass.

Cracow is not typically a monocentric city because it consists of three centers around which the city has developed (Bieniarzówna, 1992, 1997). The oldest part, currently the city center, is the Old Town with a centrally located Main Market Square; the history of this part of Cracow dates back to the 9th century, when a settlement was established in this area. Another center is Podgórze Market Square, which was the center of Podgórze, which was included to Cracow in 1915. The last such center is the Central Square around which the youngest part of Cracow, Nowa Huta, was developed. This part of Cracow was closely related to the steel industry developing in this place after the World War II. This all urban layout was additionally disturbed by included suburban areas and villages during the city growth.

2.2 Data Collection

The number of researched parks was limited to 41 (Figure 1), which, due to their functions, structure and composition, are public parks (eg. Fudali, 2005). A part of various types of urban greenery referred to as parks are omitted because they are:



Figurere 1: The distribution of researched parks in Cracow

1 – Planty Krakowskie Park, 2 – Jordan Park, 3 – Park nearby Jagiellonian Library, 4 – Krakowski Park, 5 – Teodor Axentowicz Square, 6 – Młynówka Królewska Park – east part, 7 – Strzelecki Park, 8 – Macka i Doroty Park, 9 – Swoszowice Park, 10 – Jerzmanowskich Park, 11 – Dębnicki Park, 12 – Lotników Polskich Park – south part, 13 – Lotników Polskich Park – north part, 14 – Wyspiański Park, 15 – Krowoderski Park, 16 – Bednarski Park, 17 – Nowacki Square, 18 – Decjusz Park, 19 – Kościuszki Park, 20 – Klasztorna, 21 Aleksandra Park – south part, 22 – Lilii Wenedy Park, 23 – Rżąska Park, 24 – Kurdwanowski Park, 25 – Solvay Park, 26 – Dywizjonu 303 Park, 27 – Planty Bieńczyckie Park – south part, 28 – Tysiąclecia Park, 29 – Zalew Nowohucki Park, 30 – Ratuszowy Park, 31 – Szwedzki Park, 32 – Wiśniowy Sad Park, 33 – Żeromskiego Park, 34 – Zaczarowanej Dorożki Park, 35 – Kleparski Park, 36 – Kultury Park, 37 – Park in Łuczanowice, 38 – Wadów Park, 39 – Dąbie Park, 40 – Zielony Jar Park, 41 – Saint Vincent de Paul Park. Dots on the map: Black – the Main Market Square (Rynek Główny) – middle of the city, grey – geometric middle of the city, blue dot – Podgórze Market Square (Rynek Podgórski) – center of Podgórze district, red dot – Centralny Square (Plac Centralny) – center of Nowa Huta district

- narrow green lanes with the character of squares (eg. Planty Dietlowskie Park, fragments of Vistula Boulevards);
- surroundings of forts (eg. Batowice fort);
- areas occupied by natural and semi-natural vegetation, which are not characterized by a typical layout of public parks such as " Wolski Forest", "Witkowice Forest Park";
- which are divided and not available for the public (eg Jalu Kurka Park),

The analyzed parks are located in the historic center of the city, as well as between older and newer housing estates or at the city's administrative boundaries.

In the analyzed parks, herbaceous vascular plants were noted during observations led in years 2016–2017. Each park was searched no less than 3 times during the growing season, from April to September, in order to obtain the most complete list of species.

In this work, compositional elements such as flower beds, rebates and so-called flower meadows, were omitted. These are the elements intentionally created by men and their richness and diversity is associated with the intentional action of men.

The number of species found in individual parks, the number of families represented, and then the Shannon-Weaver index (Shannon and Weaver, 1963) and the Simpson domination index (Chmiel, 2006) were determined.

For the purpose of checking the hypothesis, distances from the means of parks to individual points were calculated; yielding the following variables:

- distance to the central point defined as the middle of the Main Market Square in Cracow;
- distances to the geometric center of the city,
- distances to the central points of the Main Market Square, Podgórski Market Square and the Centralny Square,
- the shortest distance from the park to the city's administrative boundaries.

The collected data were presented in the graphs.

2.3 Data Analysis

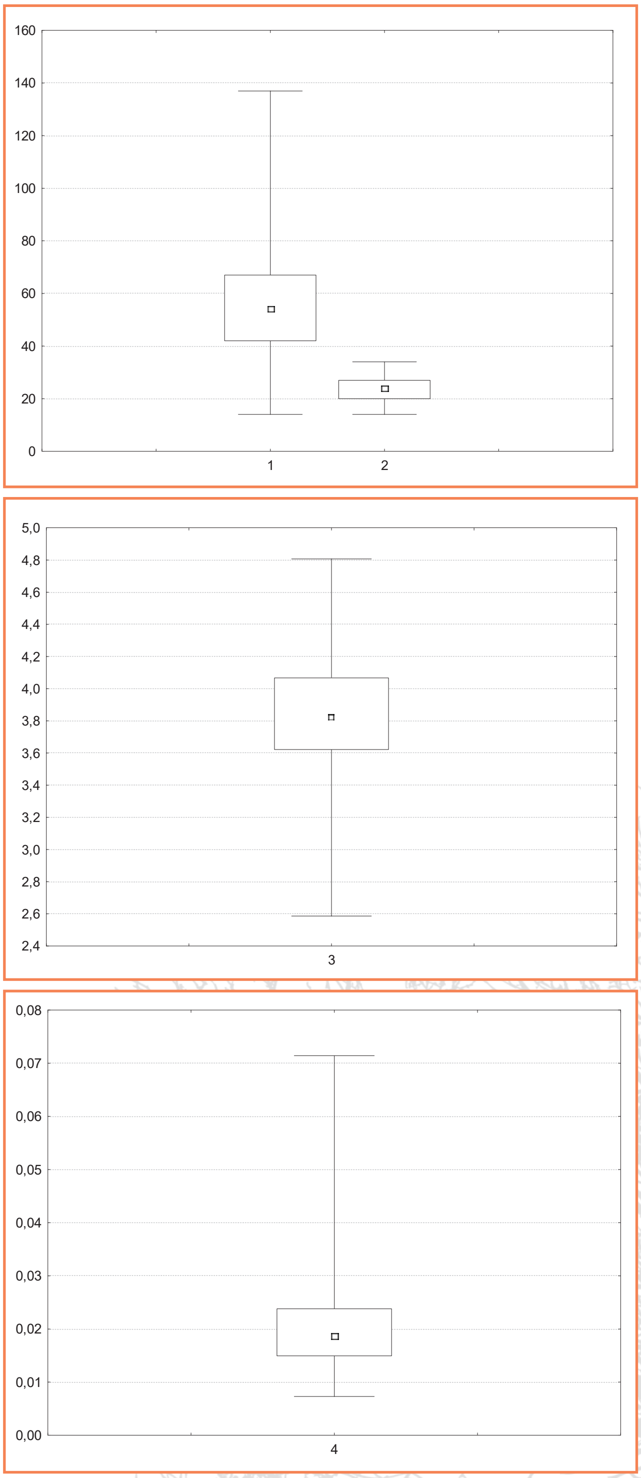
It was checked whether the tested independent variables regarding the distance of parks have a normal distribution, and their skewness was also tested. Because the variables did not show much skewness and their transformation did not improve, the data was left without transformation. For the number of species, number of families, the Shanon-Weaver diversity index and the Simpson dominance index, a separate regression model was created taking into account the four independent variables given above. In order to avoid spatial autocorrelation, only results with the highest statistical significance were taken into account.

3 Results and discussion

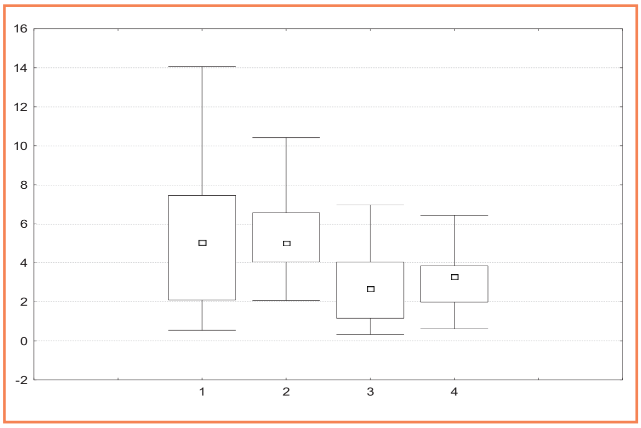
There were noted 273 species of herbaceous vascular plants (Moszkowicz and Krzeptowska-Moszkowicz 2019) in the herb layer of the studied parks in Cracow. Majority of them was found in the southern part of the Lotników Polskich Park – 137 species. The smallest portion (14 species) was identified in Strzelecki Park. On average, 55 species were recorded in the parks and the number of represented families was 24 (Figure 2). While the average number of species and families was closer to the bottom of the chart, the average diversity index almost in the middle (3.8) of its range (2.6–4.8). The dominance index, in turn, was located in the lower part of its values and amounted to 0.02 with values from 0.007 to 0.07. On this basis, it can be concluded that most parks are characterized by lower species richness and average diversity and low species dominance (Figure 2).

Based on Figure 2, it can be concluded that the median distance from the park to the middle of city is about 5 km (1) and 3/4 of them is located within the distance of 8 km from the Main Market Square. They are particularly concentrated near historic development centers (3), and over ¾ occur at a distance not exceeding 4 km from adequate centers. It can also be seen that most parks are located within rather thin compartment of distances from the geometric middle, i.e. from 4 to 6.5 km (2). Therefore, one would expect that more parks have long distances from the city border. A half of Cracow's parks are just 2 to 4 km (4) from the city limits. To take a closer look at these location features, a scatterplot (variability) with a simple match was made:

As presented in Figure 4, a negative correlation is present, but further location of the park from the adopted center is not always similar with closer distance to the city limits. There are parks whose distances are equal but, for example, smaller as in the case of Planty Bieńczyckie Park (1.7 km and 2.1 km) or similar but larger as in the case of the southern part of the Lotników Polskich Park (4.1 and 3.9). It indicates a certain unevenness of the administrative and urban planning system and the city boundaries. And the visible confidence interval for the linear value of a simple match between distances from centers and to the city limits indicates that larger number of parks in urban space is outside the 95% confidence interval.

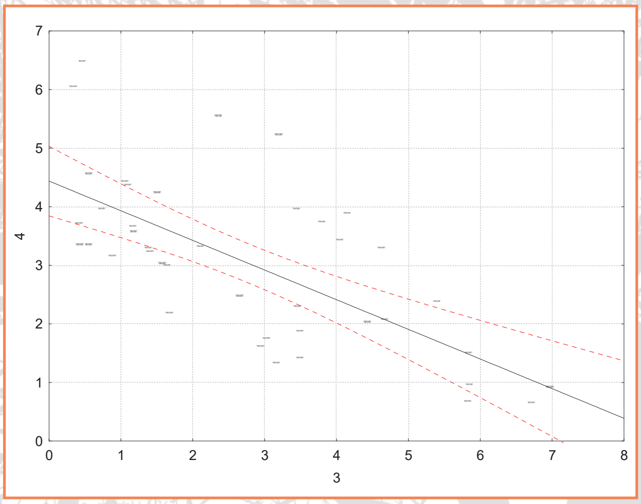


■ **Figurere 2:** Median, percentiles (25–75% of the value) and the range of variables for the number of species (1), number of families represented (2), Shanon-Weaver diversity index (3) and Simpson domination index (4) in the herb layer of Cracow parks



■ **Figurere 3:** Median, percentiles (25–75% of value) and the range of variables for (*X* axis): distance of parks from the city center (1), from the geometric city center (2), from centers around which the city grows (3) and the shortest distance from the city limits to the park (4). Distances (*Y* axis) expressed in kilometers

The impact of the studied factors on selected indicators of richness and diversity is rather small, explaining only between 12% and 24% of volatility (Table 1). It means that the richness and diversity of the herb layer of the parks studied are determined by other factors than the park's location. The distance from the middle of the city and the geometric middle did not show dependence, i.e. they would indicate the azonal nature of the herb layer of Cracow's parks. However, taking into account the historic development centers, there is a statistically highly significant relationship indicating the impact of the park's location in the city on the richness



■ **Figurere 4:** Scatter plot of the parks' distance from individual urban centers to the parks (*X*-axis) and from the parks to the nearest city border (*Y* axis). Correlation coefficient -0.67, confidence interval 95% – set with dashed lines

Table 1: Results of multiple regression for richness and diversity indicators of park location.

	Number of species	Number of species families	Shannon-Weaver index	Simpson index for species
Distance from urban centers to parks	0.67***	0.76***	0.65***	-0.348266**
Distance from the border of the city to parks	0.47**	0.49**	0.38*	
R^2	0.24	0.32	0.23	0.12

Statistical significance: *0.1> *p* >0.05; **0.05> *p* >0.01;* ***p* <0.01

and diversity of its herbaceous vascular plants. The indicators grow according to the increasing distance from urban centers. Therefore, the herb layer of parks in Cracow is not fully attributed to the azonality parks.

Also, a positive relationship shows the distance from the city borders. This is the result of a rather irregular arrangement of greenery and city borders (Figure 1, Figure 3), which could have affected the less statistically significant impact of the distance from the periphery to parks for the richness of herbaceous species and families.

Herb layer of parks is developed by habitat conditions and human activities. The climatic and habitat conditions within the urban space are usually homogeneous, more significant is the local variation that forms the system of microbiotopes (Fundali, 2005). Although the natural location of Cracow causes its large natural diversity and rich flora of vascular plants (Trzcińska-Tacik, 1979; Dubiel, 1991), this influence a little the richness and diversity of vascular herbaceous plants of city parks (Moszkowicz and Krzeptowska-Moszkowicz, 2019). Thus, the suggested azonal nature of parks in urban greenery (Jackowiak, 1990; Sudnik-Wójcikowska, 1987; Sukopp, 1990; Muller, 1993; Fojcik and Stebel, 2001) is also reflected in the park herb layer. This azonality is not observed if we analyze the parks location in relation to the historic centers around which the urban space was developed. Richness and diversity depends on the distance from this center, which can be explained by the less dense buildings and easier inflow of plant diasporas to these parks (MacArthur and Wilson, 1967; Moszkowicz, 2016) which affects the greater richness of park herb layer and more significant contribution of natural factors (Sukopp, 1992; Bianco et al., 2003; Fornal-Pieniak and Wysocki, 2009). This does not mean that all peripherally located parks are surrounded by loose or not build up areas as in the classic model of a monocentric city (Fudali, 2005). Therefore, larger distances from the peripheries influence here to a certain increase in number of species in Cracow. Another reason of that result is the occurrence of the richest and a highly diversified park near center. Its richness is not only related to the size, but also to its diversified use and the existence of natural and semi-natural elements (Fornal-Pieniak and Wysocki, 2009; Moszkowicz and Krzeptowska-Moszkowicz, 2019). This type of examples could be given more. This also shows that Cracow, in terms of the buildings overlooking the strict center, has no uniform layout, which results from its historical conditions (Bieniarzówna, 1992, 1997).

4 Conclusions

Based on the performed research, the following conclusions were drawn: Cracow as a city does not have a monocentric character and an even urban layout.

The fleet of Cracow's parks in relation to the middle of city and its geometrical center indicates an azonal character, but in relation to the centers around which the buildings were developed, the results shows the dependence of richness and diversity on the park's location in urban space according to the gradient of buildings.

The more peripheral location of parks is not conducive to the greater herb layer richness of parks and does not show any significant connections with diversity.

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CONTENTS

PLANTS
IN URBAN AREAS AND LANDSCAPE

PHOTOSYNTHETIC RESPONSE OF *CHRYSANTHEMUM* UNDER DIFFERENT WATER REGIMES

Anna Gogoláková*, Viera Paganová

Slovak University of Agriculture in Nitra, Slovak Republic

Potted chrysanthemums were subjected to drought and water stress treatments. The experiment included four treatments with different level of the substrate saturation. The net photosynthesis rate, stomatal conductance, transpiration rate and intracellular CO_2 were measured by the infrared gas analysis method. The study confirmed the trend of decreasing physiological parameters (P_n, g_s, E, Ci) with reduced water availability in the substrate. The reduced water availability significantly reduced stomatal conductance, transpiration, intracellular CO_2 concentration and, subsequently, photosynthesis. Continuous flooding significantly reduced photosynthesis and non-significantly increased transpiration and intracellular CO_2 concentration. The possible acclimatization of the plants to subsequent water deficit conditions was studied, too. Following the drying cycle, efficient and fast recovery of chrysanthemum plants was observed.

Keywords: ornamental plants, photosynthesis, P_n, transpiration, water stress

1 Introduction

In commercial nursery production systems, frequent and severe drought stress of container-grown plants can reduce crop quality, delay marketing, and, consequently, profitability. *Chrysanthemum* is one of the leading ornamental flowers worldwide, and its production faces a variety of challenges under environmental stress conditions (Chen et al., 2012). Drought stress is one of the most harmful types of stress, because it retards chrysanthemum growth. Hence, it is essential to improve the tolerance of chrysanthemum to this type of stress in order to achieve sustainable production (Satapathy et al., 2014).

Many papers are focused on the response of the plant to a single period of drought stress. These treatments are aimed either at dwarfing plants (Roeber et al., 1995), or describe a specific response of the leaf tissue to a period of wilting (Wang and Clarke, 1993). Water deficits occur when transpiration exceeds water uptake. Plants conserve water by reducing their transpiration rates by such mechanisms as modifying stomatal behaviour or in the long-term by reducing leaf area (Blum, 1996). The plants tolerant to drought stress show different adaptation mechanisms to overcome drought stress, including morphological, physiological, and biochemical modifications. These responses include increasing root to shoot ratio, growth reduction, changes of the leaf anatomy, reduction of leaf size and the total leaf area to limit water loss and guarantee photosynthesis (Toscano et al., 2019).

Techniques for measuring plant water status and inducing water stress in plants are well established. However, due to the dynamic nature of water deficits remains extremely difficult. These difficulties are enhanced when a water deficit occurs rapidly, for example when there is a limited supply of water in small pots combined with high evaporation by a flowering plant. Under such conditions, stomata may close due to low water availability in the soil – and yet leaf water potential (Ψ_L) may remain high (Davies and Zhang, 1991). According to Long and Bernacchi (2003) the infrared gas analysis (IRGA) is the only current method of widespread importance for measuring photosynthesis. These portable systems provide real-time measurement of CO_2 uptake, transpiration, stomatal conductance and map intercellular CO_2 mole fraction. The aim of the study was to determine the influence of different water irrigations to physiological parameters of chrysanthemum plants by the infrared gas analysis method. The supposed contribution was

Anna Gogoláková, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Planting Design and Maintenance, Tulipánová 7, Nitra, Slovakia
e-mail: agogolakova@gmail.com; viera.paganova@uniag.sk

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to optimize production conditions related to irrigation of chrysanthemum plants.

2 Material and methods

Potted chrysanthemum plants *Dendranthema indicum* (L.) Desmoulins ´Surf´ were grown in peat: perlite (Pindstrup substrate number 2, Mosebrug A/S) with one cutting per 10.5 cm pot in a growth chamber with constant conditions (temperature 20 °C, 60% relative humidity, 14 h light/10 h dark photoperiod, PPFD 500 µmol/m^2/s). The experiment started 25 days after the collection of cuttings from mother plants and lasted for a month. The experiment included four treatments with different availability of water. Water loss (evapotranspiration) was recorded on a daily basis with an electronic scale, for each pot individually. The control plants were irrigated individually everyday in the morning according to the weight loss since last irrigation, in order to obtain pot water holding capacity. Based on daily water consumption, control plants (variant K) were top-watered daily with amount of water (nutrient solution containing N at 286, P at 30, K at 359, Ca at 139, Mg at 21 and SO_4 at 42 ppm, EC 2.46, pH 5.8) equal to 100% of evapotranspiration. Other treatments included three different levels of water availability: continuous water deficit (variant A), cyclic water deficit (variant B) and continuous flooding (variant C). Continuous water deficit plants were given an amount of nutrient solution equal to 40% of the mean daily water consumption of control plants. The cyclic water deficit treatment was a repeating nonlethal cyclic water deficit treatment, where watering was withheld for 1 day – 24 h (variant B2) and recovery phases where the plants received the same amount of water and nutrient solution as control plants (variant B1). The experiment included 15 cycles of water deficit treatments in total. Continuous flooding (variant C) simulated overwatering plants. The pot trays were kept with permanent irrigation up to 3 cm of height minimally. Every day the trays were cleaned and irrigated with new nutrient solution to protect plants against fungal pathogens. There were 8 plants in each treatment.

The net photosynthesis rate (P_n), stomatal conductance (g_s), transpiration rate (E) and intracellular CO_2 concentration (Ci) were measured every day on single leaves of each plant with a differential CO_2/H_20 infrared gas analyzer CIRAS-1 (PP-Systems, Hitchin, UK). Gas exchange measurements of leaves were made on the most recently fully expanded leaf at photosynthetic photon flux density 500 µmol/ m^2/s, leaf temperature at 25 °C, vapour pressure deficit (VPD) at 15mbar and ambient CO_2 concentration of 400 ppm. Once the leaf was placed in the cuvette, the plant was left a further 20 min to stabilize before any measurements were recorded and each data points represented the mean of 3–5 min at steady-state. The statistical analyses were done using the SigmaStat software. ANOVA (Kruskal-Wallis one way analysis of variance on ranks) and pairwise multiple comparison procedures (Tukey test) were tested for significance at p <0.05.

3 Results and discussion

ANOVA analyses confirmed significant differences between P_n of control plants compared to the plants grown with 40% water availability. Reduced irrigation induced 59.35% lower net photosynthesis rate compared to the control irrigation. A significant difference was also confirmed between P_n of control plants compared to the plants with cyclical watering. The photosynthesis of plants with cyclical watering in days without watering decreased – by 49.85% and on days after re-watering P_n decreased – by 19% compared to the control plants. There were confirmed significant differences of P_n for plants within cyclical watering treatment. Plants after re-watering reached by 37.9% higher P_n compared to the days without watering.

Non-significant differences were observed between P_n of cyclically watered plants during the days without watering and plants with 40% reduced water availability. Cyclically watered plants during days without watering reached about 18.5% higher values of P_n compared to the plants with 40% reduced water availability. There were found significant differences in P_n of the control plants and plants with continuous supply of water. Flooding irrigation caused 10.5% decrease of P_n compared to the controls. Non-significant differences were determined between P_n of plants with continuous supply of water and cyclically watered plants in days after re-watering. P_n of plants with continuous supply of water was 10.4% higher compared to the plants with cyclical watering. However, highly significant differences were confirmed between P_n of plants with continuous supply of water and plants with 40% water availability and also between P_n of plants with continuous supply and cyclically watered plants after non-watering. Dehydrated plants with 40% water availability showed 54.6% decrease of P_n compared to the plants with continuous supply of water and cyclically watered plants after non-watering showed 44.2% decrease of P_n compared to the plants with continuous supply of water. Table 1 shows the changes of P_n in the course of drought, cyclical watering and flooding during the experiment.

Effects of water stress on photosynthetic decrease of ornamental plants have been well-documented in many reports: *Gazania rigens* (Gao et al. (2016), garden roses (Niu and Rodriguez, 2009), ornamental shrubs *Photinia* × *fraseri* and *Eugenia uniflora* (Toscano et al., 2016), *Callistemon laevis* (Álvarez et al., 2011). The debate as to whether drought mainly limits photosynthesis through stomatal closure or through metabolic impairment has been running since the earliest reports on the effects of drought on photosynthesis (Flexas and Medrano, 2002). During the last decade, stomatal closure was generally accepted to be the main determinant for decreased photosynthesis under mild to moderate drought (Ort et al., 1994). Comparing results from different authors is complex due to interspecific differences in the response of stomatal conductance and photosynthesis to leaf water potential and/or relative water content, the parameters most often used to assess the degree of drought (Medrano et al., 2002). It is clear that stomata close progressively as drought progresses, followed by parallel decreases of net photosynthesis.

Plants would be more vulnerable to water stress after rewatering or a cycled water environmental change, which occur more frequently under climatic change conditions in terms of the prediction scenarios. Plant growth, photosynthesis and stomatal aperture may be limited under water deficit, which would be regulated by physical and chemical signals. Under rewatering, the recovery of plant growth and photosynthesis would appear immediately through growing new plant parts, re-opening stomata, and decreasing peroxidation; the recovery extents (reversely: pre-drought limitation) due to rewatering strongly depend on pre-drought intensity, duration and species. Understanding how plants respond to episodic drought and watering pulse and the underlying mechanism, it is remarkably helpful to implement vegetation management practices under the conditions of climate change (Xu et al., 2010).

The results of ANOVA confirmed high significant difference in stomatal conductance between control and stressed plants with 40% water availability and also between control and both variants of cyclically stressed plants. Stomatal conductance of stressed plants with different watering regimes decreased from 75.6% to 28% (Table 1). Non-significant difference was observed between g_s of overwatered plants compared to the controls and also between g_s of cyclically watered plants after non-watering compared to the plants with 40% water availability.

As reported in several studies, water stress decrease of stomatal conductance was observed in *Olea europaea* (Chartzoulakis et al., 1999), *Morus alba* (Ramanjulu et al., 1998), and pot roses (Riseman et al., 2001). In many species, reduction in stomatal conductance with increased water stress may limit diffusion of CO_2 to chloroplasts and, consequently, net photosynthetic rate (Lawlor, 2002). Stomatal regulation plays a key role in gas exchange between vegetation and atmosphere interface. Ninety percent loss of plants is from transpiration thought stomatal opening (Wang et al., 2009). On the other hand, stomatal limitation would be recognized as a major factor for photosynthetic reduction when available water become scant, while non-stomatal limitation such as decreases in Rubisco activity, CO_2 availability in the chloroplast and PSII photochemistry efficiency is progressive gradual with water stress intensity and persistence duration (Xu et al., 2009).

Williams et al. (2000) studied the effect of reducing production water availability during cultivation on the post-production quality of potted miniature roses (*Rosa* × *hybrida*). Plants grown with cyclical water availability tolerated subsequent water stress better than plants produced with a constant supply of water, irrespective of whether the constant supply of water was adequate or not. Another study with

Table 1 Physiological characteristics of chrysanthemum with different water treatment

Treatment	P_n (μmol/m²/s)	*E* (μmol/m²/s)	g_s (μmol/m²/s)	*Ci* (ppm)
Variant K	14.06 ±0.25a	3.058 ±0.118a	288.4 ±10.4a	266.1 ±3.86a
Variant A	5.72 ±0.41b	0.967 ±0.101b	70.3 ±9.7b	203.3 ±7.69b
Variant B1	11.28 ±0.53c	2.641 ±0.141a	207.6 ±12.8c	252.1 ±8.22a
Variant B2	7.01 ±0.64b	1.155 ±0.257b	86.3 ±21.5b	200.2 ±13.04b
Variant C	12.59 ±0.32ac	3.095 ±0.089a	277.9 ±7.1a	267.8 ±4.54a

P_n – photosynthesis, *E* – transpiration, g_s – stomatal conductance, *Ci* – intracellular CO_2 concentration, K – control, A – plants with 40% water availability of control, B – cyclic water deficit (B1 – days after re-watering, B2 – days without watering), C – continuous flooding. The same letter within each column indicates no significant difference among treatments ($P \leq 0.05$) according to the Tukey´s test roses (Riseman et al., 2001) also confirmed that reduced water availability during the production of potted miniature roses improves water use efficiency, tolerance to subsequent drought stress and improves post-production performance. The two rose cultivars used different mechanisms to respond to drought. Apollo utilized osmotic adjustment while Charming modified stomatal closure.

In our study, reduced water availability also significantly influenced transpiration rate. Control plants transpired at a higher rate (+64.8%) compared to the plants with 40% water availability and at a higher rate (+62.2%) compared to the cyclically watered plants during the days without watering (Table 1). It has been reported in pot roses (Williams et al., 2000) that the cyclically-grown plants were able to restore transpiration and net photosynthesis during times of recovery similar to, but not equal to the control plants. The difference in transpiration was not significant between control and cyclically watered plants after rewatering; control plants reached higher transpiration rate (+13.6%) compared to the cyclically watered plants after rewatering. Flooding had no significant influence on *E* as well; overwatered plants reached by 1.2% higher transpiration rate than the controls (Table 1).

In order to estimate the tolerance to drought stress in plants, the transpiration ratio is essential. In fact, it has been observed that species that can retain a greater quantity of water and therefore lose less water through the stomata are more tolerant to drought (Riaz et al., 2013). As reported by Galmés et al. (2007), shrubs have a better ability to regulate transpiration compared to herbaceous plants. Soil drought stress decreases the leaf water potential, which reduces the swelling pressure and subsequently, stomatal closure. Plants experience water stress when the rate of transpiration becomes very high or when the water supply to roots become difficult (Reddy et al., 2004). Wang et al. (2006) observed a strong correlation of stomatal conductance with transpiration compared to net photosynthesis. This could be due to the soil moisture stress-induced abscisic acid (ABA) which is stimulated by soil drying through the transpiration stream resulting in stomatal closure.

Wang et al. (2006) detected that when soil water content dropped below 47% of field water capacity, the leaf water potential decreased rapidly, indicating a significant threshold reaction of soybean leaves about -1.02 MPa. Below this, the leaf water potential and net photosynthesis ratio dropped rapidly. When the soil water content was 47%, the leaf water potential and net photosynthesis ratio were nearly as high as those in CK, but the transpiration ratio was by 67% lower, indicating that transpiration was more sensitive to drought than photosynthesis. After rewatering, the water status of soybean leaves improved, the net photosynthesis ratio and transpiration ratio increased linearly, and leaf stomatal conductance also recovered quickly.

Reduced water availability induced significant decrease in intracellular CO_2 concentration (*Ci*) of plants with 40% water availability (-23.6%) compared to the control and cyclically watered plants during the days without irrigation (-24.8%) compared to the control. Within cyclical treatment, after periodic alternation of water deficit and re-watering *Ci* decreased and increased repeatedly. Re-watering of plants significantly increased *Ci* (+20.6%) compared to the non-watering. Both treatments, re-watering of cyclically watered plant and flooding, non-significantly influenced *Ci* compared to the control. Re-watering decreased *Ci* (-5.3%) and overwatering increased *Ci* (+0.6%) compared to the control (Table 1).

The influence of *Ci* on stomatal conductance was already reported (Cornic, 2000). In a study conducted by Toscano et al. (2018) on shrubs *Lantana* and *Ligustrum*, the analysis of leaf anatomical traits allowed the identification of the different strategies used during water stress conditions. During severe deficit of irrigation, *Lantana* plants increased spongy tissue rather than the palisade tissue; this anatomical modification facilitated the diffusion of CO_2 towards the fixation sites in order to increase the concentration gradient between internal air space and the atmosphere, thus enhancing the competition among cells for CO_2 and light (Fraser et al., 2009).

Chen et al. (2018) investigated that net photosynthetic rate, stomatal conductance, water use efficiency and transpiration rate in the non-grafted chrysanthemums were significantly decreased. Moreover, the intercellular CO_2 concentrations were significantly increased compared to the grafted plants at 5 and 6 d following drought stress. Non-grafted chrysanthemums were less able to resist dehydration, and repressed the genes encoding the expression of photosynthetic components. Using *Artemisia annua* grafts could alleviate drought stress in chrysanthemums by improving gas exchange capacity and maintaining *CmrbcL*, *CmrbcS*, *Cmcab* and *CmpsaB* gene expression, thereby increasing Rubisco activity and improving photosynthetic performance.

4 Conclusion

The study described sensitivity of physiological parameters to different water availability treatments. Reduced water availability significantly reduced stomatal conductance, transpiration, intracellular CO_2 concentration and, subsequently, photosynthesis. Continuous flooding significantly reduced photosynthesis and non-significantly increased transpiration and intracellular CO_2 concentration. The study confirmed resistance of chrysanthemum plants to cyclical water deficit. Following the drying cycle, efficient and fast recovery of the plants was observed. Monitored reduced water availability during the production of potted chrysanthemum plants can improve tolerance to subsequent drought stress and post-production performance. This result can be practically applied for indoor plant maintenance. *Chrysanthemum* plants can be better adapted to the water stress, when they are not irrigated regularly with less amount of water. The modulating irrigation with absence of watering for short periods can enhance their adaptability to drought.

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PLANTS
IN URBAN AREAS AND LANDSCAPE

Short communication

EVALUATION OF *AMORPHA FRUTICOSA* SEED DAMAGE BY *ACANTHOSCELIDES PALLIDIPENNIS*

Ján Kollár

Slovak University of Agriculture in Nitra, Slovak Republic

The aim of the study was the *Amorpha fruticosa* seed damage by seed beetle *Acanthoscelides pallidipennis* (Motschulsky, 1874) in the urban environment in Slovakia. The field research was carried out in spring 2013. The research was realized at localities in Trenčín – Police Station (48° 53′ 42.811″ N, 18° 2′ 19.464″ E) and Mercury Market (48° 53′ 32.971″ N, 18° 0′ 17.452″ E), Trenčianska Teplá – Príles (48° 57′ 2.680″ N, 18° 8′ 32.978″ E), Trenčianske Stankovce – Sedličná (48° 50′ 45.578″ N, 17° 59′26.509″E), Nitra – SUA (Slovak University of Agriculture) (8° 18′ 26.764″ N, 18° 5′ 31.394″ E) and Hypermarket (48° 18′ 39.043″ N, 18° 4′ 20.944″ E). A hundred of composite fruits were taken from five random shrubs at each locality. The percentage of damaged and healthy seeds was calculated from the total number of seeds for each locality. The composite fruits collections were stored according to their locations for observation in glasses. We evaluated the averages of damaged seeds, healthy seeds, unchatched and hatched beetles and number of emergence holes in seeds. All data were entered into the chart according to which it was possible to conclude the results. The first hatching was observed on September 18, 2013. The beetles hatched until the end of December. The second hatching of beetles was observed in February. We observed damage only by *Acanthoscelides pallidipennis*. The most significant damage of seeds by the pest *A. pallidipennis* was recorded in Trenčianske Stankovce (91.17%) and Nitra SUA (90.4%). The lowest damage was found in Trenčín Police Station (9.58%) and Nitra Hypermarket (14.72%). The largest average of seed with two emergence holes was observed in the locality Trenčín Police station (0.72%). The research material also included parasitoids. They were hatched in the localities Trenčianske Stankovce and Nitra SUA. Among the parasitoids there were found the following genera – *Anisopteromalus* sp. (Hymenoptera: Pteromalidae), *Dinarmus* sp. (Hymenoptera: Pteromalidae) and *Eupelmus* sp. (Hymenoptera: Eupelmidae). The research shows that *A. pallidipennis* damaged the seeds of *A. fruticosa* in high level and thus represents a threat to the generative reproduction of the studied plants. The seed beetle Acathoscellides pallidipennis also performs ecological service by reducing the intensity of *Amorpha* sp. generative propagation and distribution in the landscape.

Key words: seed beetle, *Amorpha*, introduction, pest, *Acanthoscelides parasitoid*

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Ján Kollár, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Planting Design and Maintainance, Tulipánová 7, Nitra, Slovakia
e-mail: jankollar82@gmail.com

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