Proceedings of the Fábos Conference on Landscape and Greenway Planning

Volume 7
Issue 1 *Moving towards Health and Resilience in the public realm*

Article 28

August 2022

# The Most Immediate and Easily Observed Impacts of Climate Change

Krisztina Szabó Phd
*MATE, Buda Campus*, szabo.krisztina.dendro@uni-mate.hu

Barnabás Tóth
*MATE, Buda Campus*, tothbarni96@gmail.com

Eszter Karlocaine Bakay
*MATE, Buda Campus*, karlocaine.bakay.eszter@uni-mate.hu

Camila Andressa, Pereira Rosa
*MATE, Buda Campus*, arqcamilarosa@gmail.com

Chaima Lahmer
*MATE, BUda Campus*, chaimalahmer@gmail.com

**7th Fábos Conference on Landscape and Greenway Planning**

# The impacts of climate change on maples in the Buda Arboretum

Authors: Szabó, Krisztina[1], Tóth, Barnabás[2], Karlócainé, Bakay, Eszter[1], Camila Andressa, Pereira Rosa[3], Chaima, Lahmer[3]
*[1]associate professor Hungarian University of Agriculture and Life Sciences, [2]research assistant Hungarian University of Agriculture and Life Sciences, [3]PhD student Hungarian University of Agriculture and Life Sciences*

The Buda Arboretum is one of Hungary's most outstanding collection gardens, located on the southern slope of Gellért Hill, on an area of 7.5 hectares. Although the history of the arboretum and the institution dates back nearly 150 years, the composition of the plants has been constantly evolving and changing, adapting to the increasingly extreme climate change. The climatic condition and maintenance of the garden mimic urban conditions, making it a good test site for studies in addition to its collection and educational role. Plants are very sensitive to changes, whether phenological, physiological or morphological. In our research, we have studied the different phenological phases of all taxa, their development and adaptation to the living conditions of the arboretum, which is illustrated in this paper by the example of the genus maple.

The maple is one of the most common genus in urban areas, several species are native, and several Hungarian and foreign cultivars have been tested in the recent past, in stressed urban conditions, selection work in nurseries has resulted in almost all cases in the use of horticultural cultivars instead of basic species. According to our analyses, the Buda Arboretum has a total of 33 maple taxa, 63 planted specimens, most of which showed severe leaf drying and slight dehydration during the summer drought months. Among the native taxa, with the exception of field maple (*Acer campestre*), most maples, such as the Norway maple (*Acer platanoides*) and the sycamore maple (*Acer pseudoplatanus*) are less tolerant of polluted and dry environments.

Their phenological and physiological responses to environmental changes (sprouting, dehydration, defoliation, etc.) can be used as a predictor of their urban climate tolerance. The selection of suitable taxa for urban tolerance is based on the longest possible healthy canopy. This is why the selection of suitable species for future replanting and new tree plantations is an increasingly complex task. According to our phenological and climatological studies over the last years, the most acclimatized maple taxa were the Montpellier maple (*Acer monspessulanum*), the Amur maple (*Acer tataricum* subsp. *ginnala*), which can be proposed for planting in the 21st century or can be a starting point for future breeding processes, thus providing a variety of plant application (linear element such as greenway planting, alleés, hedge, or in groups or solitary specimens) in urban public spaces, with a wide range of forms and colours.

Keywords: climate change, urban plant application, adaptation, plant phenology, *Acer* species

## 1. Introduction

In most cases, the urban plant application, whether for an alley tree or a park tree, is based on observations and experience gathered in a collection garden or botanical garden. Species which acclimatise well in a relatively sheltered environment, are then released into the public domain. The Buda Arboretum is an excellent place for imitating urban conditions, due to the relatively dry conditions and the semi-intensive maintenance.
The Buda Arboretum is one of Hungary's most outstanding collection gardens, which is also the living collection of the Hungarian University of Agricultural and Life Sciences, located on 7.5 hectare site on

the southern slope of Gellért Hill (Szögi, 1995). The history of the institution goes back for almost 170 years, since Ferenc Entz founded the Practical Institute for Horticulturists in 1853. The establishment of the Arboretum, which is closely linked to the Institute, began with the planting of the present Upper Garden (1893), while the Lower Garden, originally the propagation site of the Institute, was established in the mid-20th century (Szilágyi 2013, Jámbor 2012, Csepely-Knorr and Sárospataki 2009, Zalainé Kovács 2003, Schmidt 2012, 1994, Lauber et al.2019). The role of botanic gardens is inevitable in climate change research projects, in phenological observations of plant adaptation strategies and physiological processes (Heywood 2011). Such experiences may help the future plant use in public green areas. Collective gardens play a key role in introducing new plant species for public green areas or private gardens, as they provide the necessary scientific basis and professional responsibility for r recommending, introducing and marketing those new species (Dehnen-Schmutz et al. 2007, Hulme 2011, 2015, Sharrock 2011).

*Benefits of trees for green corridors, greenways and green infrastructure*

The role of trees in the urban environment is significant because of their climatic effects, they are also important in ecological and townscape ways. Alleys are linear elements that connect green spaces in urban areas, creating a multi-level green infrastructure. In addition to their conditioning effects, tree-lined areas also have an important ecological role, as they act as habitats and ecological corridors for urban fauna, especially insects and birds. As equally spaced elements, tree-lined streets have a strong architectural character and have a major impact on the townscape and streetscape as well.

*The impact of climate change on plants and plantations*

Climate change might lead to dramatic changes in the living world; in life processes, population dynamics, species distributions, ecosystem structure and functioning (Hughes 2000, Czúcz 2010). It has changed the phenology of plants worldwide. (Miller et al. 2007) Specifically, as a result of global warming, many plant species are now sprouting and flowering earlier than previously (Myneni et al., 1997; Parmesan and Yohe, 2003; Root et al., 1997, Parmesan, 2006). Detailed, multi European plant phenology data series spanning several decades have shown that spring phenological events such as budbreak occur earlier and earlier (1-3 days per decade on average), while autumn events such as defoliation occur later and later each year (1-2 days per decade - Ahas et al. 2002, Scheifinger et al. 2002, Menzel et al. 2003, 2008). As a consequence, the growing season of trees is on average 2 days longer per decade, which, together with elevated $CO^2$ levels, also contributes to higher plant production (Boisvenue and Running 2006).

From an urban plant application point of view, all these changes, earlier sprouting, longer vegetation, etc. may theoretically lead to more favourable environmental conditions, but all this is coupled with higher seasonal temperatures and less precipitation, which is increasingly less tolerated by the tree species planted. Metropolitan heat islands already provide shelter and incubation opportunities for many warmth-loving, drought-tolerant newcomers (Udvardy and Facsar 1999, Czúcz 2005), which in the worst case scenarios escape from the city and expand in natural habitats. In addition, it is precisely because of the warming climate that we are seeing more and more pests and pathogens every year, which are more likely to attack weakened stands.

*The importance of long lasting foliage in cities*

An urban place planted with healthy large canopy trees is an effective tool to mitigate the negative effects of urban climate. It provides an increased filtering effect in heavily polluted urban areas, a favourable microclimate, a cooling effect, a more humid environment, and a reduction in run-off from torrential rainfall. The longer the tree retains its canopy, the longer all these positive effects will last.

Some tree species used in urban areas have a very short growing season of 20-22 weeks, e.g. *Albizia*, *Gleditsia* taxa, *Fraxinus pennsylvanica*, while others have a growing season of more than 30 weeks, as is the case with *Alnus* × *spaethii*. If we look at maples at genus level, they fall into the medium category, with 21-27 weeks of growing season (based on *Acer buergerianum* and Acer *monspessulanum* in the project of Stadtgrün 2021), of course this varies by climatic conditions and by the species (Böll et al 2014).

*Historical overview of maple taxa application in urban domains*

There is relatively little documentary evidence from periods when native species were predominant in domestic urban afforestation. There is evidence that this might have taken place after 1945, when reconstruction of the war-torn country was beginning and there was little opportunity to plant higher-cost alien taxa as urban trees. At that time, the basic species of maple (*Acer campestre, platanoides, pseudoplatanus*) were popular along with native linden and birch trees. In tree application, five categories were made for propagation and maintenance. Garden designers and installers could choose from those five categories instead of choosing species to be planted.

The example of Szeged from 1882, where the original plantation plan included 21,874 ornamental trees, and later records show that the total number of ornamental trees donated was 204,960, out of which 8,408 individuals were *Acer negundo*, 720 trees *Acer platanoides*, 58 trees *Acer montana* (presumably *Acer pseudoplatanus*), 720 trees Acer campestre (Lechner 1891).

The Pesti and Tarjáni presented plant lists of 11 large parks in Budapest, based on plant surveys carried out between 1975-2011 (Pesti and Tarjányi 2011). This data clearly show that for maple taxa, a significant portion of the trees on the list are no longer present on the site. Focusing on maples planted in different parks, their summary shows that the number of taxa in the parks was very different. The greatest diversity was in Népliget (37 taxa) while on Margaret Island only 16 taxa, and less in all other parks).

In the meantime, of course, the invasive nature of the American maples (*Acer negundo, Acer saccharinum*), popular in the late 1800s, has led to a proliferation of these species, and nowadays regulations restrict their planting. The basic native species, *Acer campestre* and *Acer platanoides* are perhaps the most popular in urban areas. Under natural conditions, field maple is found in almost all forest communities, from floodplain forests to karst scrub forests, as an "obligate" species. It has a wide ecological tolerance. It is often used in large cities, industrial parks, street plantations and even in extreme conditions, despite its disadvantages (relatively slow growth and poor trunk condition). The popularity of the early maple is enhanced by the wide range of cultivars, but the drought of recent summers has caused visible damage on early maples.

*Urban application, greenway plantation of maples*

Initially, the only purpose of planting urban trees was for ornamental purposes, to provide shade without disturbing traffic. Later, constantly growing list of requirements was added, such as stress tolerance, ornamental value, central leader, trunk staying straight through the crown, optimum crown, strong branch system (not brittle) and even that the tree should have no or few fruits, and radiation tolerance, high salt and metal concentration tolerance, and finally long canopy or ability to late leaf fall (Schmidt 2003). Fontaine also highlights the importance of winter hardiness (especially against late frosts) and provision of enough space for the newly planted tree to grow. He also notes the importance of feedback from professionals (Fontaine 2021). Of course, there are no species or varieties which meets all the criteria, the designer or the client should decide, which aspects of selection are the most important (Biza 2006).

The maples used to be preferred for decades as an urban tree, but since the 2000s its popularity has decreased in urban settings. In the second half of the twentieth century, the spherical maple (*Acer platanoides* 'Globosum') alongside with the global honeylocust (*Robinia pseudoacacia* 'Umbraculifera' was a popular ornamental trees choice for street strips bordered by overhead power lines. Since the native species, like *Acer campestre*, *Acer platanoides*, and *Acer pseudoplatanus* are less tolerant of stress, maple regeneration is becoming an increasingly complex task. As a result of nursery and selection work, today's basic species are almost always replaced by horticultural varieties. A wide range of different colour and form are available nowadays.

In Germany, urban maples account for about 29% of all planted genera, the most widely planted taxon is maple, followed by linden (15%) and ash (13%) (Düring et al. 2021). Among tree species evaluated in German sites based on studies by Böll et al. (2014), *Acer buergerianum* is prone to frost cracking along the trunk. In cities with continental climate, these species should at best be planted in sheltered areas. Compared to the assessment of winter hardiness of urban tree species by Roloff et al. (2009), the results of Böll et al. (2014) led to a more negative rating of these species, but Roloff et al.'s (2009) assessment is based on literature research, not on site research, and does not take into account the risk of frost splitting in its rating. In their study, *Acer monspessulanum*, along with several other species such as *Fraxinus ornus*, *Liquidambar styraciflua*, *Magnolia kobus* and *Quercus cerris*, showed better winter hardiness (Böll et al 2014).

Urban habitats are unique and harsh environments for established plant communities, basically due to the increased stress (disturbance, pollution, drought etc.). However, there is a need to increase the green areas of cities. There are several possibilities for urban afforestation, yet most of them require the use of chemicals that burden the soil (Szabó et al. 2014). Urban survival can also be aided by mycorrhizal colonizations, many of which have been studied in maple geysers. As the importance of AM symbioses is even more pronounced in polluted and disturbed urban ecosystems (Bainard et al. 2011), the effects of artificial mycorrhizal inoculation are being intensively studied (Feldman 2008, Lanthier 2009). All maple trees form mutualistic associations with fungi, known as endomycorrhizae (Kuhns 1980, Moore et al. 2011). The species studied are colonized by arbuscular mycorrhizal (AM) fungi, but the rate of colonization is significantly lower in trees growing in urban environments than in trees growing in rural environments (Bainard et al. 2011). The effects of AM on tree survival after transplanting have been investigated in facultative mycorrhizal *Acer × freemanii* and *Acer buergerianum* species (Wiseman and Wells 2009). To date, partial results on beneficial effects on survival and growth rate of transplanted trees, including *Acer buergerianum*, have been reported in climatically diverse German cities, where grafted plant individuals showed better growth than those without mycorrhizae (Böll et al. 2014) or based on studies by Szabó et al. (2014) in young individuals.

*Maples recommended for urban afforestation* in Hungary

In 2014, a committee was set up to examine, year by year, the trees on the nursery list and the conditions under which they should be planted (Szabó et al. 2014). And to record any problems (either plant protection or application) that are currently encountered with the taxa, which can be seen in Table 1 in the latest digital version published in 2022. Other recommendations, such as the Capital's Electric Works recommend installing *Acer campestre* ‘Nana’ and *Acer platanoides* ‘Globosum’ under the wires (Bardóczi et. al. 2018.)

**Table 1 List of maple proposed for public spaces** (based on '2022_kozteruleti_sorfak.Pdf')

| Oszlop | Taxa | Available from nurseries | Hungarian selection | Urban tolerance* | Crown width (m) | Height (m) | Lime-sensitive | Plant protection** | Potential allergenicity*** | Root system | Behaviour during intervention | Sensitivity to significant crown intervention (20%<>40%) | Risks of the branch system |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Acer buergerianum | x | | 2 | 6 | 10-15 | | 3 | 1 | heart | tolerant | sensitive | V forked/ loaded crown base |
| 2 | Acer campestre | x | | 3 | 6 | 10-15 | | 2 | 1 | heart | tolerant | sensitive | V forked/ loaded crown base |
| 3 | Acer campestre 'Elsrijk' | x | | 3 | 6 | 6-16 | | 2 | 1 | heart | tolerant | sensitive | V forked/ loaded crown base |
| 4 | Acer campestre 'Korinthosz' | x | x | 3 | 4 | 8-15 | | 2 | to be reviewed | heart | tolerant | sensitive | V forked/ loaded crown base |
| 5 | Acer campestre 'Lienco' | x | | 3 | 3 | 10-12 | | 2 | to be reviewed | heart | tolerant | sensitive | V forked/ loaded crown base |
| 6 | Acer campestre 'Queen Elizabeth' | x | | 3 | 5 | 8-10 | | 2 | 1 | heart | tolerant | sensitive | V forked/ loaded crown base |
| 7 | Acer campestre 'Red Shine' | x | | 3 | 6 | 8-10 | | 2 | to be reviewed | heart | tolerant | sensitive | V forked/ loaded crown base |
| 8 | Acer campestre 'Zenta' | | x | 3 | 6 | 8-15 | | 2 | 1 | heart | tolerant | sensitive | V forked/ loaded crown base |
| 9 | Acer × freemannii 'Armstrong' | x | | 2 | 8 | 12-15 | x | 2 | to be reviewed | | | sensitive | |
| 10 | Acer × freemannii 'Jeffersred' | x | | 2 | 6 | 12-15 | x | 2 | to be reviewed | | | sensitive | |
| 11 | Acer monspessulanum | x | | 3 | 5 | 8-10 | | 3 | 1 | | | sensitive | V forked/ loaded crown base |
| 12 | Acer 'Pacific Sunset' | x | | 3 | 8 | 8-10 | | 3 | to be reviewed | | | | |
| 13 | Acer platanoides | x | | 2 | 15 | 20-25 | | 2 | 1 | heart, plate | tolerant | sensitive | V forked/ loaded crown base |
| 14 | Acer platanoides 'Autumn Blaze' | x | | 2 | 12 | 15-20 | | 2 | 1 | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 15 | Acer platanoides 'Cleveland' | x | | 2 | 10 | 10-20 | | 2 | to be reviewed | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 16 | Acer platanoides 'Columnare' | x | | 2 | 5 | 10-15 | | 2 | 1 | heart, plate | tolerant | tolerant | V forked/ split crown base |
| 17 | Acer platanoides 'Crimson King' | x | | 2 | 10 | 10-15 | | 2 | 1 | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 18 | Acer platanoides 'Deborah' | x | | 2 | 8 | 15-20 | | 2 | 1 | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 19 | Acer platanoides 'Drummondii' | x | | 1 | 7 | 8-10 | | 2 | 1 | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 20 | Acer platanoides 'Emerald Lustre' | x | | 2 | 10 | 15-20 | | 2 | to be reviewed | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 21 | Acer platanoides 'Emerald Queen' | x | | 2 | 10 | 15-20 | | 2 | 1 | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 22 | Acer platanoides 'Faassen's Black' | x | | 2 | 10 | 10-15 | | 2 | 1 | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 23 | Acer platanoides 'Fairview' | x | | 2 | 15 | 10-15 | | 2 | to be reviewed | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 24 | Acer platanoides 'Globosum' | x | | 2 | 5 | 3-5 | | 2 | 1 | heart, plate | tolerant | tolerant | loaded crown base |
| 25 | Acer platanoides 'Olmsted' | x | | 2 | 3 | 10-15 | | 2 | 1 | heart, plate | tolerant | tolerant | V forked/ split crown base |
| 26 | Acer platanoides 'Parkway' | x | | 2 | 20 | 10-20 | | 2 | to be reviewed | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 27 | Acer platanoides 'Royal Red' | x | | 1 | 15 | 15-20 | | 2 | 1 | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 28 | Acer platanoides 'Superform' | x | | 2 | 15 | 20-25 | | 2 | 1 | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 29 | Acer pseudoplatanus | x | | 2 | 15 | 25-35 | | 2 | 1 | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 30 | Acer pseudoplatanus 'Negenia' | x | | 2 | 15 | 20-25 | | 2 | 1 | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 31 | Acer pseudoplatanus 'Purpurascens' | x | | 2 | 15 | 20-25 | | 2 | 1 | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 32 | Acer pseudoplatanus 'Rotterdam' | x | | 2 | 10 | 20-25 | | 2 | to be reviewed | heart, plate | tolerant | sensitive | V forked/ split crown base |
| 33 | Acer tataricum | x | | 2 | 4 | 5-10 | x | 3 | 1 | heart, plate | | tolerant | V forked/ split crown base |
| 34 | Acer tataricum ssp. ginnala | x | | 2 | 5 | 6-7 | x | 2 | 1 | | sensitive | sensitive | V forked/ loaded crown base |

*urban tolerance: 3 = good 2 = medium 1 = poor

**plant protection: 1 = definitely need to be treated, 2 = probably need to be treated, 3 = have not needed to be treated

***potential allergenicity: 0= not allergenic; 1=slightly allergenic; 2=moderately allergenic; 3=strongly allergenic; 4=very strongly allergenic

*The aim of the work*

The aim of our research is to use the educational and living collection functions of the Buda Arboretum to develop plant application alternatives that will be able to respond to biotic and abiotic changes caused by climate change in the future, based on scientific principles. Such an assessment of the Buda Arboretum, in this case of the linden taxa, is of particular importance because the vegetation of the garden is adapted to urban conditions from a maintenance and microclimatic point of view. The studies carried out here will greatly facilitate the evaluation of the tolerance of the individual taxa. In urban environments, it is important to think in terms of selections rather than native keystone species, and we therefore built on our phenological research to answer (1) what are the criteria for inferring climate tolerance and longer ornamental value, (2) native species, and their cultivars might be suitable for public plantings, (3) which taxa are most suitable for non-native species, (4) what is typical of the native maple supply, (5) how to evaluate native recommendations in terms of all these aspects.

## 2. Methods and material

The study area was the entire area of the Buda Arboretum in 2021. During the first investigation, the plantation and all species were checked based on maps, plans and other documents (Schmidt 2013,), previous site surveys, and as a result we re-identified several taxa. After updating the plant inventory of the garden, we had the opportunity to evaluate the specimens from different aspects (phenological-ecological-aesthetic). The evaluation was based on a year-long weekly study, during which the development of the vegetative and generative organs of the arboretum specimens was observed, with details on the beginning and end of dormancy, bud development, beginning of leaf development, mature leaf, leaf colouration and leaf drop. During the development of the generative organs, the times of dormancy, bud development, beginning, middle and end of flowering, beginning of fruit development, and then fruit ripening and shedding were recorded, taking into account external factors affecting the individuals. The resulting data, along with continuous photographic documentation, can provide a credible record of the changes in the garden's plant population in 2021, providing valuable information on their urban tolerance and their ability to adapt to climate change, which are crucial prerequisites for 21st century public plant applications.

The phenological phases of taxa are strongly influenced by environmental factors. The vegetation showed different responses to the extreme results of the 2021 weather data. The measures show that the winter of 2020/2021 was 2.5 C° warmer than average. The seasonal average temperature nationally was 2.4 C°, the eighth warmest winter since 1901. The seasonal rainfall total averaged 121.5 mm nationally, slightly above average (1981-2010: 111.3mm). In terms of winter precipitation distribution, January was notable as it was 19% rainier than usual (HMS1 2021). The mild winter was followed by unfavourable spring weather. According to the National Meteorological Service, spring temperatures were 1.9°C lower, the coldest spring since 1987. Temperatures rose day by day in late March and early April, but still remained below average (14.5°C). The spring precipitation total for 2021 averaged 130.3 mm on preliminary data, only slightly below the average for the last 30 years. (1991-2020: 139.4 mm) (HMS2 2021). The mean summer temperature was 22 C°, which suggests that it was one of the hottest summers in the last 120 years, in addition to long weeks with little rainfall. Outstanding in this respect was June, which was measured as the driest June in 121 years. The monthly average rainfall was only 22% of the monthly average, while July and August were 13% and 8% respectively below the previous record (HMS 3 2021).


**Figure 1. Location of the Buda Arboretum**

## 3. Results

*Assessments for the maple genus in Buda Arboretum*

The garden contains a total of 33 maple taxa, 63 individuals. The 33 different taxa are made up of 13 basic species and their varieties and cultivars. The dominant species in terms of taxondiverism are *Acer* *platanoides*, *Acer pseudoplatanus* and *Acer campestre*, and among them *Acer platanoides* are characterized by a spontaneous spread of invasive character in the garden (Szabó and Tóth 2021).

Maples (*Acer* spp.) are developing despite the lack of rainfall in early spring and in some species the generative organs were already visible in mid-March. The maples in the arboretum are divided into three groups according to their flowering period:

1. Pre-flowering species: *Acer platanoides*, *Acer opalus*, *Acer negundo*;
2. Species flowering at the same time as the foliage: *Acer campestre*, *Acer monspessulanum*, *Acer palmatum*, *Acer capillipes*, *Acer davidii*;
3. Species that flower after the foliage: *Acer pseudoplatanus*, *Acer tataricum*, *Acer ginnala* syn. *Acer tataricum* subsp. *ginnala*, *Acer acuminatilobum* syn *Acer campestre* var. *acuminatilobum*.

Of the taxa that flower before the leaves set, the native North American *Acer negundo* develops its inflorescence as early as the second week of March, followed by the native *Acer platanoides* and the Mediterranean *Acer opalus*. maples in the early spring aspect (and in any case), these taxa have the greatest ornamental value, as their inflorescences are dominant, the vegetative organs do not attract attention. On average, *Acer platanoides* specimens have the longest flowering period of 5 weeks. The ornamental value of the taxa flowering at the same time as the foliage compared to the three taxa mentioned above, but the combined foliage and inflorescence interesting parallels. In this group, the generative organs differ not only in quality but also in duration from the compared to their earlier flowering relatives, as they are to open their inflorescences.

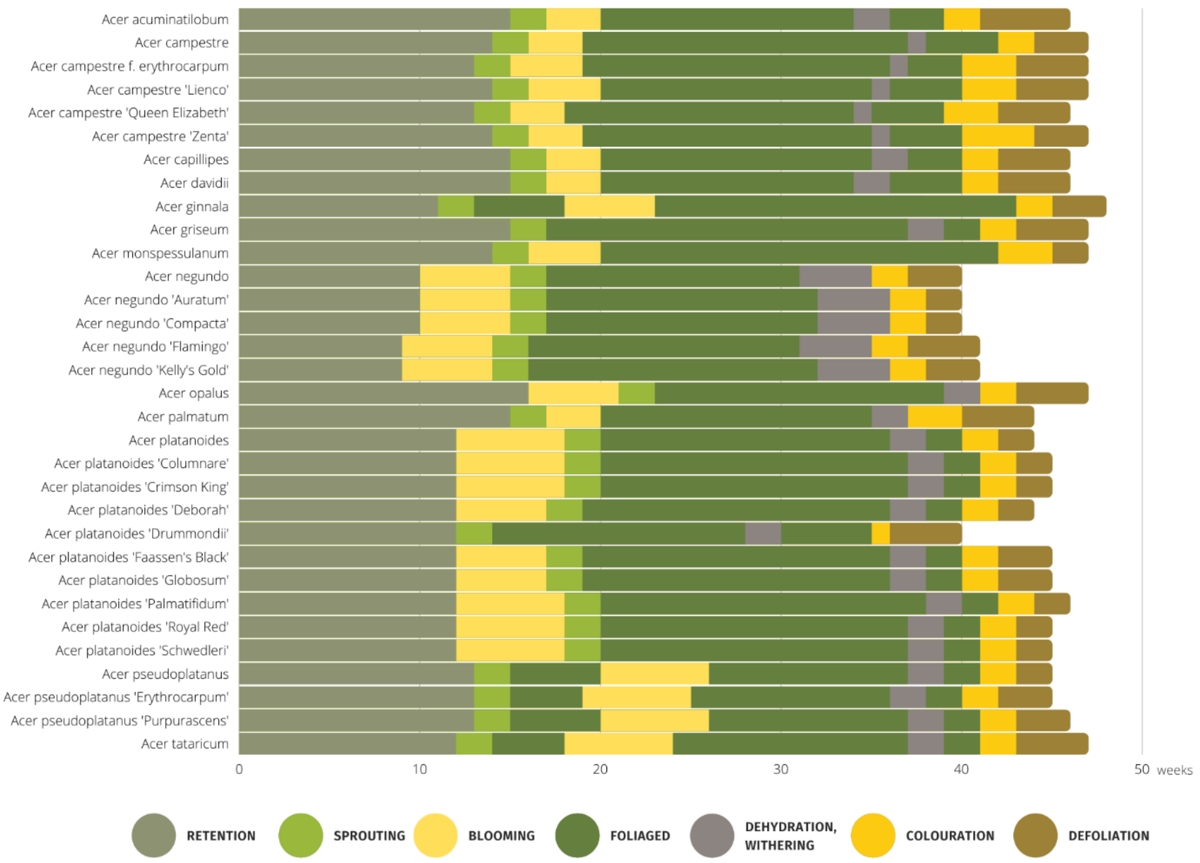


**Figure 2.** Phenological phases of maple taxa of the Buda Arboretum

The latest taxa to flower after foliage emergence are even less floriferous because of the developed foliage usually develop insignificant green inflorescences. The flowering is relatively long, lasting on average four weeks. Among *Acer pseudoplatanus* individuals only those in protected areas flowered for 5 weeks and the flowering period of these taxa mostly pushed out, from the first week of May until the first week of June. Examination of the development of leaf buds reveals that from the native species *Acer platanoides* is the earliest, while *Acer acuminatilobum* has the latest development. Most maples show severe leaf drying during the summer drought months and a slight dehydrated condition. The lack of rainfall in August was the most evident in the early defoliation of *Acer negundo*, but also in the late summer of the native species with maroon foliage or downy leaves lost much of their foliage in late summer. There were fewer area-based differences between individuals, leaf drying affected all individuals in the given taxon, larger changes in less irrigated trees that were exposed to environmental influences, and smaller changes in the more protected parts. Two taxa, *Acer monspessulanum* and, somewhat surprisingly, *Acer ginnala* did not show any leaf drying or dehydration.

Foliage colouration is a significant ornamental value in all taxa, which typically lasts two to three weeks and then began to leaf out in the third week of October. The autumn foliage of *Acer tataricum* and *Acer opalus* maples lasted for a full month. *Acer negundo* individuals, which are poorly tolerant of summer climates, have only minimal colouration, as most of their foliage had already been dried by the August heat. In terms of autumn foliage, the following species of tree species are especially beautiful; *Acer tataricum*, *Acer ginnala* and *Acer opalus*.

**4. Discussion, proposals**

Trees are the most prominent feature of green corridors. From an ecological and climatic point of view, green corridors play an important role in the green space system of our municipalities, as they are a linear element connecting green and blue infrastructure elements, thus forming a multi-system of interacting elements. In the 21st century, native taxa of the maple genus are still the main commercial species, but in response to climate change, the cultivation and application of Mediterranean and hybrid trees in Hungary has started, although is still limited.

The current taxa applications need to be revised in the light of the environmental changes brought about by climate change. The majority of species planted in urban, stressed environments suffer from various diseases and are subject to stresses that greatly affect their ecological and aesthetic benefits. For urban trees, the most important characteristics in terms of climate tolerance are long foliage, periods without wilting or leaf defoliation during the dry summer, and possibly the length of flowering. The taxa that are highlighted are also well adapted to urban conditions. Long canopies were observed for *Acer campestre*, *Acer ginnala*, *Acer monspessulanum*, *Acer platanoides* 'Palmatifidum'. Healthy foliage was observed in *Acer ginnala*, *Acer monspessulanum* taxa.

A look at the large nurseries in Hungary (Tahi Fasikola Kft., Alsótekeresi Faiskola Kft., Prenor Kertészeti és Parképítő Kft.) shows that the number of maples is relatively small. The total number of taxa (421-537 taxa) and the proportion of maple taxa (4-8%) sold by nurseries varies (PRENOR 2022. Alsótekeresi Faiskola 2022., Tahi Faiskola 2022.). Looking at European trends in urban tree planting, it can be seen that the leading nurseries of Western Europe are ahead of the Hungarian initiators, both taxonomically and in terms of research and experimentation. The Netherlands plays an important role, as a major plant-growing power and commercial leader in the agricultural sector (Böll 2018). An overview of the supply of three Dutch nurseries (Ebben, Van den Berk, Esveld) shows that they trade in many more taxa than domestic nurseries. The total number of taxons is between 1500 and 6000, of which maple taxons account for a significant 7-8%, with 105-486 different taxons being traded (Baumschule Ebben 2022., Van den Berk Boomkwekerijen 2022. Plantentuin Esveld 2022.).
In addition to taxa native to European urban landscapes, species from Mediterranean regions or hybrids are recommended, while Asian species are preferred, which are more tolerant of soil and less sensitive to dry periods, such as *Acer monspessulanum*, *Acer buergerianum*, *Acer opalus*, *Acer truncatum*, *Acer saccharum*, and of the hybrid species, *Acer* 'Pacific Sunset', *Acer* 'Norwegian Sunset', and *Acer* × *zoeschense* 'Annae' taxa are commonly recommended. Other recommendations also include *Acer cappadocicum, Acer obtusifolium, Acer heldreichii*.

*Acer buergerianum* also seems to work in research programmes, *Acer monspessulanum*, *Acer oplalus*

(Fontaine 2021, Schönfeld 2019, Böll 2018). Bassuk and her colleagues (Cowett and Bassuk, 2014) have made recommendations for urban trees that are more resilient to environmental stress. The species covered in their work, which occur in our area, are *Acer truncatum* (which we do not find in public places, only in a collection garden). Its suggested uses wide street tree lawns/pit, it may require pruning for street tree use, and tolerates prolonged periods of dry soil. Other species are *Acer tataricum*, *Acer campestre* and *Acer buergerianum*. In 2019 there was a Climate Trees Seminar where the participants reported on suitable species and cultivars according to forecasts and experience.

In Budapest, *Acer buergerianum* can be found in small numbers or as solitary trees in a few public places, while *Acer monspessulanum* is mainly planted as a park tree in the capital, but in the western part of the country, such as Szombathely, it is also planted as a row tree (Somkuthy and Tóth 2009). The hybrid *Acer* × *zoeschense* (syn. *Acer* × *neglectum*) was first planted in Budapest at the south-eastern entrance to Széllkapu Park, where, although under irrigated conditions, it is located directly along a busy metropolitan street, so it will be important to monitor it in the future

In the built environment, we cannot necessarily rely on the use of native taxa when our research shows that they do not respond adequately to changes in urban climate and increasingly difficult planting conditions by leaf drying and wilting. Urban dwellers need a liveable environment, which can be ensured by increasing the number and size of healthy canopies. The canopy is also the most important part of the tree in any ecosystem service. Of course, the above and below ground organs of trees are completely in balance, so we cannot focus on the crown alone, we need to keep our trees in the city well maintained in all respects. However, "well-keeping" can be very diverse and sustainability is a key aspect of plant management. We need to green our urban public spaces with as little effort as possible, taking into account ecological considerations, and this is well supported by the research that will be launched in 2021, based on the study of 2800 specimens, including the maples presented in this article.

We need to identify taxa that can be used to create a higher quality tree line or green belt and provide ecosystem services. Our research provides the basis for proposing a climate-adaptive species list on which nursery production can be based to initiate the supply of climate trees.

## References

Ahas, R., A. Aasa, A. Menzel, V. G. Fedotova, and H. Scheifinger. 2002. 'Changes in European Spring Phenology'. International Journal of Climatology 22 (14): 1727–38. https://doi.org/10.1002/joc.818.

Bainard, Luke D., John N. Klironomos, and Andrew M. Gordon. 2011. The Mycorrhizal Status and Colonization of 26 Tree Species Growing in Urban and Rural Environments. Mycorrhiza 21 (2): 91–96. https://doi.org/10.1007/s00572-010-0314-6.

Bardóczi, Sándor, Stefanics, Beáta, Szakács, Barnabás, Turcsányi, Katalin 2018: Zöldinfrastruktúra füzetek 4: Városi fák és közművek kapcsolata

Biza, K. 2006: Várostűrő fák. − Kertészet és szőlészet, 55 évf. 7. Szám

Boisvenue, Céline, and Steven W. Running. 2006. Impacts of Climate Change on Natural Forest Productivity - Evidence since the Middle of the 20th Century: CLIMATE CHANGE IMPACTS ON FOREST VEGETATION. Global Change Biology 12 (5): 862–82. https://doi.org/10.1111/j.1365-2486.2006.01134.x.

Böll, Dr. Susanne 2018. Stadtbäume der Zukunft – Wichtige Ergebnisse aus dem Forschungprojekt "Stadtgrün", 13.

Böll, Dr. Susanne, Schönfeld, Dr. Philipp, Körber, Klaus, Herrmann, Josef Valentin 2018: Bavarian Roadside trees facing climate change: testing stress-tolerant tree species in the research project „Urban Green 2021" State Institute for Viticulture and Horticulture, D-97209 Veitshöchheim, Germany

Böll, S.; Schönfeld, P.; Körber, K.; Herrmann, J.V. 2014. Stadtbäume im Zeichen des Klimawandels: Erste Ergebnisse aus dem Projekt „Stadtgrün 2021" und weitere Ausblicke. Jahrbuch der Baumpflege, pp. 155-170.

Cowett, F.D., and N.L. Bassuk. 2014. 'Statewide Assessment of Street Trees in New York State, USA'. Urban Forestry & Urban Greening 13 (2): 213–20. https://doi.org/10.1016/j.ufug.2014.02.001.

Csepely-Knorr, L., Sárospataki, 2009. A "Gellérthegyi Paradicsom" - a Budai Arborétum felső kertjének építéstörténete a II. Világháborúig. 4D - Tájépítészeti és Kertművészeti Folyóirat, pp. 13-16. P 2

Csérer, Gy. 1928. A város és a falu fásítása, M. Kir. Belügyminisztérium, Budapest

Czúcz B. 2010. Modelling the impacts of climate change on native semi-natural habitats (Az éghajlatváltozás hazai természetközeli élőhelyekre gyakorolt hatásainak modellezése), phd dissertation, Budapest

Czúcz, B. 2005. A budai Vár fásszárú adventív flórája. Kitaibelia 10, pp.73-87.

Dehnen-Schmutz, Katharina, Julia Touza, Charles Perrings, and Mark Williamson. 2007. 'A Century of the Ornamental Plant Trade and Its Impact on Invasion Success'. Diversity and Distributions 13 (5): 527–34. https://doi.org/10.1111/j.1472-4642.2007.00359.x.

Düring, Jens, Gstach, Doris, Knopf, Daniel 2021: Klimaanpassung durch Stadtgrün, im ProBaum 02/2021

Feldmann, F. 2008. Mycorrhiza for plant vitality: mycorrhizal fungi as factors of integrated horticultural plant production. − In: Feldmann, F.; Kapulnik Y.; Baar, J. (eds): Mycorrhiza Works. DPG Publisher Braunschweig, Germany, pp. 7-17.

Heywood, Vemon H. 2011 'The Role of Botanic Gardens as Resource and Introduction Centres in the Face of Global Change' Biodiversity and Conservation 20 (2) 221-239. https://doi.org/10.1007/s10531-010-9781-5.

Hulme, Mike. 2011. 'Reducing the Future to Climate: A Story of Climate Determinism and Reductionism'. Osiris 26 (1): 245–66. https://doi.org/10.1086/661274.

Jámbor, I. 2012. Education from garden design to landscape architecture in Hungary. 4D - Tájépítészeti és Kertművészeti Folyóirat 25-28. P 12.

Kuhns, L.J. 1980. Potential benefits of mycorrhizae in the urban environment. Proceeding of the third conference of the Metropolitan Tree Inprovement Alliance (METRIA). Held at Rudgers The State University of New Jersey June 18-20,

Lanthier, M. 2009. Mycorrhizal inoculation of nursery trees: benefits for arborists. North Okanagan Organics Association Workshops on Soil Biology

Lauber, L. J. Szendrói, D. Schild, and B. Kardos 2019. 'Budapest 100 Újratervezés Redesign' Budapest100 (blog) Accessed 12 May 2021 http://budapest100.hu/en/house/menesi-ut-44-48/.

Lechner L. 1891: Szeged Újjá Építése. Szeged, 55.p.

Menzel, A, E Cleland, I Chuine, H Mooney, and M Schwartz. 2007. 'Shifting Plant Phenology in Response to Global Change'. Trends in Ecology & Evolution 22 (7): 357–65. https://doi.org/10.1016/j.tree.2007.04.003.

Menzel, Annette. 2003. 'Plant Phenological Anomalies in Germany and Their Relation to Air Temperature and NAO'. Climatic Change 57 (3): 243–63. https://doi.org/10.1023/A:1022880418362.

Miller-Rushing A., Katsuki T., Primack R., Hiroyoshi Higuchi 2007. Impact of global warming on a group of related species and their hybrids: Cherry tree (Rosaceae) flowering at Mt. Takao, Japan. American Journal of Botany 94(9):1470-8. DOI:10.3732/ajb.94.9.1470

Moore, D.; Robson, G.D.; Trinci, A.P.J. 2011. 21st Century Guidebook to Fungi. Cambridge University ISBN: 9780521186957.

Myneni, R. B., C. D. Keeling, C. J. Tucker, G. Asrar, and R. R. Nemani. 1997. 'Increased Plant Growth in the Northern High Latitudes from 1981 to 1991'. Nature 386 (6626): 698–702. https://doi.org/10.1038/386698a0.

Parmesan, Camille, and Gary Yohe. 2003. 'A Globally Coherent Fingerprint of Climate Change Impacts across Natural Systems'. Nature 421 (6918): 37–42. https://doi.org/10.1038/nature01286.

Parmesan, Camille. 2006. 'Ecological and Evolutionary Responses to Recent Climate Change'. Annual Review of Ecology, Evolution, and Systematics 37 (1): 637–69. https://doi.org/10.1146/annurev.ecolsys.37.091305.110100.

Pesti, László, and Ferenc Tarjányi. 2011. 'Budapesti Nagy Parkok Növényjegyzéke'. https://docplayer.hu/9355356-Pesti-laszlo-tarjanyi-ferenc-budapesti-nagy-parkok-novenyjegyzeke.html.

Roloff, Andreas, Sandra Korn, and Sten Gillner. 2009. 'The Climate-Species-Matrix to Select Tree Species for Urban Habitats Considering Climate Change'. Urban Forestry & Urban Greening 8 (4): 295–308. https://doi.org/10.1016/j.ufug.2009.08.002.

Root, T. 1997, 'How to Approach Assessing Climate Impacts on Animals', in Hassol, S. J. and Katzenberger, J. (eds), Elements of Change 1996, Aspen Global Change Institute, Aspen, CO, pp. 203–206.

Scheifinger, Helfried, Annette Menzel, Elisabeth Koch, Christian Peter, and Rein Ahas. 2002. 'Atmospheric Mechanisms Governing the Spatial and Temporal Variability of Phenological Phases in Central Europe'. International Journal of Climatology 22 (14): 1739–55. https://doi.org/10.1002/joc.817.

Schmidt, G. 2003: Növények a kertépítészetben, Mezőgazda Kiadó, pp. 243-251

Schmidt, G., Honfi, P. 2006: Budapesti fák élete és halála. − Budapest folyóirat 29. Évf. 7. Sz. pp. 2-6.

Sharrock, S., S. Oldfield, and O. Wilson. 2014. 'Plant Conservation Report 2014: A Reviewof Progress towards the Global Strategy for Plant Conservation 2011-2020.' CBD Technical Series, no. No.81. https://www.cabdirect.org/cabdirect/abstract/20143358453.

Sjöman H., Gunnarsson A., Pauleit S., Bothmer R., 2012; Selection Approach of Urban Tree for Inner-city Environments: Learning from Nature, ISA Arboriculture & Urban Forestry 38(5): pp. 194-204

Szabó, K.; Böll, S.; Erős-Honti, Zs. 2014. Applying artificial mycorrhizae in planting urban trees. Applied Ecology and Environmental Research, 12(4): 835-853

Szilágyi, K. 2013. A kerttörténet és a kertművészet oktatásának és kutatásának száz éve - a Kertészeti Tanintézettől a Tájépítészeti karig = Hundred years of education and research in garden history and garden art - from the Institute for Horticultural education to the Faculty of Landscape Architecture. 4D - Tájépítészeti és Kertművészeti Folyóirat pp. 29-32 p.25.

Udvardy, L., Facsar, G. 1999. Vascular adventives signing changes in the global and local climate in Hungary. In: Eliáš, P.(ed.) Invázie a invázne organizmy. Príspevky z Vedeckej Konferencie Nitra, 18–20. November 1998. 8 pp.

Weryszko-Chmielewska E, Piotrowska-Weryszko K, Haratym W, Dmitruk M, Sulborska A, Vorobets N., 2016; Changes in the pollen seasons of Acer spp. In Lublin, centraleastern Poland, in 2001–2015. Acta Agrobot, 69(2):1670. Http://dx.doi.org/10.5586/ aa.1670

Wiseman, P.E.; Wells, C.E. 2009. Arbuscular Mycorrhizal Inoculation Affects Root, Development of Acer and Magnolia Species. J. Environ. Hort., 27(2), 70–79.

Links:

HMS1 2021: 'A Nyolcadik Legmelegebb Tél 1901 Óta – Előzetes Elemzés - Hírek - Met.Hu'. 2022. Országos Meteorológiai Szolgálat. 21 March 2022.

HMS2 2021: 'A Leghidegebb Tavasz 1987 Óta – Előzetes Elemzés - Hírek - Met.Hu'. 2022. Országos Meteorológiai Szolgálat. 21 March 2022. https://www.met.hu/omsz/OMSZ_hirek/index.php?id=4277&m=2.

HMS3 2021: 'Az Ötödik Legmelegebb Nyár – Előzetes Elemzés - Hírek - Met.Hu'. 2022. Országos Meteorológiai Szolgálat. 21 March 2022. https://www.met.hu/omsz/OMSZ_hirek/index.php?id=3083&hir=Az_otodik_legmelegebb_nyar_%E2%80%93_elozetes_elemzes.

Prenor 2022: Prenor Kertészeti és Parképítő Kft. Növénykatalógus: https://noveny.prenor.eu/index.php/arjegyzek/keszletlista

Alsótekeresi Faiskola 2022: Alsótekeresi Faiskola Növénykatalógus: https://www.altekfa.hu/hu/products/7/novenykatalogus

Tahi Faiskola 2022: Tahi Faiskola Kft. Növénykatalógus: https://www.tahi.hu/novenykatalogus

Baumschule Ebben 2022: Baumschule Ebben Növénykatalógus: https://www.ebben.nl/de/treeebb/

Van den Berk Boomkwekerijen 2022: Van den Berk Boomkwekerijen Növénykatalógus: https://www.vdberk.nl/bomen/

Plantentuin Esveld 2022: Plantentuin Esveld Növénykatalógus: https://esveld.nl/a/winkel/