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ANALYSIS OF INVASIVE FLORA IN CEMETERY TERRITORIES OF THE CITY OF DAUGAVPILS

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Abstract. *Alien species are reaching different areas, including also cemeteries. Inventory of invasive flora of cemeteries of the city of Daugavpils actually is the first such type of work to such level of detail on the Latvian scale.*
Field studies were conducted in 10 cemeteries of the city of Daugavpils. The obtained results are indicative of a comparatively high proportion of invasive plant species in the cemeteries. 49 invasive alien species were found. In the cemetery areas these are spreading mainly from greeneries, but there are also such taxa, which have accidentally reached the cemeteries. The most frequent plant in the Daugavpils cemeteries is Spiraea chamaedryfolia. Taking into account the trends of migration, sex-age structure of population, climate change, availability of exotic and new ornamental plants, it is most likely that the number of invasive species will grow in the future.

Key words: *invasive alien plants, cemeteries, plantations, Daugavpils.*

Introduction

The primary role of any cemetery is to provide a place to bury and to commemorate the dead, and to provide a focal point for mourning and religious observance. However, because they provide green oases within built-up areas, cemeteries are also places for rest and contemplation in a more general sense, offering opportunities for fresh air and exercise, or simply a place for quiet communion with nature. The coexistence of nature and art, sometimes in an uneasy alliance, accounts for much of their character and makes them a unique historical, cultural and natural resource [1]. For that reason cemeteries are often an object for research for researchers of culture and historical heritage [1, 2].
Taking into account the significant impact of human activities in cemeteries, the microclimatic, soil et al. characteristics of site, which are essential for plants, specific flora is forming here. However research of flora in cemeteries and speed and nature for introduction of alien invasive plants, geospatial distribution in cemeteries and adjacent territories both in Latvia and worldwide is a direction being explored to comparatively small extent. Globally studies of the invasive alien species has been commenced with C. Elton, a pioneer of Invasion Biology as a field of science, in 1958 having published a book with regard to ecology of invasions by plants and animals. Research of the invasive plants of cemeteries was started significantly later, for example, in England the first results of studies regarding these matters have been published only in 2002 [1]. Research of invasive alien taxa in the territory of Latvia began in the 80s of the 20th century, but the studies were fragmentary and realized mainly in the central part of Latvia. Actually the only research of invasive flora of cemeteries in Latvia has been conducted by M. Laiviņš and S. Jermacāne (1999). Much more attention both from geospatial and historical distribution of plants to these matters is devoted in Lithuania [3].
The first inventory of the flora in Daugavpils was compiled in 1975–1983 [4] and the first paper on alien invasive trees appeared twenty years later [5]. The research performed with regard to invasive flora of the Daugavpils cemeteries is the first study of such type and degree of detail in Latvia.

Materials and methods

Study area

Daugavpils is situated in the south-eastern part of Latvia. The city is the second largest in Latvia with 102,496 inhabitants [6], situated on the banks of the river Daugava and covers an area of 72.48 km^2. The city is situated at the cross-roads of important motorways and railways. The flora of the city of Daugavpils is unique and one of the richest in Latvia. From E. Lehmann's [7] investigations at the end of the 19^{th} century until 2009, 1014 species have been found here, 250 of them - invasive alien species [8]. Such a number of species in the city can be explained by a high diversity of natural habitats encountered here.

Field research

The field research was carried out from spring to autumn in 2007 till 2010. In course of research 10 cemeteries of the city of Daugavpils were surveyed. The data were processed using the GPS equipment THALES Mobilemapper CE. Data of records were obtained from examining specimens in the Daugavpils University Herbarium (DAU).

Results and discussion

In total, 49 invasive plant species were found in the Daugavpils city cemetery areas.

From the found caulescent plants (27 species), the highest frequency had *Erigeron canadensis* (Table 1) *Jovibarba globifera*, *Euphorbia cyparissias*. With a lower frequency were found *Sedum sexangulare*, *Phalacroloma annuum* and *Impatiens glandulifera.*

Erigeron canadensis is frequent alien species that easily spreads in different habitats. *Euphorbia cyparissias* and *Jovibarba globifera* are used as the ornamental plants and from plantations often go wild. *Jovibarba globifera* can tolerate drought, is modest in terms of soil fertility. *Euphorbia cyparissias* is also able to adapt to different growth and environmental conditions. According to the data of Laiviņš and Jermacāne, in Latvia on the year 1999 in the aggregate 28 *Sedum sexangulare* and 96 *Euphorbia cyparissias* fields were known. Since the data of Laiviņš and Jermacāne (1999) have so far been the only data on the cemetery flora and their field studies were mainly carried out in cemeteries of the western part of Latvia, acquiring information with regard to the remaining part of Latvia from the existing herbaria, the authors believes that the main cause for such an essential increase in quantities of these plant fields most likely is insufficient flora studies of the territory of Latvia.

Table 1.

Summary table of alien species recorded in 10 analysed cemeteries

Species	Number of records	Mean of introduction in cemetery	Frequency[1] (%)
Spiraea chamaedryfolia L.	92	I	100%
Syringa vulgaris L.	90	I	100%
Euphorbia cyparissias L.	66	I	80%
Sorbaria sorbifolia (L.) A.Braun	56	I	80%
Spiraea x billardii Hérincq	52	I	60%
Caragana arborescens Lam.	49	I	70%
Phalacroloma annuum (L.) Dumort.	44	U	70%
Erigeron canadensis L.	41	U	90%
Sedum sexangulare L.	39	I	70%
Aquilegia vulgaris L.	38	I	60%
Sambucus racemosa L.	36	I	60%
Impatiens glandulifera Royle	34	U	70%
Cotoneaster lucidus Schltdl.	31	I	60%

Species	Number of records	Mean of introduction in cemetery	Frequency[1] (%)
Amelanchier spicata (Lam.) K.Koch	27	I	70%
Jovibarba globifera L.	24	I	90%
Asparagus officinalis L.	20	I	60%
Solidago Canadensis L.	18	I	60%
Lupinus polyphyllus Lindl.	16	I	30%
Helianthus tuberosus L.	14	U	40%
Impatiens parviflora DC.	14	U	60%
Malus domestica Borkh.	11	U	60%
Erysimum hieracifolium L.	11	U	50%
Medicago falcata L.	11	U	60%
Bunias orientalis L.	10	U	50%
Sedum rupestre L.	9	I	40%
Sedum album L.	9	I	40%
Caragana frutex (L.) K. Koch	8	I	40%
Spiraea x rosalba Dipp	8	I	40%
Acer pseudoplatanus L.	6	I	20%
Sisymbrium loeselii L.	4	U	20%
Armoracia rusticana P.Gaertn., B.Mey. et Scherb.	4	U	30%
Acer negundo L.	4	U	20%
Galinsoga parviflora Cav.	4	U	40%
Echinocystis lobata (Michx.) Torr. et A.Gray	3	U	30%
Lamium album L.	3	I	30%
Spiraea alba Duroi.	3	I	30%
Physocarpus opulifolius (L.) Maxim.	3	I	30%
Populus laurifolia Ledeb.	3	U	10%
Medicago lupulina L.	2	U	20%
Populus alba L.	2	U	20%
Rosa rugosa Thunb.	2	I	20%
Robinia pseudoacacia L.	2	I	10%
Bellis perennis L.	2	I	20%
Lepidium densiflorum Schrad.	1	U	10%
Rumex confertus Willd.	1	U	10%
Populus x canadensis Moench.	1	U	10%
Sedum spurium M.Bieb	1	I	10%
Salix daphnoides L.	1	I	10%
Spiraea media Schmidt.	1	I	10%

[1] Plant occurrence frequency was calculated according to the formula ((number of cemeteries, where the plant was found / total number of cemeteries)*100).

From shrubs (15 species) in all the cemeteries were found (Table 1) *Spiraea chamaedryfolia* and *Syringa vulgaris*. With a lower frequency were found *Sorbaria sorbifolia*, *Caragana arborescens*, *Amelanchier spicata*, *Cotoneaster lucidum*. *Spiraea chamaedryfolia* and *Sorbaria sorbifolia* are widely distributed decorative bushes rapidly multiplying via root offshoots and occupying large areas, as well as creating dense groups around greeneries, for that reason their delimitation is recommended by walkways, waters [9]. While cemetery areas are remaining unmanaged, spiraeas are quickly spreading around the original plantations. Also *Syringa vulgaris* and *Caragana arborescens* as decorative shrubs are used in greeneries,

wherefrom they are spreading also over wider surrounding areas. Many of shrubs used in the greeneries are not only ornamental, but also fast-growing, winter-hardy, able to tolerate shade, etc. *Cotoneaster lucidum* is the most popular malleable hedge plant in Latvia [10].

From tree plants in cemetery areas were found 7 species (Table 1). *Malus domestica* is a food crop, culture escapee and wild self-sown trees have been found in very different habitats. *A Robinia pseudoacacia is grown* as an ornamental plantation tree. *Acer negundo*, *Populus balsamifera, Populus alba* and *Populus laurifolia* in the cemetery areas most likely have come from roadside greeneries. It should be noted that *Acer negundo* is an aggressive invasive species, which distribution is rather difficult to bring under control [11], because the plant is characterized by rapid distribution during the first years of growth. The seeds are easily spread during the leaf fall. In Latvia the plant is naturalized and a large number of fields are found in roadside areas [12].

20 (41%) (Table 1) from the invasive species found in the cemetery areas can be classified as unintentionally introduced species. These species are mainly accidentally introduced, for example, via transport or used in greeneries (however, not in cemeteries, but, for example, along the roadsides), and via either root offshoots or animals have reached the cemeteries – *Erigeron canadensis*, *Lepidium densiflorum* and *Populus* species. This group includes also *Amelanchier spicata* - food plant, which could have reached the territory of cemeteries by the bird-distributed seeds. *Impatiens parviflora* and *Impatiens glandulifera* in the cemetery territories most likely have also arrived with seeds from the surrounding area. Although the latter two species have reached the Latvian flora as ornamental garden escapees, however in the cemeteries these are not used in greeneries.

The remaining 29 species (59%) can be classified as intentionally introduced species, which are used as ornamental plants in the cemeteries. This category is mainly represented by the genus *Rosa*, *Sedum*. Genus *Sedum* are garden escapees, having adapted to growth in dry areas, therefore quite often found outside the cemetery greeneries [13]. Genus *Rosa* in many areas is used in greeneries, and is characterized by an aggressive root system - *Spiraea chamaedryfolia, Sorbaria sorbifolia* [10].

Much of the intentionally introduced taxa in cemeteries are spreading under influence of human activities – during the cemetery is put in order the plant vegetative parts, flowers, seeds, roots are getting outside the graves. Many of these plants continue to grow and to integrate into the local plant communities in the cemeteries, as well as outside their territories.

The highest number of invasive species was found in the Orthodox Cemetery (Table 2) and in the Communal Cemetery, while the lowest - in the Brethren Cemetery.

The most frequent plant in the Old Military Cemetery is *Sorbaria sorbifolia*. Since this is one of the oldest cemeteries of the city, a large part of the territory is not managed any more, *Sorbaria sorbifolia* is forming spacious stands in many places. In the cemetery also greenery plants, such as *Syringa vulgaris, Caragana arborescens, Spiraea chamaedrifolia, Spiraea x billardii* are widespread. Of the caulescent plants the most frequently met - *Aquilegia vulgaris, Erigeron canadensis, Aquilegia vulgaris* in cemeteries is cultivated as the grave greenery plant.

In the most shaded part of the Griva cemetery (the oldest part of cemetery) bushy plants are more frequent - *Syringa vulgaris, Caragana arborescens*, while in the sunniest areas frequent are such species as *Phalacroloma annuum, Euphorbia cyparissias, Lupinus polyphylla* and several species of *Crassulaceae*, which is widely distributed beyond the grave plantations. *Sedums* in the cemeteries are used as covering plants both on the graves, and around the said [14].

Table 2.

Invasive alien plant species in cemeteries of the city of Daugavpils

Cemeteries	Area of cemetery (ha)	Number of species	Number of the families found	The most widely distributed families	Number of the woody plant species	Number of the bushy plant species	Number of the caulescent plant species
Brethren cemetery	1	8	6	Rosaceae (2 species) Leguminosae (2 species)	1	4	3
Old military cemetery	8	25	9	Rosaceae (8 species)	1	10	14
Griva cemetery	12	28	13	Asteraceae (5 species)	2	5	21
Communal cemetery	22	30	13	Asteraceae (5 species) Rosaceae (7 species)	1	9	20
Catholic cemetery	12	24	12	Rosaceae (6 species) Asteraceae (4 species)	2	10	12
Lutheran cemetery	4	20	11	Rosaceae (3 species)	1	6	9
Liģinišķi cemetery	3	11	7	Rosaceae (4 species)	1	5	5
Orthodox cemetery	13	33	12	Rosaceae (10 species)	2	12	19
Old Believers' cemetery	8	28	14	Rosaceae (7 species)	3	10	15
Common graves and Babtist cemetery	3	12	7	Rosaceae (5 species)	1	7	4

In the Brethren cemetery the most frequent taxa are *Syringa vulgaris, Medicago falcata, Caragana arborescens*. Small number of species in the Brethren cemetery could be explained by small area of the cemetery, as well as the fact that in the cemetery there is a large solid lawn, separate plantations are not formed (which also explains the dominance of *Medicago falcata*) and there is also a single operator.

The most frequent Communal cemetery plants - *Cotoneaster lucidum, Impatiens glandulifera, Euphorbia cyparissias, Sedum sexangulare, Cotoneaster lucidum* is very widely used in the W part of the cemetery in order to isolate individual burial places and in this area invasion of the said plant outside greeneries is also observed. Quite interestingly, many authors [10] refer to the fact that *Cotoneaster lucidum* is an expressed sun-loving plant, but the performed studies are presenting evidence that the plant feels very well also in strongly shaded areas. In this cemetery there is one of the largest diversities of invasive caulescent plants on the city scale. Comparatively high overall proportion of invasive plant species could be related to the fact that the cemetery area today continues to expand rapidly, to the number of existing denominations are added new ones, for example, Islam, and also in the greeneries from time to time certain "fashion plants" are observed, which are used more frequently than other ornamental plants. The said facts in future could significantly contribute to the growth in the proportion of invasive species.

In the Catholic cemetery most frequently found are *Spiraea x billardii, Euphorbia cyparissias, Spiraea chamaedrifolia, Sorbaria sorbifolia, Syringa vulgaris, Caragana arborescens*. Large proportion of *Rosaceae* bushy plants is attributed to the fact that in the E and N part of the cemetery *Sorbaria sorbifolia, Caragana arborescens* are forming wide-growing stands and spreading well beyond the cemetery area in the undergrowth.

The most frequently found in the Lutheran cemetery are *Syringa vulgaris, Caragana arborescens, Spiraea chamaedrifolia, Spiraea x billardii, Aquilegia vulgaris*. Dominance of

the invasive bushy plants can be explained by the fact that part of this cemetery is not under operation any more, and these plants are forming dense monodominant stands.

The most frequently found in the Old Believers' cemetery are *Euphorbia cyparissias, Spiraea chamaedrifolia, Syringa vulgaris* Since the cemetery area is not extending anymore and more new burials are not made, "entering" of new species from the greeneries is actually not occurring any more. Number of species in the future may increase mainly on account of the accidentally introduced species. Similar situation is observed also in the Common graves and the Baptist cemetery. Here, the most frequently found plant - *Sambucus racemosa*.

The largest number of species was found in the Orthodox cemetery, the most frequent - *Spiraea chamaedrifolia, Caragana arborescens, Sambucus racemosa*. There the highest proportion of invasive bushy plants was also listed.

In the Liginišķi cemetery the most frequently found - *Impatiens glandulifera*, *Sambucus racemosa* and *Impatiens glandulifera*. Interestingly that historical data on the age of the cemetery are different - it is mentioned that this is one of the oldest cemeteries in the city, but it is not marked on the city maps neither in 1917, nor 1928 [15]. Number and composition of the invasive species is presenting more evidence, however, that is a comparatively new cemetery, since here more dominant are invasive plants, the primary use whereof is not the cemetery plantations.

In general, all the cemeteries were dominated by the *Rosaceae* (12 species), *Leguminosae* (6), *Asteraceae* (5) and *Crassulaceae* (5) plants. The orpine family (*Crassulaceae*) was dominated by the *Sedum* species. Comparatively wide distribution of the *Sedum* could be explained by the fact that as ornamental plants they are widely used in the grave greeneries, and they do not require special care [16, 17]. The highest concentration of these was observed in the sunny and sandy cemetery areas. Plants have adapted to grow in dry places [9]. Many of the *Asteraceae* species, which are popular in cemeteries as ornamental plants, have also been adapted for seed dispersal through wind and frequently escape into the surrounding environment [3].

Correlation diagram shows that a significant positive linear correlation exists between the area of cemeteries and the number of invasive species found (correlation: r = 0.838472). Conclusion can be drawn that in the majority of the cemeteries number of species is dependent on the cemetery area. However, there are also other factors that are having an impact on the number of species in the cemeteries - human influence, circumstances of growth, habitats.

Upon analysis and correlation of the data on the number of species and age of the formation of cemetery, no significant correlation was observed. Practically no correlation exists between the age of the cemetery and the number of species found (correlation: r = 0.021322).

Data obtained are indicative of increase in the numbers of invasive plant species.

Proportion of the number of invasive species in the cemetery is not affected also by the represented denomination. Perhaps, some plants are planted in cemeteries with symbolic meaning, however, majority of the plants are having highly ornamental mode of application. Plants found in the cemeteries of all denominations are *Jovibarba globifera, Spiraea x billardii, Euphorbia cyparissias, Spiraea chamaedryfolia, Erigeron canadensis***,** *Sedum sexangulare, Sorbaria sorbifolia, Impatiens parviflora, Phalacroloma annuum*. Bushy plants of the Rose family are widely distributed in majority of the cemeteries, in many places forming also big stands outside the greeneries.

Invasive plants are spreading also beyond the graveyards - on roadsides, in nearby meadows, edges of a forest, in ditches. Plant distribution is facilitated both by natural elements - wind, water, birds, as well as human activities, when landfills adjacent to the cemeteries are reached by the plant flowers, seeds, parts of roots, new offshoots, some of which survive, continue to grow and to spread [3, 16, 17].

Plants cultivated in gardens, other ornamental plantations, and in cemeteries particularly, possess no danger to the environment until they remain in cultivation. However, any plant that has escaped from cultivation should not be neglected because this process can be the start of species naturalization and future invasion [18].

Conclusion

49 invasive alien plant species have been found in cemetery areas of the city of Daugavpils, which amounts to 5% from the total number of species in Daugavpils.

The identified plants are representing 16 families, of which the largest number of species is for the *Rosaceae*, *Crassulaceae* and *Leguminosae*.

There is a strong correlation between the area of cemeteries and the number of invasive species in them. Age and religious affiliation of cemeteries has no effect on the diversity of species.

Majority of the invasive species have entered the cemetery areas from the grave or hedge greeneries.

Many of the identified species have adapted to conditions of growing in cemeteries and their spreading continues. Distribution of invasive species was also observed outside the cemetery territories - in neighboring meadows, edges of a forest, in ditches, where plants are getting both under impact of natural factors and with human assistance. As an important intermediate for the migration of species from cemeteries to the surrounding areas can be considered the landfills adjacent to the cemeteries.

During the research also the opposite process was observed that species (*Acer negundo*, *Erigeron canadensis*, *Bunia orientalis*, etc.), which are not used for cemetery greeneries, are getting into cemeteries from the surrounding areas.

Species such as *Sorbaria sorbifolia*, *Acer negundo*, *Erigeron canadensis* etc. may be considered to be aggressive, which are not only spreading without human involvement; however it is difficult to impose restrictions on their distribution.

Number of invasive species in the future will tend to increase as the species adapt to the specific growing conditions in cemeteries, are occupying increasingly new niches, displacing the local plant species.

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