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HERBACEOUS PLANTS FOR CLIMATE ADAPTATION AND INTENSELY DEVELOPED URBAN SITES IN NORTHERN EUROPE: A CASE STUDY FROM THE EASTERN ROMANIAN STEPPE

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Abstract

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In the increasingly compact city, services currently provided for in parks will in future be compressed into smaller green unit-structures, often associated with paved surfaces. Left-over spaces in urban environments, such as traffic roundabouts and strips along paths, roads and other corridors, will be important in the future city in order to deliver different eco-system services, especially stormwater management. It is therefore essential to start now to develop the knowledge and experience needed to create sustainable plantings for these sites. This paper presents the findings of a field survey in eastern Romania that sought to identify potential species for urban paved plantings in the Scandinavian region (northern Europe). The research approach is rooted in the hypothesis that studies of natural vegetation systems and habitats where plants are exposed to environmental conditions similar to those in inner-city environments can: 1) identify new or non-traditional species and genotypes adapted to urban environments; and 2) supply information and knowledge about their use potential concerning growth, flowering, life form, etc. In total, 117 different herbaceous species, all of which experience water stress regimes comparable to those in urban paved sites in Scandinavia. The initial information obtained from this field survey present a base of knowledge of which species that have a future potential for use in urban environment, which is of great importance in the following work within this project instead of testing species randomly without this knowledge of the species tolerance and performance in similar habitats.

Key words: urban planning, ecosystem services, steppe meadows, flowering field layers, urban horticulture.

Introduction

Although aesthetic experiences are fundamentally important to human well being (Grahn, Stigsdotter, 2003), green infrastructure in urban environments must provide more than this.

Enhancement of biological diversity, stormwater management, urban heat island and pollution mitigation, are additional services urban vegetation must provide (Forman, Godron, 1986; Maco, McPherson, 2003; Tyrväinen et al., 2005; Nowak et al., 2006; King, Davis, 2007). In the increasingly compact city, services currently provided for in parks will in future be compressed into smaller green unit-structures, often associated with paved surfaces. Leftover spaces in urban environments, such as traffic roundabouts and strips along paths, roads and other corridors, will be important in the future city in order to deliver the above-mentioned functions and qualities, especially stormwater management. It is therefore essential to start now to develop the knowledge and experience needed to create sustainable plantings for these sites. Due to road traffic such sites are potentially difficult and even dangerous to access to undertake management. It is therefore important that these plantings have very limited management demands while at the same time be aesthetically pleasing throughout the year. Since the scale of roadside sites often limits the use of trees and sometimes also shrubs, and since the latter have high costs associated with managing the boundary between paving and canopy, herbaceous plantings are important in these sites.

In the Scandinavian region, the trend is for these sites to adopt a horticultural approach, with classical perennial species originating from forest habitats, such as *Geranium* spp. and *Alchemilla* spp. (Grime et al., 2007). However, plantations of these species require extensive maintenance in order to persist, including watering, mulching and weeding, since roadside sites have more in common with e.g. dry steppe meadow systems than moist forest habitats. These problems will be further exacerbated with climate change. All planting if it is to be successful, involves compromise between what is aesthetically desirable and what is possible; in the ecological reality (Dunnett, 2005). Historically, horticultural technology was employed to override what was ecologically possible on any given site, but this has additional economic and environmental costs. Where there is an ecologically well-informed basis for the choice of plant species, designed plantings has the potential to achieve maximum aesthetic effect with relatively little site modification (Hitchmough, Dunnet, 2005). Choosing plants according to fitness to site also reduces the need for resource-intensive site manipulations and future management demands (Dunnett, 2005).

Paved urban environments experience periodic severe moisture stress due to precipitation loss. This is caused by the surface drainage systems of buildings and infrastructure, as well as from interception of tree canopies locally. Climate change predictions for the Scandinavian region, which include higher average temperature and less precipitation in summertime (IPCC, 2007; Allen et al., 2010) will exacerbate this. The predominantly mesic native meadow flora of Scandinavia is relatively poorly fitted to these conditions. Many of the most attractive forbs are small stress-tolerating species (Grime et al., 2007), which are subject to competitive displacement by the most vigorous community dominants on highly productive soils in the absence of summer hay cutting. Cutting and removal of the meadow canopy in summer is culturally problematic in the urban situations (Hitchmough et al., 2004). If cut for hay, meadows effectively disappear in summer and are replaced by yellowing stubble. If cutting is delayed until autumn they tend to "flop" post flowering and may be regarded as untidy or unattractive. In urban landscapes, this restricts the use of mesic native meadows to situations where these visual characteristics are acceptable (Hitchmough et al., 2004). This is often at a distance from where people gather, live or work. In intensely scrutinised paved urban landscapes, longer term structure plus dramatic flowering over a long period appear to be very important to members of the public. In the case of the Scandinavian region, the use of exotic species is necessary to satisfy these requirements in paved environments.

Eastern Romania has been identified as a future source area of plants for inner-city environments of Scandinavia, as its native plants are exposed to similar climate and stress regimes as those associated with urban paved sites (Sjöman, Richnau, 2009; Sjöman et al., 2012). Due to the higher summer temperatures and lower rainfall compared with Western Europe, large areas of steppe communities have developed in eastern Romania (Breckle, 2002). The steppe is typically associated with sites that experience cold winters, moist springs and hot dry summers – situations very comparable to those at urban paved environments of the Scandinavian region. Since the eastern European steppe is very rich in species (Tutin et al., 1964–1980), there should be a high possibility of identifying valuable species and sub communities within this region.

This paper presents the findings of a field survey in eastern Romania that sought to identify potential species for urban paved plantings in the Scandinavian region. The research approach was rooted in the hypothesis that studies of natural vegetation systems and habitats where plants are exposed to environmental conditions similar to those in inner-city environments can: 1) identify new or non-traditional species and genotypes adapted to urban environments; and 2) supply information and knowledge about their use potential concerning growth, flowering, life form, etc. This study represents the first step in a research programme initiated by the Swedish University of Agricultural Sciences and Sheffield University to examine selection of site-adapted species for urban paved sites in the Scandinavian region. Specific objectives of this first phase were as follows:

- Compare climatic and edaphic characteristics of three steppe vegetation habitats in Romania with generalised conditions in Copenhagen, Denmark
- To undertake a botanic survey of the species present in these sites
- To undertake a preliminary review of these species in terms of likely value to designed plant communities for use in Southern Scandinavia

Material and methods

Case study area

Eastern Romania has a temperate continental climate, with hot summers, and long, cold winters. In north-east Romania, steppe communities require annual spring cutting or burning in order to avoid invasion by shrubs and trees, while in more southernly areas the climate is sufficiently warmer and drier, to result in largely treeless grasslands, in which woody plants are represented by shrubs such as *Cotinus coggygria* and the adventive and invasive species *Elaeagnus angustifolia* (Ciocârlan, 2009). Much of the original steppe in eastern Romania has been in retreat for the past 100 years due to agricultural intensification. In order to protect the species-rich steppe systems from extinction, several nature reserves have been established throughout eastern Romania. During May 2012, field studies were carried out along a north-south transect in three such nature reserves in order to study steppe meadows along a climate gradient, with drought stress increasing with decreasing latitude. The study sites were: Alah Bair Hill (44°29´859N, 28°13´522E), Jurilovca at Doloşman Cape (44°45´314N, 28°55´973E), and David Valley (47°11´575N, 27°28´184E) – Fig. 1.

Climate data for the field study areas (Table 1) were obtained from the nearby meteorological stations of Iaşi (David Valley), Tulcea (Jurilovca), and Constanţa (Alah Bair Hill), based on mean values from 1980–2010. Accord-

Fig. 1. The case study sites in eastern Romania (Illustration by Björn Wiström).

ing to these data, Iași differs from the other two sites by having higher precipitation and lower mean annual temperature. Iași experiences much more precipitation in July and August than the other two sites (see Table 1). Tulcea and Constanța differ mainly in terms of mean annual precipitation, with 62 mm more rain at Constanța, while the annual mean temperature does not differ.

Since the ability to withstand summer drought is one of the key selection criteria in choosing urban plant species, where irrigation is limited or unavailable (Dunnett, Kingsbury, 2008), it is important to compare water stress between the wild habitat of species and the proposed cultivation site. In this study, the potential water stress at the study sites was calculated and compared with data for inner-city environments in Copenhagen (Denmark), one of the largest cities in the region to make a preliminary assessment of the suitability and usefulness of the plants in eastern Romania for urban

Table 1. Mean monthly temperature (°C) and precipitation (mm) at the study sites.

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual mean[a]
Iasi (David Valley)													
Mean monthly temp. (°C)	0	0.4	3.6	11.2	16.6	20.8	22	21.5	16.3	10.2	4	0	M=10.6
Mean monthly precipitation (mm)	23.7	14.7	20.1	30	34.8	44.3	60.3	68.4	35.2	25.7	19.9	22.2	S=399.3
Tulcea (Jurilovca)													
Mean monthly temp. (°C)	1	3	6	11.5	16.9	21.1	23.1	22.1	18.2	12	8.5	1	M=12.0
Mean monthly precipitation (mm)	14.9	11.7	18.3	22.7	42.4	35	34.5	29.1	34.9	16.6	31.8	22	S=313.9
Constanța (Alah Bair Hill)													
Mean monthly temp. (°C)	2	3.5	6.5	10.1	16	21	23	23.1	18.2	13.6	7.7	1.5	M=12.2
Mean monthly precipitation (mm)	11	9	18.7	25	59.9	24.2	35.6	47.8	49.5	23.9	42.8	28.6	S=376.0

a Mean annual temperature (M) and cumulative precipitation (S) in the respective area sites in Scandinavia (Fig. 2). For calculation of potential evapotranspiration, the regression presented by Thornthwaite (1948) was used, with monthly potential evapotranspiration based on the values of temperature (Table 1), number of sunshine hours per day and cloudiness. Sunshine hours per day were estimated on a monthly basis by combining them with information about day length (Meeus, 1991), while days with rainfall were used as an indicator of cloudiness (Ursu, 2005). Estimates of water run-off for the studied meadows were based on P90 (2004), with an assumed 10% run-off. Urban sites in Copenhagen currently have a mean annual temperature of 8-12 °C when the urban heat island effect is included (+1-3 °C) (DMI, 2009; US EPA, 2009) and mean annual precipitation of 525 mm (DMI, 2009). In calculating potential water stress (net water difference) for urban paved environments in Copenhagen, water run-off was assumed to be 70% (P90, 2004; Sjöman, Richnau, 2009).

Field measurements

At each study site, an inventory of plants was carried out on 2x2 m plots located on transect with 10 m distance between each plot. Each transect contained 20 plots over a total distance of 190 m, with a total plot area of 80 m^2 for each transect. Three such transects were randomly laid out at each study site, resulting in 60 plots per site with a total plot area of 240 m^2. Within each plot, all plant species were documented and the incidence of species in each plot was divided into intervals of 10% (Table 3).

In the compilation of identified species, flowering period, flowering colours, height and growth type were added in order to determine their horticultural value. Growth habit was divided into ground-covering or clump growth (Hansen, Stahl, 1993). In addition, the life form of the species was divided into annual, biennial or perennial (Table 3). This information was obtained from local floras (Burduja, 1959; Tutin et al., 1964–1980; Mititelu et al., 1969; Kovàcs et al., 1970; Ciocârlan, Costea, 1997; Petrescu, 2004, 2007; Prina, 2009; Table 3).

In all plots, soil texture, humus content and pH value were determined. Soil samples were collected at three different depths (0–20, 20–30 and 30–50 cm) from 10 pits randomly distributed in each field area (Klute, 1986; FAO, 2006; Table 2). The replicate samples for each depth and plot were pooled before analysis (FAO, 2006). Soil texture was analysed using the soil grain analyser method (Ehrlich, Weinberg, 1970), organic matter using the $K_2Cr_2O_4$ method (Sims, Haby, 1971), and pH using the potentiometric determination method (soil/water = 1 : 2) (Tan, 2005). In order to investigate the resource load of the soil, biologically available phosphorus (P) and total P were analysed. Since nitrogen (N) is a very mobile nutrient, both inside the plant and in the soil, we opted to analyse only the amount of P in the soil, as it is much more stable and can hence give an insight into the resource load on the study sites (Vitousek, 2004). Biologically available P and total P were analysed using the ammonium lactate-acetic acid (AL-AA) method (Pierzynski, 2000).

Table 2. Selected properties of the soil in the study sites. Values shown are the mean of three different sampling depths.

Site	Mean clay (%)	Mean silt (%)	Mean humus (%)	Mean pH	Total P	Available P
David Valley	35.3	59.3	7.7	7.2	28.9	1.8
Jurilovca	13.0	45.0*	5.2	7.8	49.2	4.5
Alah Bair Hill	15.3	72.0	8.6	7.6	50.8	4.4

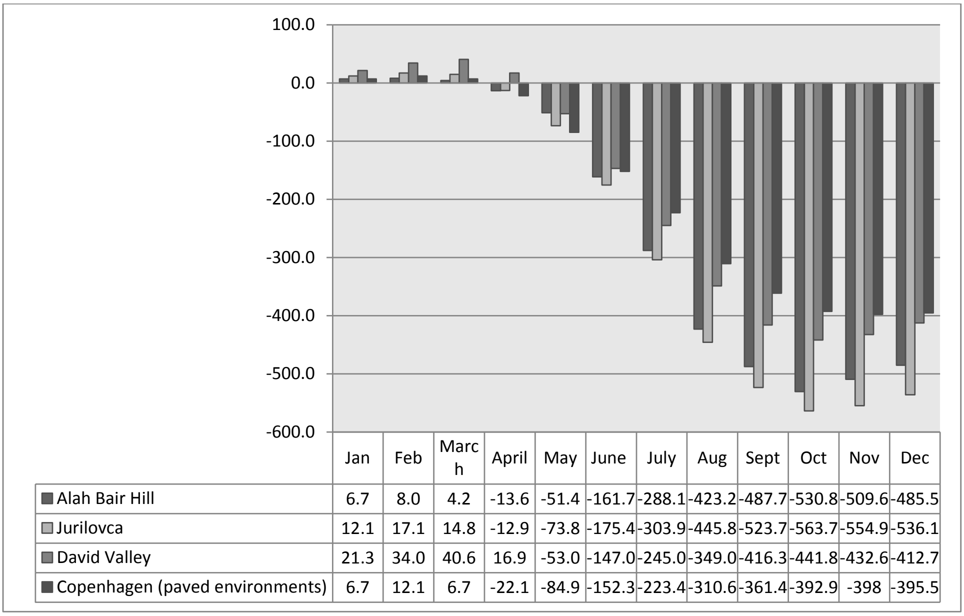
*13-17% of the soil texture at Jurilovca comprised sand grains larger than 20 mm.

Results

Site evaluation

Calculation of potential water stress at the study sites showed that both Alah Bair Hill and Jurilovca experienced an early negative net water balance, of 13.6 and 12.9 mm respectively, in April, while in the David Valley near Iaşi city a negative water net difference (of 53 mm) did not develop until May, due to the cooler and moister conditions at that site (Table 1). This trend for a much more severe negative water net level for Alah Bair Hill and Jurilovca compared with David Valley continued throughout the season. Comparing the two southern sites, Jurilovca experienced more severe potential water stress than Alah Bair Hill due to less precipitation, especially in late summer (Table 1). Urban paved sites in Copenhagen experience a greater negative water net difference during April and May than all three study sites. This difference is greatest in comparison with David Valley. In June and July, the three study sites experience similar or more severe potential water stress than paved environments in Copenhagen (Fig. 2).

The soil analyses revealed high levels of clay (35.3%) in David Valley, while the clay content was lower at the other two sites (13–15%). All study sites had very high levels of silt (25–72%), indicating good to high water-holding capacity. It is anticipated that David Valley would have the highest water holding capacity, and Jurilovca the least due to its coarse soil texture, with 13–17% of the soil texture comprising gravel fractions larger than 20 mm (Table 2). Available P, were highest at Alah Bair and Jurilovca, and lowest at David Valley. However, since high pH levels (> 8) make it difficult for plants to utilise available P, Alah Bair Hill (pH 7.6) and Jurilovca (pH 7.8) can also be considered sites with low levels of available P (Table 2).



	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
■ Alah Bair Hill	6.7	8.0	4.2	-13.6	-51.4	-161.7	-288.1	-423.2	-487.7	-530.8	-509.6	-485.5
■ Jurilovca	12.1	17.1	14.8	-12.9	-73.8	-175.4	-303.9	-445.8	-523.7	-563.7	-554.9	-536.1
■ David Valley	21.3	34.0	40.6	16.9	-53.0	-147.0	-245.0	-349.0	-416.3	-441.8	-432.6	-412.7
■ Copenhagen (paved environments)	6.7	12.1	6.7	-22.1	-84.9	-152.3	-223.4	-310.6	-361.4	-392.9	-398	-395.5

Fig. 2. Calculated potential net differences in the study plots and at urban paved sites and park environments in Copenhagen, Denmark, illustrating the site match between the study plots and urban sites.

Plant material

In total, 117 different herbaceous species, most of which were perennials were found at the three study sites. The most species-rich site was David Valley, with a total of 77 species, followed by Jurilovca (50 species) and Alah Bair hill (45 species) (Table 3). Concerning plant height, there was great variation from very low-growing plants to tall species reaching 150–200 cm. As regards the growth habit of the species found on the study sites, there was a dominance of clump-forming species. Of the 117 species found, only 13 were present at all three study sites. The most dominant species at David Valley were *Teucrium chamaedrys* and *Phlomis herba-venti* subsp. *pungens*, which occurred in 44 and 43 study plots, respectively. Their mean coverage in the plots was 20–30% (Table 3). At Jurilovca the most common species was *Artemisia lerchiana*, which was found at all 60 study plots, with a mean coverage of 30–40%. At Alah Bair Hill *Euphorbia cyparissias* was found in all plots, with a mean coverage of 10–20%.

Since the field work was carried out in the end of May, many early flowering species had entered dormancy, which resulted in the main flowering period of the species found being from late May to August (Table 3).

Discussion

This study is the first step in a programme of research to develop knowledge on continental steppe vegetation as climate change adaptation vegetation for left-over spaces in paved surfaces in the modern compact city. The specific purpose of the study described in this paper was to identify potentially useful species for these types of situations, and to begin to develop understanding of the nature of the communities they occur in. Natural habitats with the best match to paved environments are often unproductive habitats occupied by stress-tolerant forbs and grasses (Lundholm, 2011).

At the three different study sites surveyed, 117 different species were found, all of which experience water stress regimes comparable to those in urban paved sites in Scandinavia. In order to evaluate the match between the study sites and urban paved sites in Scandinavia, a comparison was made between their cumulative water deficit and that at paved environments in Copenhagen, Denmark. In this comparison, both Jurilovca and Alah Bair Hill showed a much more severe negative water net difference than paved sites in Copenhagen in summer, while David Valley was a closer match. However, this gave a somewhat skewed picture, especially for Alah Bair hill and Jurilovca, since the soil texture at those sites provided good water-holding capacity. Water-holding capacity was even higher at David Valley due to rather high levels of clay (Brady, Weil, 2002). Soil texture and structure counteracted the cumulative water deficit in the study plots. However, the plants at the sites, particularly at Alah Bair Hill and Jurilovca, will still experience periods of drought that are a fairly close match to conditions at paved sites in Copenhagen in summer.

As herbaceous plants have substantial capacity to increase tolerance of moisture stress through increasing their root:shoot ratios through a reduction in leafiness and canopy size, it is difficult to be categorise on whether these species would be sufficiently drought tolerant in Scandinavia on the basis of habitat characterisation. The next step would be to test seedlings of the steppe species across moisture and nutrient gradients within experiments in Scandinavia that reflect likely field conditions.

When analysing the plant data from the study sites, it is important to consider the current use and maintenance of the meadows. Since the climate in north-east Romania allows tree

T a b l e 3. Plant species found at the study site: Number of plots where the species was found/incidence of the species in the study plots (divided into intervals of 10% where •= less than 10%, ••=10–20%, •••=20–30%, ••••=30–40%, •••••=40–50%, ••••••=50–60%, •••••••=60–70%). Flowering time is classified by dividing the month into two halves; early and late. Life form is classified as annual (A), biennial (B) or perennial (P). Growth habit is classified as ground-covering (GC) or clump-forming (Cl). Information on flowering time, flower colour/s, life form, growth habit and height were taken from existing floras (Burduja, 1959; Tutin et al., 1964–1980; Mititelu et al., 1969; Kovàcs et al., 1970; Ciocârlan, Costea, 1997; Petrescu, 2004, 2007; Prina, 2009).

	Study site			Flowering period																								Flower colour	Life form	Growth type		Height (cm)
Species	David Valley	Jurilovca	Alah Bair	J		F		M		A		M		J		J		A		S		O		N		D				GC	Cl	
Achillea coarctata	-	58 / (••)	-											X	X	X	X											yellow	P		X	20–90
Achillea setacea	37 / (•)	16 / (•)	49 / (•)											X	X	X	X	X	X									white	P		X	15–60
Adonis flammea	46 / (••)	22 / (•)	-									X	X	X	X	X	X	X	X									red bright	A		X	20–50
Adonis vernalis	47 / (••)	-	-							X	X	X	X															golden-yellow	P		X	10–40
Agrimonia eupatoria subsp. *eupatoria*	5 / (•)	-	-											X	X	X	X	X	X									yellow	P		X	15–150
Agropyron cristatum subsp. *pectinatum*	13 / (•)	30 / (••)	6 / (•)									X	X	X	X	X	X											light yellow	P	X		20–60
Agropyron repens (syn. *Elymus repens)*	-	12 / (•)	-											X	X	X	X											green	P	X		30–150
Ajuga chamaepytis	-	-	1 / (•)									X	X	X	X	X	X	X	X									yellow	A	X		10–30
Ajuga laxmanni	10 / (•)	-	-									X	X	X	X													light yellow	P		X	20–50
Allium rotundum subsp. *rotundum*	-	5 / (•)	1 / (•)											X	X	X	X											violet	P		X	30–50
Amaranthus spp.	-	-	1 / (•)											X	X	X	X	X	X	X	X							green	A	X	X	–100 cm
Anchusa ochroleuca	1 / (••)	-	-									X	X	X	X	X	X											white to light yellow	P	X	X	30–80
Aristolochia clematitis	1 / (•••••••)	-	-									X	X	X	X													yellow	P		X	20–40
Anthemis austriaca	-	-	15 / (•)											X	X	X	X											white & yellow	A		X	10–60
Artemisia campestris subsp. *campestris*	-	-	1 / (•)											X	X	X	X	X	X	X	X							yellow	A	X	X	20–120
Artemisia lerchiana	-	60 / (••••)	47 / (••)															X	X	X	X							yellow	P		X	20–40
Asparagus officinalis subsp. *officinalis*	25 / (•)	-	-									X	X	X	X													green	P		X	30–150 (–200)
Aster oleifolius	3 / (••••)	-	-													X	X	X	X	X	X							yellow	P		X	15–35
Bassia prostrata	1 / (•)	1 / (•)	1 / (•)													X	X	X	X	X	X							green	P	X		10–60
Bromus commutatus	-	27 / (••)	51 / (•••)									X	X	X	X													light yellow	A,B		X	30–90
Campanula sibirica	11 / (•)	-	-									X	X	X	X	X	X											blue	A		X	15–60
Carduus acanthoides	-	48 / (••)	19 / (•)											X	X	X	X	X	X	X	X							violet	A		X	50–150
Carex humilis	7 / (•)	-	-					X	X	X	X	X	X															green	P	X		3–15
Centaurea gracilenta	-	23 / (•)	-											X	X	X	X											violet	B		X	15–50
Centaurea orientalis	9 / (•)	-	46 / (•)											X	X	X	X	X	X									yellow	P		X	50–120
Cerinthe minor	5 / (•)	-	-											X	X	X	X											yellow	A,B	X	X	20–60
Chondrilla juncea	-	15 / (•)	-													X	X	X	X	X	X							yellow	B,P		X	30–100
Clematis integrifolia	26 / (•)	-	-									X	X	X	X													deep blue	P		X	30–70
Convolvulus arvensis	5 / (•)	16 / (•)	4 / (•)									X	X	X	X	X	X	X	X	X	X							white	P	X		20–100

T a b l e 3. Continuation.

	Study site			Flowering period																								Flower colour	Life form	Growth type		Height (cm)
Species	David Valley	Jurilovca	Alah Bair	J		F		M		A		M		J		J		A		S		O		N		D				GC	Cl	
Convolvulus cantabrica	-	17 / (•)	6 / (•)									X	X	X	X	X	X											pink	P	X		15–40
Convolvulus lineatus	-	1 / (•)	9 / (•)											X	X	X	X											pink	P	X		10–40
Coronilla varia	18 / (•)	-	1 / (•)											X	X	X	X	X	X									white and blue	P	X	X	20–120
Crambe tataria var. *tataria*	15 / (••)	-	-							X	X	X	X	X	X													white	P		X	60–150
Cytisus nigricans	40 / (•)	-	-											X	X	X	X	X	X									yellow-brown spotted	P		X	30–150
Dianthus membranaceus	49 / (•)	-	-											X	X	X	X	X	X									red	P		X	30–70
Coronilla varia	18 / (•)	-	1 / (•)											X	X	X	X	X	X									white and blue	P	X	X	20–120
Crambe tataria var. *tataria*	15 / (••)	-	-							X	X	X	X	X	X													white	P		X	60–150
Cytisus nigricans	40 / (•)	-	-											X	X	X	X	X	X									yellow-brown spotted	P		X	30–150
Dianthus membranaceus	49 / (•)	-	-											X	X	X	X	X	X									red	P		X	30–70
Echinops ritro subsp. *ruthenicus*	-	2 / (•)	-											X	X	X	X	X	X									blue-white	P		X	40–200
Echium vulgare	2 / (•)	7 / (•)	-											X	X	X	X	X	X									blue	B		X	20–70
Erodium ciconium	-	7 / (•)	3 / (•)									X	X	X	X													blue	A	X		10–60
Eryngium campestre	22 / (•)	49 / (•)	39 / (•)													X	X	X	X									white-green	P		X	20–70
Erysimum diffusum	25 / (•)	43 / (•)	26 / (•)									X	X	X	X	X	X											yellow	B,P		X	30–120
Euphorbia agraria	-	3 / (•)	-													X	X	X	X									green-yellow	P		X	30–90
Euphorbia cyparissias	-	13 / (••)	60 / (••)									X	X	X	X													green-yellow	P		X	15–50
Falcaria vulgaris (syn. *Falcaria sioides)*	5 / (•)	-	-													X	X	X	X									green	A,B		X	20–60
Festuca callieri	-	6 / (••)	10 / (••)									X	X	X	X													green	P	X	X	15–35
Festuca valesiaca	9 / (•)	-	32 / (••)									X	X	X	X	X	X											green	P	X	X	25–40
Filipendula vulgaris	30 / (•)	-	-									X	X	X	X	X	X											white	P		X	30–80
Fragaria viridis subsp. *viridis*	12 / (•)	-	-									X	X	X	X													white	P	X		8–15
Fumaria schleicheri	-	4 / (•)	-									X	X	X	X	X	X	X	X									violet	A	X		10–30
Galium humifusum	-	34 / (•••)	9 / (•)											X	X	X	X	X	X									white	P	X		40–150
Galium verum	9 / (•)	-	-									X	X	X	X	X	X	X	X									yellow	P		X	30–100
Galium octonarium	24 / (•)	-	-									X	X	X	X													white	P		X	30–80
Galium volhynicum	-	5 / (•)	-											X	X	X	X											white	P		X	40–80
Haplophyllum suaveolens	-	5 / (••)	-											X	X	X	X											yellow	P		X	15–30 (–50) cm
Helichrysum arenarium subsp. *arenarium*	-	2 / (•)	15 / (•)													X	X	X	X	X	X							golden-yellow	P		X	10–30 (–50)
Herniaria incana	-	6 / (•)	-													X	X	X	X	X	X							white-grey	P	X		10–25 (–30)
Hieracium bauhinii	6 / (•)	-	-									X	X	X	X	X	X											yellow	P	X	X	20–60
Inula britannica	35 / (••)	-	-													X	X	X	X									yellow	P		X	20–60

T a b l e 3. Continuation.

	Study site			Flowering period																								Flower colour	Life form	Growth type		Height (cm)
Species	David Valley	Jurilovca	Alah Bair	J		F		M		A		M		J		J		A		S		O		N		D				GC	Cl	
Inula ensifolia	10 / (••)	-	-													X	X	X	X									yellow	P		X	10–40
Inula germanica	6 / (••••)	-	-													X	X	X	X									yellow	P		X	30–60
Inula hirta	14 / (•••)	-	-											X	X	X	X	X	X									yellow	P		X	15–45
Inula oculus-christi	1 / (•••)	4 / (•)	-											X	X	X	X	X	X									yellow	P		X	20–60
Iris aphylla subsp. *hungarica* (syn. *I. hungarica)*	1 / (•)	-	-									X	X	X														blue-deep violet	P		X	15–35
Iris brandzae	4 / (•)	-	-									X	X															blue	P		X	15–25
Jurinea consanguinea subsp. *arachnoidea*	9 / (•)	-	-									X	X	X	X													blue-violet	P		X	30–70
Knautia arvensis	39 / (•)	-	-									X	X	X	X	X	X	X	X	X	X							blue	P		X	30–100 (–150)
Lathyrus pallescens	11 / (•)	-	-									X	X	X	X													yellow	P		X	10-30
Lavatera thuringiaca	5 / (•)	-	-									X	X	X	X	X	X	X	X	X	X							light blue - pink	P		X	60–200
Linaria genistifolia subsp. *genistifolia*	-	35 / (•)	3 / (•)													X	X	X	X									yellow	P		X	50–100
Linum austriacum	2 / (•)	4 / (•)	8 / (•)											X	X	X	X											blue	P		X	10–60
Linum hirsutum	-	10 / (•)	2 / (•)									X	X	X	X	X	X											white	A		X	20–60
Lithospermum arvensis subsp. *arvensis (*syn. *Buglossoides arvensis* subsp. *arvensis)*	4 / (•)	-	-									X	X	X	X	X	X	X	X	X	X							yellow	P		X	10–30 (–45)
Lotus corniculatus	-	24 / (•)	-											X	X	X	X											blue	P	X	X	5–35
Marrubium peregrinum	17 / (••)	41 / (•••)	15 / (••)											X	X	X	X	X	X									white	P		X	30–60
Melampyrum arvense	42 / (•)	-	-											X	X	X	X	X	X									red	A		X	15–50
Melica ciliata subsp. *ciliata*	5 / (•)	-	-											X	X	X	X											white-green	P		X	20–60
Muscari tenuiflorum	35 / (•)	-	-											X	X													deep blue	P		X	20–50
Nonea pulla	1 / (•)	-	-									X	X	X	X	X	X											deep red	P		X	15–50
Onobrychis viciifolia	1 / (•)	3 / (•••)	-											X	X	X	X	X	X									pink	P		X	10–80
Onopordum acanthium	1 / (•)	5 / (•)	6 / (•)													X	X	X	X									violet	B		X	30–200
Onopordum tauricum	-	2 / (••)	-											X	X	X	X											violet	B		X	80–200
Onosma visianii subsp. *visianii*	-	1 / (•)	2 / (•)									X	X	X	X	X	X											yellow	P		X	30–60
Pastinaca graveolens	23 / (•)	-	-													X	X	X	X									yellow	B		X	40–100
Phlomis herba-venti subsp. *pungens*	43 / (•••)	-	-											X	X	X	X											deep violet	P		X	30–60
Phlomis tuberosa	35 / (••)	-	-											X	X	X	X											violet	P		X	50–150
Plantago argentea	30 / (•)	9 / (•)	-									X	X	X	X	X	X											white - green	P		X	10–40 (–70)
Plantago media	-	-	17 / (•)									X	X	X	X	X	X	X	X									white - green	P		X	10–50
Potentilla argentea subsp. *argentea*	2 / (•)	-	-											X	X	X	X	X	X	X	X							yellow	P		X	10–50
Potentilla erecta	9 / (•)	22 / (••)	4 / (•)									X	X	X	X	X	X	X	X									yellow	P		X	10–30
Ranunculus polyanthemos subsp. *polyanthemoides*	6 / (•)	-	-									X	X	X	X	X	X											yellow	P		X	30–130

T a b l e 3. Continuation.

	Study site			Flowering period																								Flower colour	Life form	Growth type		Height (cm)
Species	David Valley	Jurilovca	Alah Bair	J		F		M		A		M		J		J		A		S		O		N		D				GC	Cl	
Reseda lutea	1 / (•)	21 / (•)	6 / (•)									X	X	X	X	X	X											light yellow	B,P	X	X	30–70
Rhinanthus minor	11 / (•)	-	-									X	X	X	X	X	X	X	X									yellow	A		X	5–30
Salvia aethiopis	-	25 / (•)	29 / (•)												X	X	X	X											white	B,P		X	30–100
Salvia austriaca	19 / (•)	-	-							X	X	X	X	X	X													white	P		X	5–30
Salvia nemorosa	54 / (••)	8 / (•••)	36 / (•••)											X	X	X	X	X	X									deep blue to violet	P		X	30–60
Sanguisorba minor subsp. *minor*	-	-	11 / (•)							X	X	X	X	X	X	X	X											red	P		X	20–90
Senecio vernalis	-	30 / (•)	10 / (•)									X	X	X	X	X	X	X	X									yellow	A		X	15–50 (–80)
Silene otites subsp. *hungarica*	12 / (•)	-	-									X	X	X	X	X	X	X	X									light green to yellow	B,P		X	50–150
Silene vulgaris subsp. *vulgaris*	1 / (•)	-	-													X	X	X	X									white	P		X	30–100
Stachys officinalis	25 / (••)	-	-											X	X	X	X	X	X									violet	P		X	10–100
Stachys recta subsp. *recta*	51 / (••)	3 / (•)	-									X	X	X	X	X	X											white	P			25–100
Stipa pulcherrima subsp. *pulcherrima*	5 / (•••)	-	-									X	X	X	X													light green	P		X	60–100
Stipa tirsa subsp. *tirsa*	34 / (•••)	-	33 / (•••)									X	X	X	X													light green	P		X	40–80
Taraxacum officinalis	-	-	2 / (•)							X	X	X	X	X	X													yellow	P		X	5–60
Teucrium chamaedrys	44 / (•••)	26 / (••)	12 / (••)											X	X	X	X	X	X	X	X							violet	P	X	X	10–30
Teucrium polium subsp. *capitatum*	-	-	5 / (•)													X	X	X	X									white	P		X	10–40
Thalictrum minus subsp. *minus*	16 / (•)	-	-									X	X	X	X	X	X	X	X									green	P		X	15–120 (–150)
Thymus glabrescens	4 / (•)	7 / (••)	12 / (•••)									X	X	X	X	X	X	X	X									light violet	P	X		5–15
Tragopogon floccosus subsp. *floccosus*	-	34 / (•)	4 / (•)											X	X	X	X											yellow	B,P		X	30–60
Tragopogon pratensis subsp. *orientalis*	1 / (•)	-	-											X	X	X	X	X	X									yellow	B,P		X	30–70
Trifolium alpestre	11 / (••)	-	-											X	X	X	X	X	X									red to violet	P	X	X	10–30
Trinia ramosissima	1 / (•)	-	-									X	X	X	X													yellow	B,P		X	–80
Verbascum banaticum	-	8 / (•)	-											X	X	X	X											yellow	B		X	50–100
Verbascum phoeniceum	-	-	6 / (•)									X	X	X	X	X	X											yellow	P		X	30–100
Verbascum lychnitis	-	-	1 / (•)													X	X	X	X									yellow, rarely white	B		X	50–150
Veronica austriaca subsp. *austriaca*	25 / (•)	-	-											X	X	X	X											blue	P	X		(10–) 30–70
Vinca herbacea	7 / (•)	-	-									X	X	X	X													blue	P	X		10–40
Vincetoxicum hirundinaria subsp. *hirundinaria*	6 / (•)											X	X	X	X	X	X											white	P		X	20–80

species to establish on unmanaged land, the meadow at David Valley needs annual cutting in order to preserve its diversity. This cutting is done in the end of August (Burduja, 1959; Kovàcs et al., 1970). The reserve at Jurilovca is managed through harrowing at intervals of 5 to 10 years in order to preserve the diversity of species. Without this constant disturbance of the meadows, they would ultimately contain significantly fewer species as a result of dominance by *Marrubium perregrinum*. Concerning grazing, Jurilovca and David Valley are protected and guarded from local farmers and their sheep. However, at Alah Bair Hill, no such protection exists, which has resulted in extensive grazing by sheep and cattle. This in turn has resulted in a somewhat skewed species composition compared with a situation without grazing. From the inventory carried out at Alah Bair Hill, it became clear that the most dominant species are those that are unpalatable to the grazing animals.

Species richness was markedly higher at David Valley than the other two sites, which were very similar in the total number of species identified. As might be expected given the similarity in degree of moisture stress, more species were shared between Julilovca and Alah Bair Hill. The species identified on the three sites are dominated by perennial forbs with a stress tolerating ecological strategy (Hansen, Stahl, 1993; Grime et al. 2001, 2007; Craine, 2009). Grasses (8) were also typically stress tolerators and although less species rich than the forbs (105), allowing for identification/sampling errors that may have lead to under-representation. There were also a number stress-avoiding annual forb species (15) such as; *Adonis flammea*, rosette forming biennials such as *Echium vulgare* and *Onorpordon* species (19), plus a small number (4) of geophytes, *Allium, Iris* and *Muscari* species. Biennials and geophytes tended to be associated more strongly with the two most xeric sites, which are more open in summer that the David Valley site. In terms of their architecture, most of the plants were small to medium in size, and typically clump formers with limited lateral shoot extension, and hence low to medium dominance potential. Exceptions to this generalisation were a few species that spread to form extensive patches, for example *Teucrium chamaedrys, Vinca* and *Vincetoxicum*. The pre-ponderance of clump forming architectures, with foliage mostly distributed near the ground is common in floras subject to summer soil moisture stress (Craine, 2009) and suggests that many of these species would be suitable for use in species-rich, designed plantings, where the clump forming habit facilitates co-existence of a diversity of species. This diversity would be further facilitated by the use of less productive soils, potentially based on recycled crushed building rubble.

Species with foliage distributed close to the ground rather than distributed on tall leafy stems is also an attractive phenotype from an urban design and management perspective. Plantings in paved areas are likely to be subjected to incidental trampling, and the species that best tolerate this are typically those with predominantly basal foliage as described. In urban situations these species visually "carry" trampling damage better, because the broken stems and shoots are much less evident. Taller stem species are therefore problematic in terms of wear and tear in high use areas, but nevertheless important in a design sense in terms of producing designed vegetation with vertical accents that allow more visual seasonal drama to be created.

Flowering is distributed over a long season, commencing with vernal species such as *Adonis vernalis*, although as might be expected given the high summer temperatures, there are relatively few species that flower in late summer or autumn. This is potentially problematic for urban designed vegetation, long flowering, for example, *Potentilla argentea*, and autumn-flowering species such as *Aster oleifolius* are particularly important in order to maintain public support for nature like vegetation. Future field work in Romania may uncover additional species that flower late in the year. Late season aspects such as seed heads, autumn colours etc., were not included in the current study as there was only one inventory occasion, in May. Alternatively, it may be possible to use mechanical cutting in summer after the main flowering wave to generate new shoots some of which may produce flowers in autumn. A final approach might be to draw on Steppe as a more vegetation type that is represented in many parts of the world, rather than just that occurring in Eastern Europe. This would potentially create a vegetation that is more florally attractive in autumn, for example, by using the purple-lavender, October flowering, *Aster sericeus* from North America.

Of particular importance in creating the overall character and visual impact of the Steppe in designed planting are key "signature" species (Robinson, 2011). These tend to be either particularly visually iconic or larger species. In many cases, they are relatively common and hence contribute disproportionately to the appearance and character of the vegetation. Amongst the grasses, *Stipa*, which are particularly beautiful when in flower during May and early June, represent the key character species of the Steppe. Amongst the forbs, visually important-characterful species include; *Crambe tatarica*, *Euphorbia* species, *Inula* spp., *Salvia nemorosa*, *Phlomis tuberosa* and *P. herba venti* var. *pungens*, and *Stachys recta*. Of the 117 species investigated in this study, approximately 30% might be considered to be highly attractive as horticultural plants, although many of these species were relatively patchily distributed in the habitat and did not always contribute significantly to character as a result. They would have much more capacity to do so in designed vegetation. Some of the most attractive of these species were; *Adonis vernalis, Aster oleifolius, Centaurea orientalis, Clematis integrifolia, Convolvulous cantabrica, Echinops ritro* subsp. *ruthenicus, Paeonia tennuifolia*, *Polygala major*, and *Salvia ringens*.

The plant inventory in this study can be seen as a qualitative compilation of species growing in climates and sites comparable to those at urban paved sites in Scandinavia, with much more intense drought at the southern sites compared with David Valley. Furthermore, since the inventory was carried out at the end of May, more early flowering species, which had disappeared at the time of this field inventory, are probably under-represented. This study is only the first step in developing new plant communities for urban paved sites in Scandinavia. Our starting hypothesis was that studies of natural vegetation systems and habitats, where plants are exposed to environmental conditions similar to those in inner-city environments can identify species and genotypes adapted to urban environments and supply information and knowledge about their use potential concerning growth, flowering, height, etc. The initial information obtained from this field survey will facilitate the following phases of the project, including selection of plants to be included compared with choosing plants randomly without this first-hand guidance on their use potential for periodically harsh conditions. The next step in plant evaluation will be to identify, which of the 117 species found in this field survey are of greatest value as regards their growth, height, flowering, etc. in order to devise functional planting schemes for urban paved sites. These high-ranking species will thereafter be collected at different sites in eastern Romania in order to evaluate different genotypes of the species and determine any differences within the species (Mackay et al., 2005). This evaluation will provide knowledge on the growth and performance of the different species/ genotypes in another climate region and their tolerance towards local biotic and abiotic stress agents. The collection of species and different genotypes will create a genetic pool of available species, from which to select types fit for purpose. This includes differences in growth, leaves, flowering, etc. – important features in future design aspects of urban paved sites (Mijnsbrugge et al., 2010). Invasiveness is another aspect to include in the plant evaluation in order to avoid introducing species or genotypes which can create biological and economical inconvenience to local flora. Further studies of importance within this project will include planting bed evaluation in order to create suitable habitats for the species, where they can compete and perform successfully over a long time. Such studies will include evaluation of soil texture mixtures and nutrient levels.

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