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Ornamental grasses as part of public green, their ecosystem services and use in vegetative arrangements in urban environment

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Abstract: Ornamental grasses as an integral part of vegetation are an important landscape component. Their decorativeness emphasize and enhance compositional-aesthetic and cultural-historical value of landscape picture. Incorporation of ornamental grasses positively affects the landscape homeostasis and contributes to improvement of landscape diversity. Lawn planting with ornamental grasses increases the scale of landscape creations in residential and recreational zones in urban residences. This study was conducted to assess the importance and possibilities of ornamental grasses utilisation in vegetative treatments in urban landscape. During 1999 – 2010 ecological requirements, persistency, propagation, growth habit, plant height, flowering period, decorative effect, winterhardiness and possibilities of ornamental grasses growing at Grassland and Mountain Agriculture Research Institute in Banská Bystrica (Slovak Republic) was evaluated. The collection comprised 36 species of ornamental grasses and 7 species grass-like plants where aesthetic value of ornamental plant was characterised as follows: ornamental foliage (*Arundo donax, Carex muskingumensis, Festuca pallens, Hakonechloa macra* 'Aureola', *Imperata cylindrica, Juncus inflexus, Miscanthus sinensis* 'Zebrinus', *Phalaris arundinacea*), ornamental stems (*Molinia arundinacea* 'Windspiel', *Phragmites australis*) and

ornamental inflorescens and fruits (*Armeria maritima, Briza maxima, Hordeum jubatum, Chionochloa conspicua*, *Lagurus ovatus, Luzula nivea, Melica ciliata, Miscanthus sacchariflorus, Panicum virgatum, Pennisetum alopecuroides, Phalaris canariensis, Sesleria sadlerana, Stipa* spec. div.).

Keywords: ornamental grasses, lawn, landscape creation, vegetation, vegetation arrangements, public green.

Introduction

In many aspects, urban landscape has been recognizing as very vulnerable ecosystem with the lowest ecological stability and biological diversity (GRIMM et al. 2008). One of possibilities of improving this state is the use of natural values of vegetative components (green) with its important environmental and ecological functions. Of this aspect, lawn planting appropriately supplemented with ornamental grasses has an important role. The importance of ornamental grasses is mainly in delivering of aesthetic, recreational and health-hygienic (HRABĚ et al. 2003). Progressive trends in management of urban landscape has tended to increase of proportion of nature, mainly vegetative elements, environment improving and creation of spaces for rest, recreation, sport and cultural-society activities (SUPUKA et al. 1999).

Public, private and protective green space performs several favourable benefits and important ecosystem services in urban environment (REHÁČKOVÁ & PAUDITŠOVÁ 2006, TURISOVÁ et al. 2010, TOMAŠKIN & TOMAŠKINOVÁ 2012):

a) Landscape aesthetic (evoke feelings of beauty, harmony, consistency, etc.)
b) Sports and recreation (relaxation in a harmonious environment)
c) Bio-homeostatic (contributes to the functional state of dynamic equilibrium and stability of the landscape by biodiversity improvement)
d) Water management and soil protection, erosion control (role of grass sward)
e) Micro-climate regulation (impact on improvement of air quality, air humidity, air flow, thermal regime of surrounding areas)
f) Health and hygiene (bacteriostatic and bactericidal effects, reduction of noise, dustiness, offensive odor and radioactivity, lawn growing reduce of tramway ground vibrations, etc.)
g) Indicator of the state of the urban environment especially of air pollution
h) Sanitation and reclamation (dump remediation)
i) Production (recycling of plant biomass in the process of composting, production of soil substrate).

BOLUND & HUHAMMAR (1999) note that locally generated services contribute to the quality of urban life and should be accepted by city planners. Similarly, BOTKIN & BEVERIDGE (1997) argue that „Vegetation is essential to achieving the quality of life that creates a great city and that makes it possible for people to live a reasonable life within an urban environment". ULRICH et al. (1991) reported the results of study on the response of persons put under stress under different environments. The results showed when subjects of the study were exposed to

natural environments the level of stress decreased rapidly, whereas during exposure to the urban environment the stress levels remained even increased. This study documents that green spaces can increase the physical and psychological well-being of urban citizens.

The aim of the study was to a) evaluate collection of ornamental grasses (biological and aesthetic characteristics, growing requirements) b) propose their use in vegetative arrangements in urban landscape, c) assess the importance of their ecosystem services, d) show risks and restrictions of their planting (invasive nature, pollen allergens).

Material and Methods

The collection of ornamental grasses and grass-like plants was collected during 1996 – 1998. The collection had also been continuously completed during 1999 – 2009. The majority of the collection consisted of vegetative propagated clones, which were acquired by purchase, exchange or gift. The smaller part was grown from seeds, which were bought in specialised stores (e.g. Agrokomplex – international agricultural and food exhibition in Nitra). Plant nomenclature follows the Euro+Med PlantBase (EURO+MED 2006 onwards), for cultivares see BRICKELL et al. (1993), GRAU et al. (1998), KUBÁT et al. (2002), HRABĚ et al. (2003) and BURNIE et al. (2007).

In spring 1999, the experiment was set up at the Grassland and Mountain Agriculture Research Institute in Banská Bystrica (48° 44´N, 19° 09´E) at 355 m a.s.l. The site is located in the Kremnické vrchy mountain range and lies in a moderately cold and moderately wet climatic region. At the study site, the mean annual rainfall and the mean sum of growing season rainfall are 853 and 441 mm, respectively. The mean annual temperature and the mean of growing season temperature are 8.1 ℃ and 13.6 ℃, respecti vely (Department of Meteorological Service Banská Bystrica). Lang´s rainfall factor is 106 and snow cover lasts 80 days. The basic meteorological data, mean air temperature (℃) and rainfall sum (mm) during the growing season and the year for reporting period are shown in Tab. 1 and Tab. 2.

A total of 43 plant species belonging to five different families were included into the experiment: 36 plant species belonged to Poaceae family, Cyperaceae, Juncaceae and Typhaceae families were represented by 2 plant species and one plant species belonged to Plumbaginaceae family (Tab. 3a, Tab. 4a). Perennial plants were planted in experimental plots at spacing of 0.7 x 0.7 m. The robust plant species were planted in plots at spacing of 1.2 x 1.2. Annual plants were regularly planted in experimental plots at spacing of 0.8 x 0.8 m in the number of 15 – 20 seeds. Plant health was very good; plants did not suffer from diseases and pests. Theoretical information on requirements of ornamental grasses were obtained from the work by ONDŘEJ et al. (1998), NOORDIUS (2001), OPATRNÁ & SOUČKOVÁ (2003), NOVÁKOVÁ (2004), LEYHE (2004), MARINELLI (2006) and ARDLE (2008). Plants with similar characteristics and requirements were planted together; shade-loving plants were located next to tall grasses which shaded them during day. Hygrophilous plants were planted in an artificial lake.

Tab. 1. Mean air temperature (℃) during growing se ason and year (1999 – 2010)

Month	Year											
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
I	-1.6	-3.2	-1.0	-2.8	-3.0	-4.5	-1.8	-5.7	2.9	0.2	-3.4	-3.4
II	-1.5	0.6	0.2	2.4	-3.5	0.2	-3.8	-3.0	2.7	2.2	-0.6	-0.6
III	4.3	3.0	4.0	5.3	3.8	3.2	0.8	1.2	6.4	3.7	3.0	3.0
IV	10.5	11.8	8.7	9.0	8.1	10.0	9.8	10.0	11.5	9.9	13.0	13.0
V	13.8	15.9	15.9	16.5	16.8	11.9	14.2	13.1	15.3	14.6	14.7	14.7
VI	17.8	18.5	16.0	18.6	19.8	16.2	16.6	17.4	18.2	18.1	16.2	16.2
VII	19.5	17.1	19.8	20.3	20.3	18.0	18.7	21.3	19.7	18.7	19.9	19.9
VIII	17.4	19.9	19.8	18.9	20.3	17.6	16.8	16.3	19.1	18.3	19.6	19.6
IX	16.5	13.7	12.3	13.0	14.1	12.8	14.5	15.4	11.8	13.0	15.8	15.8
X	8.5	11.6	11.7	7.3	5.8	9.9	9.2	10.1	8.5	10.0	8.4	8.4
XI	2.4	7.0	1.7	4.9	5.3	4.3	2.1	6.2	2.3	5.3	5.2	5.2
XII	-1.5	0.8	-5.3	-2.3	-0.8	-0.9	-1.4	1.2	-2.5	1.5	-0.7	-0.7
IV - IX	15.9	16.2	15.4	16.1	16.6	14.4	15.1	15.6	15.9	15.4	16.5	15.3
I - XII	8.8	9.7	8.7	9.3	8.9	8.2	8.0	8.6	9.7	9.6	9.3	8.6

(Source: Department of Meteorological Service Banská Bystrica)

Tab. 2. Rainfall sum (mm) during growing season and year (1999 – 2010)

Month	Year											
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
I	37.0	54.4	99.1	29.3	66.0	74.0	70.0	68.0	162.0	71.0	66.0	54.8
II	82.4	51.5	36.1	93.5	12.0	59.0	79.0	53.0	65.0	30.0	63.0	63.4
III	45.7	132.6	77.9	35.5	4.0	50.0	37.0	53.0	74.0	97.0	94.0	19.5
IV	95.9	63.6	59.4	33.0	39.0	49.0	97.0	51.0	0.0	63.0	12.0	64.8
V	66.7	35.4	25.7	59.5	86.0	82.0	50.0	93.0	139.0	62.0	66.0	75.8
VI	128.5	47.1	71.9	127.7	11.0	145.0	24.0	65.0	108.0	106.0	105.0	121.4
VII	212.7	77.0	142.9	118.9	119.0	69.0	86.0	56.0	44.0	159.0	58.0	214.8
VIII	85.1	31.2	29.8	140.4	23.0	118.0	112.0	106.0	82.0	38.0	39.0	148.6
IX	17.7	22.1	185.5	82.7	27.0	39.0	34.0	5.0	64.0	38.0	48.0	173.3
X	56.3	62.7	14.1	111.0	94.0	77.0	11.0	34.0	23.0	65.0	103.0	53.0
XI	35.3	136.2	65.5	68.0	41.0	77.0	79.0	56.0	58.0	71.0	105.0	192.0
XII	79.7	73.7	60.7	70.0	35.0	64.0	177.0	19.0	50.0	116.0	170.0	53.0
IV - IX	606.6	276.4	515.2	562.2	305.0	502.0	403.0	376.0	437.0	466.0	328.0	798.7
I - XII	943.0	787.5	868.6	969.5	557.0	903.0	856.0	659.0	869.0	916.0	929.0	1234.4

(Source: Department of Meteorological Service Banská Bystrica)

The properties of the soil substrate were as follows: pH in KCl – 7.25, content of N_{tot} – 6.88 $g.kg^{-1}$, C_{ox} – 81.10 $g.kg^{-1}$, humus – 139.82 $g.kg^{-1}$, content of plant-available nutrients P – 283.34 $mg.kg^{-1}$, K – 395.00 $mg.kg^{-1}$, Mg – 576.21 $mg.kg^{-1}$. The fertilisers were applied as follows: 12 $g.m^{-2}$ of nitrogen was split in two doses (50 % in spring and 50 % in summer), 3 $g.m^{-2}$ of phosphorus and 6 $g.m^{-2}$ of potassium was applied in spring. Where appropriate, plants were mechanically hoed (weed control) and irrigated during the growing season. Mature seeds of

annual plants were picked for the subsequent propagation and planting. In autumn, plants susceptible to frost were covered by thick layer of leaves or stored indoor. During the growing seasons, plants were not mown. In early spring, the dried foliage was pruned, plants were fertilized and perennial plants were vegetative propagated.

In the paper, the averages of the three-year period (2008 – 2010) are shown. During growing season, plants were evaluated once in flowering date. Ecological requirements, persistency, propagation, growth habitat, plant height, flowering period, decorativeness (e.g. leaves, whole plants, inflorescences are decorative during the whole flowering period), winterhardiness and possibilities of ornamental grasses growing in Slovakia were evaluated.

Results and Discussion

The collection of 43 ornamental grasses and grass-like plants were evaluated (Tab. 3a, Tab. 3b, Tab. 4a, Tab. 4b). The collection was dominated by perennial and vegetative propagated species. A smaller group included generatively propagated annual plants (*Briza maxima*, *Briza minor*, *Eragrostis tef, Hordeum jubatum*, *Lagurus ovatus*, *Panicum capillare, Phalaris canariensis*, *Setaria italica*). Because of planting annuals every year, there is a low interest in their use in landscape creation and they are used mainly for decorative purposes (flower decorations). In general, they generate a large number of seeds in their spikelet and have very good breeding success. New plants of vegetatively propagated plants are formed by dividing of rhizomes. By contrast to annual grasses, vegetatively propagated species produce usually fewer daughter plants (1 – 6). Very successful propagation was observed at *Miscanthus* plants. This species produced more than 10 – 15 daughter plants every year. Because of very high invasive potential, growing plants of the genus *Miscanthus* should therefore be undertaken with caution. Very good propagation was also observed at *Glyceria maxima, Phalaris arundinacea,* and *Phragmites australis*. Parent plants of *Bouteloua gracilis, Festuca pallens, Helictotrichon sempervirens,* and *Luzula nivea* produced from 1 to 2 new plants, what can be considered as lower propagation ability. The other vegetatively propagated plants produced from 3 to 5 daughter plants every year what can be considered as good propagation ability (Tab. 3a, Tab. 4a).

Some perennial species (*Festuca pallens*, *Festuca gautieri*) have ability for vegetative and generative propagation as well. These plant species have the tendency to spontaneous self-sowing. Only 10 % of offspring conserve decorative characteristics of parent plants, the rest of seedlings lost an ornamental character. As a consequence of this negative effect, daughter plants lost decorativeness, colour, they are lesser vital and non desirable in the lawn. In landscape gardening we recommend eliminating self-sowing by regular removing of fertile stems.

Growth habit was also evaluated. Some grasses form clump (clump forming grasses), the other prefer spreading by rhizomes, what enabled to colonize living-space. According to the growth form, ornamental grasses of the collection were divided into two groups:

1. Creaping grasses (*Arundo donax, Glyceria maxima, Imperata cylindrica, Miscanthus sacchariflorus, Phalaris arundinacea, Phragmites australis*).
2. Clump forming with a big clump of foliage, which is ornamental during whole growing season (the rest of evaluated plant species belonged to this group). *Deschampsia cespitosa*, *Festuca pallens*, *Festuca gautieri*, *Helictotrichon sempervirens*, *Koeleria glauca, Sesleria sadlerana* are evergreen species.

Perennial ornamental grasses remain intact through the winter, died stems were pruned in the spring of next year. It has been recognized that plant stems create interesting scenery also during the winter time and died stems and foliage protect mother plant from the frost.

The height of evaluated ornamental grasses and other grass-like species was different (Tab. 3b, Tab. 4b) and varied from 0.15 m (*Armeria maritima* and *Festuca gautieri*) to 2.5 m (*Miscanthus sacchariflorus, Cortaderia selloana*). Plant height affects variability of the use of ornamental grasses in gardens or residential areas. Moreover, different flowering time and appropriate combination of grasses could achieve interesting aesthetic appearance from early spring to late autumn. In our research *Sesleria sadlerana* belonged to early flowering species in April, whereas *Calamagrostis brachytricha***,** *Hakonechloa macra***,** *Chasmanthium latifolium, Miscanthus,* and *Pennisetum alopecuroides* flowered from August to September. Flowering length was also different. The longest flowering time was observed at *Armeria maritima* (from May to September). Above mentioned plant species did not have any special soil and climatic requirements. *Arundo donax, Carex grayi, Glyceria maxima, Juncus inflexus, Phalaris arundinacea, Phragmites australis, Typha latifolia,* and *Typha minima* requires moist sites. By contrast *Festuca pallens, Koeleria glauca, Melica ciliata, Stipa capillata*, *S. gigantea,* and *S. parviflora* are well adapted to dry conditions. Tab. 3b and Tab. 4b shows, which parts of ornamental grasses were the most attractive. Aesthetic value of ornamental plants were ornamental foliage (*Arundo donax* 'Versicolor'*, Carex muskingumensis, Festuca pallens, Festuca gautieri, Glyceria maxima, Hakonechloa macra* 'Aureola'*, Helictotrichon sempervirens, Imperata cylindrica, Juncus inflexus, Koeleria glauca, Miscanthus sinensis* 'Zebrinus'*, Phalaris arundinacea*), ornamental stems (*Molinia caerulea, Molinia arundinacea* 'Windspiel'*, Phragmites australis*) and ornamental inflorescences and fruits (*Armeria maritima, Bouteloua gracilis, Briza maxima, Briza minor, Eragrostis tef, Hordeum jubatum, Chasmanthium latifolium, Chionochloa conspicua***,** *Lagurus ovatus, Luzula nivea, Melica ciliata, Miscanthus sacchariflorus, Panicum capillare, Panicum virgatum, Pennisetum alopecuroides, Phalaris canariensis, Sesleria sadlerana, Setaria italica, Stipa* spec. div.). Fresh or dry decorative inflorescences of annual plants (*Briza maxima, Hordeum jubatum*) are appropriate for flower decorations. For successful overwintering, plants of *Hakonechloa macra, Imperata cylindrica,* and *Stipa gigantea* should be stored indoors. *Arundo donax* 'Versicolor' and *Cortaderia selloana* died, and *Koeleria glauca, Melica ciliata,* and *Pennisetum orientale* showed low ability to overwinter under climatic conditions at the experimental site. The rest of evaluated plants overwintered in good condition after appropriate arrangements (cover by leaves, storing indoors).

Tab. 3a. Collection of ornamental grasses (family Poaceae) and their evaluation

Species	Persistency	Type of propagation	Propagation success	Growth habitat
Arundo donax 'Versicolor'	PG	VEG	G	RG
Bouteloua gracilis	PG	VEG	M	CG
Briza maxima	AG	GEN	VG	CG
Briza minor	AG	GEN	VG	CG
Calamagrostis brachytricha	PG	VEG	G	CG
Chasmanthium latifolium	PG	VEG	G	CG – RG
Chionochloa conspicua	PG	VEG	G	CG
Cortaderia selloana	PG	VEG	–	CG
Deschampsia cespitosa	PG	VEG	G	CG, EG
Eragrostis tef	AG	GEN	VG	CG
Festuca pallens	PG	VEG	M	CG, EG
Festuca gautieri	PG	VEG	G	CG, EG
Glyceria maxima	PG	VEG	VG	RG
Hakonechloa macra 'Aureola'	PG	VEG	G	CG – RG
Helictotrichon sempervirens	PG	VEG	M	CG, EG
Hordeum jubatum	AG	GEN	VG	CG
Imperata cylindrica	PG	VEG	G	RG
Koeleria glauca	PG	VEG	G	CG, EG
Lagurus ovatus	AG	GEN	VG	CG
Melica ciliata	PG	VEG	G	CG
Miscanthus sacchariflorus	PG	VEG	VG	RG
Miscanthus sinensis 'Zebrinus'	PG	VEG	VG	CG
Molinia arundinacea 'Windspiel'	PG	VEG	G	CG
Molinia caerulea 'Variegata'	PG	VEG	G	CG
Panicum capillare	AG	GEN	VG	CG
Panicum virgatum	PG	VEG	G	CG
Pennisetum alopecuroides 'Japonicum'	PG	VEG	G	CG
Pennisetum orientale	PG	VEG	G	CG
Phalaris arundinacea 'Feesey'	PG	VEG	VG	RG
Phalaris canariensis	AG	GEN	VG	CG
Phragmites australis	PG	VEG	VG	RG
Sesleria sadlerana	PG	VEG	G	CG, EG
Setaria italica	AG	GEN	VG	CG
Stipa capillata	PG	VEG	G	CG
Stipa gigantea	PG	VEG	G	CG
Stipa parviflora	PG	VEG	G	CG

Legend: AG – annual grass**,** PG – perennial grass, GEN – generative, VEG – vegetative, VG – very good, G – good , M – medium, CG – clump grass, RG – rhizomatous grass, EG – evegreen grass

Tab. 3b. Collection of ornamental grasses (family Poaceae) and their evaluation

Species	Plant height (m)	Flowering period (month)	Ornamental effect	Requierements for soil moisture	Overwintering
Arundo donax 'Versicolor'	1.6 – 1.8	–	L	H	VP
Bouteloua gracilis	0.2 – 0.3	VII – VIII	I	N	G
Briza maxima	0.3 – 0.4	V – VII	I	N	–
Briza minor	0.2 – 0.4	V – VII	I	N	–
Calamagrostis brachytricha	0.8 – 1.1	VIII – IX	I	N	G
Chasmanthium latifolium	0.7 – 1.2	VIII – IX	I	N	G
Chionochloa conspicua	1.1 – 1.2	VI – VIII	I	N	G
Cortaderia selloana	2.0 – 2.5	–	WP	N	VP
Deschampsia cespitosa	0.9 – 1.1	VI – VIII	I	N	G
Eragrostis tef	0.3 – 0.5	V – VI	I	N	–
Festuca pallens	0.3 – 0.4	–	L	D	G
Festuca gautieri	0.1 – 0.2	–	L	N	G
Glyceria maxima	0.7 – 1.0	VII – VIII	L	H	G
Hakonechloa macra 'Aureola'	0.3 – 0.4	VIII – IX	L	N	Indoor
Helictotrichon sempervirens	0.9 – 1.0	VI	L	N	G
Hordeum jubatum	0.3 – 0.5	VI – VIII	I	N	G
Imperata cylindrica 'Rubra'	0.3 – 0.4	–	L	N	Indoor
Koeleria glauca	0.3 – 0.6	VI – VII	WP	D	P
Lagurus ovatus	0.2 – 0.3	V – VIII	I	N	–
Melica ciliata	0.3 – 0.4	VI – VIII	I	D	P
Miscanthus sacchariflorus	2.0 – 2.2	VIII – IX	I	N	G
Miscanthus sinensis 'Zebrinus'	1.2 – 1.6	VIII – IX	WP	N	G
Molinia arundinacea 'Windspiel'	1.5 – 2.0	VII – VIII	WP	N	G
Molinia caerulea 'Variegata'	0.7 – 1.0	VII – VIII	S	N	G
Panicum capillare	0.5 – 0.6	VII – IX	I	N	–
Panicum virgatum	1.2 – 1.5	VIII	WP	N	G
Pennisetum alopecuroides 'Japonicum'	0.7 – 1.3	VIII – IX	I	N	G
Pennisetum orientale	0.4 – 0.5	VII – VIII	I	N	P
Phalaris arundinacea 'Feesey'	1.2 – 1.6	VI – VII	L	H	G
Phalaris canariensis	0.2 – 0.8	VI – VIII	I	N	–
Phragmites australis	1.0 – 1.5	VIII	S	H	G
Sesleria sadlerana	0.4 – 0.5	IV	WP	N	G
Setaria italica	0.6 – 0.8	VII – X	I	N	–
Stipa capillata	0.5 – 0.6	VII – VIII	WP	D	G
Stipa gigantea	1.8 – 2.0	VI – IX	WP	D	Indoor
Stipa parviflora	0.4 – 0.5	VI – VII	WP	D	G

Legend: L – leaves, WP – whole plant, S – stems, I – inflorescences, N – normal, D – dry, H – hygrophilous, G – good, P – poor, VP – very poor

Tab. 4a. Collection of ornamental grass-like plants and their evaluation

Species	Family	Persistency	Type of propagation	Propagation success
Armeria maritima	Plumbagynaceae	P	VEG	G
Carex grayi	Cyperaceae	P	VEG	G
Carex muskingumensis	Cyperaceae	P	VEG	G
Juncus inflexus	Juncaceae	P	VEG	G
Luzula nivea	Juncaceae	P	VEG	P
Typha latifolia	Typhaceae	P	VEG	G
Typha minima	Typhaceae	P	VEG	G

Legend: P – perennials, VEG – vegetative, G – good , P – poor

Tab. 4b. Collection of ornamental grass-like plants and their evaluation

Species	Plant height (m)	Flowering period (month)	Ornamental effect	Requierements for soil moisture	Overwintering
Armeria maritima	0.15 – 0.2	V – IX	WP	N	G
Carex grayi	0.5 – 0.6	VI – VIII	I	H	G
Carex muskingumensis	0.6 – 0.8	VI	L	N	G
Juncus inflexus	0.4 – 0.6	VI – VII	WP	H	G
Luzula nivea	0.4 – 0.6	VI – VII	WP	N	G
Typha latifolia	0.9 – 1.3	VII – VIII	WP	H	G
Typha minima	0.5 – 0.7	VI – VII	WP	H	G

Legend: L – leaves, WP – whole plant, I – inflorescences, N – normal, H – hygrophilous, G – good

Ornamental grasses are adapted to a relatively broad gradient of planting conditions; however they are sensitive to frost. This fact limits planting of some ornamental species under environmental conditions of Slovakia. We can conclude that after considering planting and environmental conditions, collection of selected (evaluated) grasses could be successfully used in landscape and garden design. An exception is *Arundo donax* 'Versicolor' and *Cortaderia selloana* which were not able to overwinter and after storing indoors, they did not flower. In consistency with results of our research we can recommend the use of ornamental grasses and grass-like plants for vegetative arrangements in urban landscape, their use for landscape design and incorporation in landscape creation as follows:

The use of ornamental grasses for vegetative arrangements in urban landscape

On the base of plant requirements, plant height, spatial robustness, decorativeness, overwintering and persistency we can recommend following selection and grouping of particular plant species for vegetative treatments:

a) *Luzula nivea*, *Carex* spec. div. are suitable for undergrowth and edge of woody vegetation.
b) Tall species as *Deschampsia cespitosa, Chasmanthium latifolium, Chionochloa conspicua, Miscanthus, Pennisetum* are very appropriate for open spatial like gardens, parks, lawns or for heathland garden.
c) Thermophilic species *Bouteloua gracilis, Festuca pallens, Festuca gautieri, Helictotrichon sempervirens, Koeleria glauca, Melica ciliata, Panicum* spec. div., *Stipa* spec. div. are very good adapted for rock- and steppe-gardens.
d) Grass species of small growth habitat such as *Festuca pallens, Festuca gautieri, Stipa* spec. div. should be preferred for green roof growing, atrium and terraces.
e) Containers and pots with *Festuca pallens, Festuca gautieri, Hakonechloa macra,* and annual plants should be used for mobile green space.
f) Shady and hygrophilous vegetation as *Carex grayi, Carex muskingumensis, Glyceria maxima*, *Phalaris arundinacea, Phragmites australis* are good for riparian parts of streams, ponds and lakes.
g) *Typha* spec. div. and *Arundo* spec. div. are considered suitable for planting in water environment, stagnant water, marshes and wetlands.
h) Grass species of small growth habitat such as *Festuca pallens, Festuca gautieri, Koeleria glauca, Melica ciliata, Stipa capillata* are appropriate for road junctions and roundabouts.

Landscape design of ornamental plants:

a) Individual planting - solitaires: *Helictotrichon sempervirens, Chasmanthium latifolium, Chionochloa conspicua, Miscanthus sinensis, Pennisetum alopecuroides.*
b) Small groups in small-scale plots: *Festuca pallens, Festuca gautieri, Koeleria glauca, Melica ciliata, Stipa capillata.*
c) Companion planting vegetation: all evaluated species could be integrated as companion planting vegetation. Neutral green elements complement very good conifers, shrubs, spring bulbs, perennials of lower habit, roses, annuals, ferns.

Lawns and ornamental grasses as compositional elements of landscape architecture are:

a) Superior in composition with natural materials (wood, stone, sand, gravel, soil, water).
b) Often in composition with the art objectives (sculpture, woodcarving).

Ecosystem services of ornamental grasses and lawns

Lawns and ornamental grasses provide regulating and cultural services. Out of regulating services (KANIANSKÁ 2012), human benefits from regulation of air quality and climate and bio-homeostasis, cultural services include mainly aesthetic, landscape and recreation (MILLENNIUM ECOSYSTEM ASSESSMENT 2005; BEZÁK & LYYTIMÄKI 2011). Decorativeness of ornamental grasses and their

incorporation in gardening emphasize and enhance compositional-aesthetic and cultural-historical value of landscape picture, that they are part of the landscape in the true sense of the word. Selecting of suitable species could achieve interesting aesthetic effects throughout the year, including winter, when dried frozen and snowy inflorescence are special ornament of sleeping garden or landscape as well. Incorporation of exotic species should be chosen very carefully to not disturb the natural harmonic balance of natural parts of the landscape. Incorporation of ornamental grasses positively affects the landscape homeostasis and in composition with the other vegetation contributes to the harmonious symbiosis of natural and anthropogenic elements and processes in landscape (naturalization process). Similarly NOVÁKOVÁ (2004) reported that ornamental grasses participate in the creation of garden and park design.

It is necessary to note that incorporation of ornamental grasses in garden arrangements and landscaping brings along unquestionable benefits also some risks to humans and the environment. It has been recognised that majority of plant species of the family Poaceae produce high amounts of pollen which is a serious health risk for people with a predisposition to allergens. Similarly, ornamental grasses also produce increased amounts of allergens (CARIŃANOS & CASARES-PORCEL 2011). Therefore health (hygiene) aspects must be taken into consideration when planning of planting of ornamental grasses. It means restriction of planting of highly allergenic species and their exclusion from particular sites as playgrounds and school facilities.

The second danger is the invasive nature of some species of ornamental grasses. They are uncontrollably spreading into the indigenous flora habitats or managed plant ecosystems what has resulted into their dominance and consequently habitat degradation. Gradually large-scale swards of non-native grass species have been established in urban environment which are characterised by low species diversity and high competitive potential for indigenous plant species. Similarly to LAVERGNE & MOLOFSKY (2004) and HOLZMUELLER & SHIBU (2012) our study confirmed that *Phalaris arundinacea, Phragmites australis*, *Imperata cylindrica* and *Miscanthus sacchariflorus* belonged among the most aggressive invasive species out of ornamental grasses.

Conclusions

On the base of our study on evaluation of ornamental grasses collection indicates we can conclude:

- Aesthetic value of ornamental plant is characterised as:
  1. ornamental foliage (*Arundo donax, Carex muskingumensis, Festuca pallens, Festuca gautieri, Glyceria maxima, Hakonechloa macra* 'Aureola'*, Helictotrichon sempervirens, Imperata cylindrica, Juncus inflexus, Koeleria glauca, Miscanthus sinensis* 'Zebrinus'*, Phalaris arundinacea*),
  2. ornamental stems (*Molinia caerulea, Molinia arundinacea* 'Windspiel'*, Phragmites australis*)

3. ornamental inflorescence and fruits (*Armeria maritima, Bouteloua gracilis, Briza maxima, Briza minor*, *Eragrostis tef, Hordeum jubatum, Chasmanthium latifolium, Chionochloa conspicua***,** *Lagurus ovatus, Luzula nivea, Melica ciliata, Miscanthus sacchariflorus, Panicum capillare, Panicum virgatum, Pennisetum alopecuroides, Phalaris canariensis, Seslerias adlerana, Setaria italica, Stipa* spec. div.).

- Collection of ornamental grasses and grass-like species is very plastic, widely suitable for planting in all functional urban areas (city). The only exceptions are *Arundo donax* 'Versicolor', and *Cortaderia selloana*, which showed low ability to overwinter under temperate climate conditions.
- Ornamental grasses and grass-like plants can be incorporate into landscape creation as compositional elements of landscape architecture and recommend for vegetative arrangements in urban landscape.
- Incorporation of ornamental grasses emphasizes and enhances compositional-aesthetic and cultural-historical value of landscape picture and positively affects landscape homeostasis and its biodiversity.

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