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Original Article

Floristic diversity of plants spontaneously spreading in the botanical garden of the University of Łódź (Poland)

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***Abstract*:**
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The aim of the paper is to characterize plants spontaneously spreading outside the flower beds within the territory of the botanical garden of the University of Łódź. Floristic studies rivealed that many cultivated species also appear outside their original planting sites. Total of 124 taxa of vascular plants were found to be subject of spontaneous spreading. Various directions of spontaneous migration of species from sites of their planting were observed within the garden: the "oak-hornbeam lawn", shaded lawns, sunny lawns, shaded paths, sunny paths, limestone rock garden on hillside. Most species occurred exclusively in one of the above-listed sites. The analysed group of vascular plants includes a predominant representation of native species – 103 species (83.1 %) and predominance of herbal perennial plants – hemicryptophytes (80 species; 67.7 %).

Key words: botanical garden, migration patterns, plant collection, spontaneous spread

Introduction

There are many reasons for growing plants in modern botanic gardens, including species conservation, scientific research, cultivar development, education, public amenity and pleasure, and cultural heritage (Wyse Jackson & Sutherland, 2000, Maunder *et al*., 2001). Historically, their main activities were horticultural and taxonomic research, but the urgent need for biodiversity conservation, biotechnological outreach and education have become an increasingly important focus (Kojs & Kojs, 2004, Rybczyński *et al*., 2004, Havens *et al*., 2006, Chang *et al*., 2008).

For this reason, botanical gardens are areas of intensive cultivation of numerous plants and a key pathway for the introduction of new species. Most plant species introduced to a new country or region has originated from ornamental horticulture (Dehnen-Schmutz & Touza, 2008, Virtue et al., 2008, Galera & Sudnik-Wójcikowska, 2010). Botanical gardens, as well as private flower gardens are often in service to alien taxa as bridgeheads in the process of successful colonisation of new territories (Reichard & White, 2001, Smith et al., 2006, Dehnen-Schmutz *et al*., 2007, Dawson *et al*., 2008, Virtue *et al*., 2008, Galera & Sudnik-Wójcikowska, 2010). Due to this phenomenon, botanical gardens might influence the plant species inventory that contributes to enrichment of country or regional flora with new, mainly exotic taxa.

Floristic studies carried out in the Teaching and Experimental Botanic Garden of the University of Łódź, led to the observation that many cultivated species also appear outside of their original planting

sites. These observations supplemented by the analysis of data contained in the documentation of garden collections, formed the basis for the preparation of the present work, aiming to characterize those plants that spontaneously spread outside the flower beds within the territory of the university botanical garden.

Materials and methods

The Botanical Garden of the University of Lodz is situated in the centre of Lodz (19° 29' 05" E and 51° 46' 40" N) and occupies total area of 1.02 ha. The garden does not constitute a separate legal entity, being internally managed by the Faculty of Biology and Environmental Protection. The object was established in 1985, and has status of a teaching and experimental garden, i.e. the collections are mainly used for teaching purposes and for scientific research. Management duties include the selection of plant material, creation of necessary collections to be used for the education of biology and environmental protection students, and care of aesthetic qualities and the external image of the garden. The garden features herbaceous and ligneous plants, represented by species of both native and foreign origin (Stefaniak & Bomanowska, 2011).

Collection of the garden includes 793 taxa: 295 species and varieties of trees and shrubs as well as 498 taxa of herbaceous plants (Stefaniak & Bomanowska, 2011). The herbaceous collection is spread over 189 cultivation plots, each having an area of 3.75 m^2. Garden collections are a reflection of habitat and taxonomic diversity of the vascular flora of Poland. Numerous plants of alien origin (mainly Mediterranean, American) are also cultivated in the garden.

Detailed floristic studies were carried out in the garden in the period of 2007-2008. Observations were performed both on the cultivation plots and on the dividing paths and in the internal buffer zone of the garden. The present study includes selected data from these floristic observations, with some additional data from the years 2006 and 2009. Only those cultivated species, for which individuals where observed to have spontaneously spread outside their original planting sites, were included in the analysis. The relevant individuals occurred outside the actual area of cultivation of the given plant species, on ground with a different land management profile, e.g. on a path, a lawn, in the garden buffer zone etc. In the case of vegetatively reproducing plants, only independent separated rametes were considered as spontaneously occurring individuals (Falińska, 2002).

Biological classification of species was based on the system of Raunkiaer's life forms, with the life form for each species taken from Zarzycki et al. (2002) and from the „BiolFlor" database (http://www.ufz.de/biolflor). The remaining data on the biology of a species such as manner of reproduction, dispersal of diasporas and life strategies were compiled from available sources (Van der Pjl, 1972, Handel & Beatie, 1990, Lindacher, 1995, Tokarska-Guzik, 2005) as well as from the on-line databases (BiolFlor, FloraWeb, Liu *et al*., 2008) and personal observations.

The geographical and historical classification of the flora as proposed by Kornaś (1981) and modified by Jackowiak (1990). Status of species within this classification was determined using the studies of Zając (1979), Mirek *et al*. (2002), Tokarska-Guzik (2005), but it was related to local conditions. Due to the history of ground usage and the group of analysed plants (exclusively species escaping from cultivation), all analysed species were treated as synanthropic ones. Native species were ascribed the status of oekiophytic apophytes (oekiophytes), i.e. native species escaping from cultivation (Sudnik-Wójcikowska & Koźniewska, 1988). Species of alien origin, on the other hand, were classified as metaphytes (archaeophytes and kenophytes) if they are permanently naturalised in the Polish flora and occur spontaneously in plant communities, or as diaphytes (ergasiophygophytes) if they are exclusively cultivated plants which appear in the spontaneous flora of Poland transiently as a result of temporary "escape" from cultivation.

The nomenclature of herbaceous vascular plants follows Mirek *et al*. (2002) and Gawryś (2009), whereas names of woody species are from Seneta & Dolatowski (2000).

Results

In the course of field research in the garden, 124 taxa of vascular plants were found to be subjects of spontaneous spreading, belonging to 47 families and 107 genera (Table 1). In distinguished group the most numerously represented families are: *Asteraceae* (12 species) and *Lamiaceae* (11), as well as *Poaceae* (8) and *Ranunculaceae* (8) and *Rosaceae* and *Apiaceae* represented by seven species each (Table 1). The majority of families (35) have only one or two species.

The analysed group of vascular plants includes a predominant representation of native species, i.e. oekiophytes – 103 species (83.1%). Among alien species, ergasiophygophytes (14 species; 11.3%)

predominate over metaphytes (7; 5.6%). The comparision of the life form spectrum showed a predominance of herbal perennial plants – hemicryptophytes (80 species; 64.5%) over other life forms. 11 species (8.9%) are chamaephytes. The proportion of woody species (megafanerophytes, nanofanerophytes) and species which are both geophytes and hemicryptophytes is 7.3% for each of these groups.

Table 1. Cultivated taxa spontaneously spreading in the Experimental and Teaching Botanical Garden of the University of Łódź.

Abbreviations and symbols: Status (affiliation to geographical-historical groups): OE – oekiophyte, ME – metaphyte, AR – archaeophyte, KE – kenophyte, ER – ergasiophygophyte; life forms: Ch – chamaephyte, G – geophyte, H – hemicrytophyte, M – megaphanerophyte, N – nanophanerophyte, li – liana; life strategy: C – competitor, S – stres tolerator , R – ruderal; types of reproduction: s – seed, sv – seed and vegetatively, ssv – mosty by seed, rarely vegetatively, vvs – mosty vegetatively, rarely by seed, v – vegetatively; dispersal mode: ane – anemochory, aut – autochory, anthr – anthropochory, bar – barochory, dys – dyszoochory, end – endozoochory, epi – epizoochory, hyd – hydrochory, myr – myrmecochory; directions of spontaneous migration: OHL – oak-hornbeam lawn, SHL – shaded lawns, SUL – sunny lawns, SHP – shaded paths, SUP – sunny paths, LIM – limestone rock, HILL – hillside.

No.	Species	Family	Status	Life form	Life strategy	Reproduction	Dispersal mode	directions of spontaneous migration						
								OHL	SHL	SUL	SHP	SUP	LIM	HILL
1.	*Abies alba* L.	*Pinaceae*	OE	M	C	s	ane	+	+	+	+	+	+	+
2.	*Acer platanoides* L.	*Aceraceae*	OE	M	C	s	ane	+	+	+	+	+	+	+
3.	*Acer pseudoplatanus* L.	*Aceraceae*	OE	M	C	s	ane	+	+	+	+	+	+	+
4.	*Aegopodium podagraria* L.	*Apiaceae*	OE	H	C	vvs	aut	+						
5.	*Agrimonia eupatoria* L.	*Rosaceae*	OE	H	C	s	epi					+		
6.	*Agrimonia procera* Wallr.	*Rosaceae*	OE	H	CS	sv	epi					+		
7.	*Ajuga reptans* L.	*Lamiaceae*	OE	H	CSR	sv	myr, aut	+						
8.	*Allium ursinum* L.	*Liliaceae*	OE	G	CSR	ssv	end		+					
9.	*Angelica archangelica* L. subsp. *archangelica*	*Apiaceae*	OE	H	CS	s	ane, hyd	+						
10.	*Anthemis tinctoria* L.	*Asteraceae*	ME [AR]	H	CS	s	aut, epi					+		
11.	*Anthriscus sylvestris* (L.) Hoffm.	*Apiaceae*	OE	H	C	ssv	epi, dys		+					
12.	*Aquilegia x hybrida* Hort.	*Ranunculaceae*	ER	H	?	s	?		+					
13.	*Arrhenatherum elatius* (L.) P. Beauv. ex J. Presl et C. Presl	*Poaceae*	OE	H	C	ssv	ane, anthr					+		
14.	*Asclepias syriaca* L.	*Asclepiadaceae*	ME [KE]	G, H	C	sv	ane, anthr					+		
15.	*Astragalus glycyphyllos* L.	*Fabaceae*	OE	H	C	s	epi, dys					+		
16.	*Betonica officinalis* L.	*Lamiaceae*	OE	H	C	sv	?		+					
17.	*Betula pendula* Roth	*Betulaceae*	OE	M	C	s	ane, epi	+	+	+	+	+	+	+
18.	*Borago officinalis* L.	*Boraginaceae*	ER	H	CR	s	epi					+		
19.	*Brachypodium sylvaticum* (Huds.) P. Beauv.	*Poaceae*	OE	H	CS	sv	epi		+					
20.	*Campanula rapunculoides* L.	*Campanulaceae*	OE	H	CSR	sv	aut	+	+	+	+	+	+	+
21.	*Cardamine pratensis* L.	*Brassicaceae*	OE	H	CSR	vvs	aut		+					
22.	*Carex brizoides* L.	*Cyperaceae*	OE	G,H	CSR	sv	ane, aut		+					
23.	*Carum carvi* L.	*Apiaceae*	OE	H	C	s	dys					+		
24.	*Centaurea jacea* L.	*Asteraceae*	OE	H	C	s	dys, ane, aut					+		
25.	*Centaurea stoebe* L.	*Asteraceae*	OE	H	CSR	s	ane, epi, anthr					+		
26.	*Cerastium tomentosum* L.	*Caryophyllaceae*	ER	Ch	C	sv	ane					+		
27.	*Cerinthe minor* L.	*Boraginaceae*	ME [AR]	H	CSR	s	?				+			
28.	*Chaerophyllum hirsutum* L.	*Apiaceae*	OE	H	C	sv	epi, ane		+					
29.	*Clematis vitalba* L.	*Ranunculaceae*	ME [KE]	N	C	s	ane, epi, aut	+	+	+	+	+	+	+
30.	*Clinopodium vulgare* L.	*Lamiaceae*	OE	H	CS	sv	ane, epi, aut					+		

31.	*Convallaria majalis* L.	*Liliaceae*	OE	G, H	CS	sv	end, aut, anthr		+					
32.	*Coronilla varia* L.	*Fabaceae*	OE	H	C	?	epi, ane, aut			+				
33.	*Corydalis cava* (L.) Schweigg. et Körte	*Fumariaceae*	OE	G	CSR	s	aut, myr		+					
34.	*Corynephorus canescens* (L.) P. Beauv.	*Poaceae*	OE	H	CS	s	ane			+				
35.	*Cynoglossum officinale* L.	*Boraginaceae*	OE	H	CS	s	epi	+	+	+	+	+	+	+
36.	*Deschampsia cespitosa* (L.) P.Beauv.	*Poaceae*	OE	H	C	s	ane, anthr	+	+	+	+	+	+	+
37.	*Dianthus barbatus* L.	*Caryophyllaceae*	ER	Ch	?	s	ane, anthr					+		
38.	*Digitalis grandiflora* Mill.	*Scrophulariaceae*	OE	G, H	C	sv	aut, ane, epi					+		
39.	*Epiliobium hirsutum* L.	*Oenotheraceae*	OE	H	C	sv	ane					+		
40.	*Epilobium roseum* Schreb.	*Oenotheraceae*	OE	H	CS	sv	ane					+		
41.	*Eranthis hyemalis* (L.) Salisb.	*Ranunculaceae*	ER	G	CSR	s	?	+	+	+	+	+	+	+
42.	*Euonymus europea* L.	*Celastraceae*	OE	N	C	s	end		+					
43.	*Euphorbia cyparissias* L.	*Euphorbiaceae*	OE	G,H	CSR	sv	aut, myr					+		
44.	*Festuca ovina* L.	*Poaceae*	OE	H	CSR	s	epi, dys, aut, anthr						+	+
45.	*Ficaria verna* Huds.	*Ranunculaceae*	OE	G, H	CSR	vvs	aut, myr		+					
46.	*Fragaria vesca* L.	*Rosaceae*	OE	H	CSR	sv	end, epi, aut		+					
47.	*Galium mollugo* L.	*Rubiaceae*	OE	H	C	s	dys		+					
48.	*Galium verum* L.	*Rubiaceae*	OE	H	CS	sv	epi		+		+			
49.	*Genista tinctoria* L.	*Fabaceae*	OE	Ch	CS	s	aut						+	+
50.	*Geranium pratense* L.	*Geraniaceae*	OE	H	C	sv	aut, epi					+		
51.	*Geum urbanum* L.	*Rosaceae*	OE	H	CSR	ssv	epi		+					
52.	*Hedera helix* L.	*Araliaceae*	OE	N,Ch	SC	sv	end		+					
53.	*Helianthemum nummularium* (L.) Mill.	*Cistaceae*	OE	Ch	CS	ssv	?					+		
54.	*Hepatica nobilis* Schreb.	*Ranunculaceae*	OE	H	CSR	sv	aut, myr	+						
55.	*Heracleum sphondylium* L.	*Apiaceae*	OE	H	C	ssv	dys, epi, ane					+		
56.	*Hieracium pilosella* L.	*Asteraceae*	OE	H	CSR	sv	ane, aut, epi					+		
57.	*Hieracium sabaudum* L.	*Asteraceae*	OE	H	C	sv	ane		+					
58.	*Hippophaë rhamnoides* L.	*Eleagnaceae*	OE	N	C	sv	end, anthr	+	+	+	+	+	+	+
59.	*Holcus lanatus* L.	*Poaceae*	OE	H	C	sv	ane, end, anthr	+	+	+	+	+	+	+
60.	*Holcus mollis* L.	*Poaceae*	OE	G, H	CSR	vvs	ane, anthr	+	+	+	+	+	+	+
61.	*Humulus lupulus* L.	*Cannabaceae*	OE	H, li	C	sv	ane		+					
62.	*Inula helenium* L.	*Asteraceae*	ME [KE]	H	C	sv	ane, epi, myr						+	+
63.	*Junglans regia L.*	*Junglandaceae*	ER	M	C	s	bar, ane, end	+	+	+	+	+	+	+
64.	*Knautia arvensis* (L.) J.M.Coult.	*Dipsacaceae*	OE	H	C	s	end, epi					+		
65.	*Lathyrus pratensis* L.	*Fabaceae*	OE	H	C	ssv	aut, ane, dys					+		
66.	*Lathyrus vernus* (L.) Bernh.	*Fabaceae*	OE	G	CSR	sv	aut		+					
67.	*Leontodon hispidus* L.	*Asteraceae*	OE	H	CSR	sv	ane	+	+	+	+	+	+	+
68.	*Leucanthemum vulgare* Lam.	*Asteraceae*	OE	H	C	sv	ane, epi, dys					+		
69.	*Ligustrum vulgare* L.	*Oleaceae*	OE	N	C	s	end, anthr, aut	+	+	+	+	+	+	+
70.	*Linum perenne* L.	*Linaceae*	ME [KE]	H	CS	sv	aut, epi, anthr						+	+
71.	*Lychnis flos - cuculi* L.	*Caryophyllaceae*	OE	H	CSR	sv	ane, epi		+					
72.	*Lysimachia vulgaris* L.	*Primulaceae*	OE	H	CS	sv	ane, epi, hyd, aut		+					
73.	*Lythrum salicaria* L.	*Lythraceae*	OE	H	CS	ssv	ane, epi	+	+	+	+	+	+	+
74.	*Mahonia aquifolium* (Pursh) Nutt.	*Berberidaceae*	ER	N	C	sv	anthr, end	+	+	+	+	+	+	+
75.	*Melica nutans* L.	*Poaceae*	OE	G,H	CS	sv	aut, myr	+						
76.	*Melissa officinalis* L.	*Lamiaceae*	ER	H	C	sv	?					+		
77.	*Mercurialis perennis* L.	*Euphorbiaceae*	OE	G,H	CS	sv	aut, myr	+						
78.	*Origanum vulgare* L.	*Lamiaceae*	OE	C,H	CSR	sv	ane, aut						+	+

79.	*Ornithogalum umbellatum* L.	*Liliaceae*	OE	G	CSR	vvs	bar, myr, aut	+	+	+	+	+	+	+
80.	*Picea abies* (L.) H.Karst.	*Pinaceae*	OE	M	C	s	ane, end	+	+	+	+	+	+	+
81.	*Pimpinella saxifraga* L.	*Apiaceae*	OE	H	CS	s	anthr, epi					+		
82.	*Plantago media* L.	*Plantaginaceae*	OE	H	CSR	sv	aut					+		
83.	*Potentilla micrantha* Ramond ex DC.	*Rosaceae*	OE	H	CSR	sv	ane, aut		+					
84.	*Primula veris* Huds.	*Primulaceae*	OE	H	CSR	sv	ane					+		
85.	*Prunella vulgaris L.*	*Lamiaceae*	OE	H	CSR	sv	hyd, epi, dys, aut		+					
86.	*Pulmonaria obscura* Dumort.	*Boraginaceae*	OE	H	CSR	sv	myr	+						
87.	*Pulmonaria officinalis* L.	*Boraginaceae*	OE	H	CSR	sv	myr	+						
88.	*Pyracantha coccinea* M. Roem.	*Rosaceae*	ER	N	?	?	end	+	+	+	+	+	+	+
89.	*Quercus robur* L.	*Fagaceae*	OE	M	C	s	ane, end, bar	+	+	+	+	+	+	+
90.	*Ranunculus cassubicus* L.	*Ranunculaceae*	OE	H	?	sv	epi		+		+			
91.	*Ranunculus lanunginosus* L.	*Ranunculaceae*	OE	H	CS	sv	epi		+					
92.	*Rudbeckia laciniata* L. *'Gold Kugel'*	*Asteraceae*	ME [KE]	H	C	sv	ane, aut, epi, myr		+					
93.	*Rumex acetosa* L.	*Polygonaceae*	OE	H	C	sv	ane, epi, dys, hyd	+	+	+	+	+	+	+
94.	*Salvia sclarea* L.	*Lamiaceae*	ER	H	?	?	aut	+	+	+	+	+	+	+
95.	*Salvia verticillata* L.	*Lamiaceae*	OE	H	CSR	ssv	aut						+	+
96.	*Sanguisorba minor* Scop.	*Rosaceae*	OE	H	CSR	ssv	ane, hyd, aut					+		
97.	*Scabiosa ochroleuca* L.	*Dipsacaceae*	OE	H	CSR	s	ane						+	+
98.	*Scilla sibirica* Haw.	*Liliaceae*	ER	G	CSR	sv	aut, myr, anthr		+					
99.	*Scorzonera hispanica* L.	*Asteraceae*	ER	H	CSR	s	?		+					
100.	*Scropularia nodosa* L.	*Scrophulariaceae*	OE	H	CS	sv	ane, epi, aut		+		+			
101.	*Sedum acre* L.	*Crassulaceae*	OE	Ch	S	sv	hyd, myr, aut					+		
102.	*Sedum reflexum* L.	*Crassulaceae*	OE	Ch	S	sv	hyd, myr, aut					+		
103.	*Sedum sexangulare* L.	*Crassulaceae*	OE	Ch	S	sv	hyd, myr, aut					+		
104.	*Solanum dulcamara* L.	*Solanaceae*	OE	N, Li	C	sv	end, epi, aut		+					
105.	*Stachys recta* L.	*Lamiaceae*	OE	H	CSR	s	?				+			
106.	*Stachys sylvatica* L.	*Lamiaceae*	OE	H	CS	sv	epi, ane, hyd, aut	+						
107.	*Tanacetum balsamita* L.	*Asteraceae*	ER	H	C	sv	ane, epi, anthr					+		
108.	*Taxus x media* Rehder	*Taxaceae*	ER	N	?	?	end	+	+	+	+	+	+	+
109.	*Thalictrum minus* L.	*Ranunculaceae*	OE	H	CS	sv	ane, epi, hyd	+	+	+	+	+	+	+
110.	*Thymus kosteleckyanus* Opiz	*Lamiaceae*	OE	Ch	CSR	s	aut						+	+
111.	*Thymus pulegioides* L.	*Lamiaceae*	OE	Ch	CSR	ssv	aut, myr						+	+
112.	*Tilia cordata* Mill.	*Tiliaceae*	OE	M	C	ssv	ane	+	+	+	+	+	+	+
113.	*Tragopogon orientalis* L.	*Asteraceae*	OE	H	CSR	s	ane, epi					+		
114.	*Trifolium fragiferum* L.	*Fabaceae*	OE	H	CSR	ssv	ane, epi					+		
115.	*Ulmus levis* Pall.	*Ulmaceae*	OE	M	C	ssv	ane	+	+	+	+	+	+	+
116.	*Valeriana officinalis* L.	*Valerianaeae*	OE	H	C	sv	ane, epi, hyd, aut	+	+	+	+	+	+	+
117.	*Verbascum densiflorum* Bertol.	*Scrophulariaceae*	OE	H	C	s	ane, epi							+
118.	*Verbascum nigrum* L.	*Scrophulariaceae*	OE	H	C	s	ane, epi							+
119.	*Verbascum phlomoides* L.	*Scrophulariaceae*	OE	H	C	s	ane							+
120.	*Veronica teucrium* L.	*Scrophulariaceae*	OE	T	C	s	ane, aut, hyd, anthr						+	+
121.	*Vinca minor* L.	*Apocynaceae*	OE	Ch	CS	sv	aut, myr, anthr	+						
122.	*Vincetoxicum hirundinaria* Medik.	*Asclepiadaceae*	OE	H	CS	sv	ane, aut	+						
123.	*Viola reihenbachiana* Jord. Ex Boreau	*Violaceae*	OE	H	CSR	sv	aut, myr		+					
124.	*Viola riviniana* Rchb.	*Violaceae*	OE	H	CSR	sv	myr		+					

As many as 49 escaped species are plants with competitive strategy. Quite a large group (25 species) are species whose competitive abilities are limited by the stress (CS strategy). As many as 40 are species with the mixed, CSR strategy. Only one species (*Borago officinalis*) represents the CR strategy.

The distinguished group of escaped plants the most numerous are species that reproduce by seeds (40 species; 32.3%) or both by seeds and during vegetatively (75; 60.5%). Only 5 species prefer vegetative reproduction: *Aegopodium podagraria*, *Cardamine pratensis*, *Ficaria verna*, *Holcus mollis*, *Ornithogallum umbellatum* (Table 1).

The group of spontaneously spreading species in the garden is very diverse with respect to different ways of spreading. Anemochorous plants prevail over others – 54 species (43.5%). The share of myrmeko-, baro- and autochorous species is also significant. Most species use several ways of dispersal.

The migration of species appears to be multi-directional (Fig.1, Table 1). Various directions of spontaneous migration of species from sites of their planting were observed within the garden: the "oak-hornbeam lawn", shaded lawns, sunny lawns, shaded paths, sunny paths, limestone rock garden on the hillside. Most species (93; 75%) occurred exclusively in one of the above-listed sites. Among abovementioned species, most have chosen shaded places, such as lawns, paths and "oak-hornbeam lawn" (43 species; 34.7%). Escaped species appeared also quite numerously on the sunny paths and lawns (37 species; 29.8%; Fig.1). Only 13 species (10.5%) occurred spontaneously in limestone rock garden and hillside. There was also a relatively numerous group of plants (28 species; 22.6%) which spread all over the territory of the garden

Discussion

The phenomenon of spontaneous spread of cultivated species, observed in the botanical garden of the University of Łódź, confirms the tendencies observed in other botanical gardens (Reichard & White, 2001, Galera, 2003, Galera & Sudnik-Wójcikowska, 2004, 2010, Dawson *et al*., 2008, Virtue *et al*,. 2008). Even though the number of plants escaping from cultivation is much smaller there (124) than in other gardens in Poland (Galera, 2003), this stems probably from the smaller size and less rich collection of the garden in Łódź. Still, on the local scale the "escaped species" flora is relatively rich, since it constitutes 15.5% of the whole plant collection in the garden.

Characteristic features of the described group are determined by the specific range of plants cultivated in the particular garden as well as biological propensities of some species for spreading. The influence of these local factors is

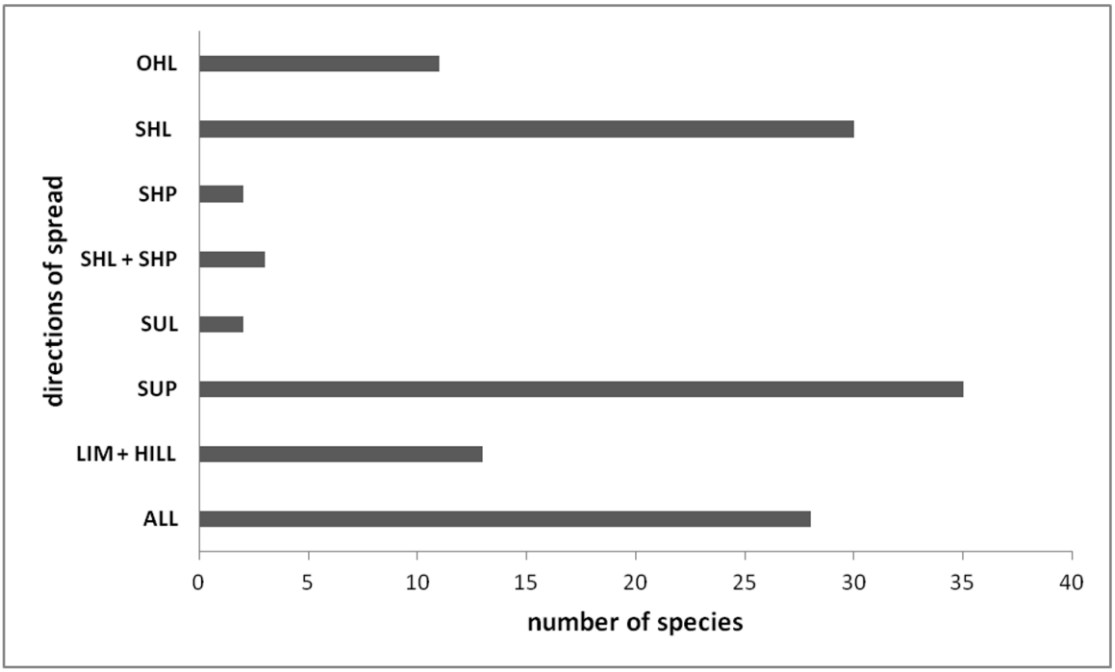

Figure 1. Directions of spontaneous migrations of cultivated plants in the university botanical garden. Abbreviations: see Table 1.

reflected both in the taxonomic structure and in the ecological characteristics of the investigated group of species.

The high frequency of escaping plants from *Poaceae* and *Asteraceae* families is related to the fact that the majority of the herbaceous collection in the garden belongs to these families, like the majority of species in the Polish flora (Stefaniak & Bomanowska, 2011). Moreover, biological characteristics of many species from these families (i.a. the ability to use various dispersal routes) predisposes them to spread and to occupy new diverse habitats (Mizianty, 1995; Pyšek, 1997).

The biological spectrum with its preponderance of hemicryptophytes is also a reflection of the species composition of Polish flora and selection of species cultivated in the garden (Zarzycki et al., 2002, Stefaniak & Bomanowska, 2011). The collection of herbaceous plants is composed mainly of perennials and a small number of biannual species. The lack of therophytes among spontaneously spreading plants may be explained by the fact that few plants from this group are cultivated in the university garden, with most of them being cultivars which produce no seeds. In other investigated polish botanical gardens this is numerous group of runaway species (Galera & Sudnik-Wójcikowska, 2004).

The most numerous group of the described flora is oekiophytes (native escaped species). The cultivated flora of university garden is also represented mainly by this group, while in the remaining botanical gardens in Poland there is similar share of two groups: native species and ergasiophygophytes (Galera & Sudnik-Wójcikowska, 2004). It is probably because the garden collection is composed mainly of native species (Stefaniak & Bomanowska, 2011).

Distribution of Grime's life strategies showing a similar share of species representing C-type and CSR-type strategies in the described flora reflects the habitat conditions in the garden which is an anthropogenically transformed area, but with stable ecological conditions (with homogeneous manners of exploitation). This conclusion may be supported by the preference for generative reproduction shown by spontaneously spreading species, even though it requires significantly more ecological effort than vegetative reproduction (Falińska, 2002).

Most plants that spread spontaneously in the university botanical garden uses several different ways of dispersion of propagules. The diversity of strategies helps species to spreadp0''', migrate and settle on new habitats (Van der Pijl, 1972, Kollmann, 2000, Soons & Ozinga, 2000, Vittoz & Engler, 2007).

Composition of the described group is clearly dominated by anemochorous plants, including species from *Asteraceae* and *Poaceae* families, as well as some trees (e.g. maples). These results are in agreement with those obtained for Warsaw botanical gardens (Sudnik-Wójcikowska & Galera, 2005). Species disseminated by the wind spread in different directions: the lawns and paths, both sunny and shady, and on limestone hills.

In case of many plant species the main vector which spreads propagules are animals, including birds (Adamowski & Knopik, 1996, Gosper et al., 2005 and literature cited therein). Garden of the University is a food source and resting site for many bird species, which eat the fleshy fruits of many species (e.g. *Taxus x media*, *Euonymus europaea*, *Mahonia aquifolia*, *Pyracantha coccinea*), thereby contributing to their spread. Plants with seeds that have prehensile trichomes or hooks (e.g. *Agrimonia officinalis*, *Borago officinalis*) are spread around within the garden by mammals, especially by rodents, but also by house cats (own observations). Seeds of species such as *Corydalis cava*, *Scilla sibirica*, *Viola reichenbachiana, V. riviniana*, as well as some plants from *Asteraceae* and *Lamiaceae* families, which have elaiosome bodies, are spread by ants (Van der Pijl, 1972, Handel, 1990, Gorb et al., 2000).

Anthropochory is also of significant importance in spread of plants (Faliński, 1972, Vittoz & Engler, 2007). The unintentional transport of diaspores of in the garden takes place both during gardening procedures and while teaching field classes with groups of students. In this manner, the following species may have spread: *Arrhenatherum elatius, Centaurea stoebe, Cynoglossum officinale.*

Species spreading in zoochoric or anthropochoric way, most often spread on paths – places where most visitors walk, as well as living and penetrating it occasionally animals.

Among native species which spontaneously spread in the university garden particular speciallz significant is very rare species, e.g. *Potentilla micrantha*, a vulnerable species (VU) included in the Polish Red Data Book of Plants (Kaźmierczakowa & Zarzycki, 2002). It is a characteristic species of broadleaf forests, and for this reason it has been planted in the most shaded site, the so-called "oak-hornbeam lawn". Secondary localities of this plant appeared spontaneously on lawns in other parts of the garden. This is another

case of the positive function of botanical gardens in aiding the spread of plants.

This escape of species from flower beds in the garden can be dangerous to the native flora if it contributes to expansion of invasive species (Reichard & White, 2001, Dehnen-Schmutz et al., 2007, Dawson et al., 2008, Křivánek & Pyšek, 2008, Galera & Sudnik-Wójcikowska, 2010). It seems that this is not a real and present danger in the described case, since among the plants which appear spontaneously in the garden, few show any tendencies towards expansion or invasiveness. Potentially, this description may fit only to *Asclepias syriaca* and *Carex brizoides*, two species which have a high reproductive potential, which grow quickly and reproduce both via seeds and vegetatively (Liu et al., 2008; BiolFlor database). The common milkweed is a new arrival in our flora (1872 – first record in Polish territory; Tokarska-Guzik, 2005), introduced as an ornamental plant, which has in recent times spread rather quickly in anthropogenic habitats (Tokarska-Guzik, 2005). In the university garden, individuals of the milkweed have also been observed to quickly occupy new habitats. The quaking grass sedge, although native to our flora, is considered an invasive species and an indicator of degeneration of oak-hornbeam forest phytocoenoses (Chmura & Sierka, 2007).

The potential threat to the local flora may be derived from spontaneously spreading cultivars that are able to hybridise with native species (Jackowiak, 1999). Invasive species can show a number of patterns of hybridization with native species, from hybridization without introgression to complete admixture (Rhymer & Simberloff, 1996, Allendorf et al., 2001). Among the species described here, this type of danger may be expected from the hybrid taxon *Aquilegia x hybrida*. This plant undergoes intense generative reproduction and has a tendency to spread quickly, so that cultivating it in the vicinity of natural localities of the original native species *Aquilegia vulgaris* carries the risk of introgressive hybridisation (Galera, 2003).

Even though a realistic evaluation of the potential of these two species for further expansion is very difficult since the colonisation success of an alien species depends on numerous factors that are often difficult to predict (Heger & Trepl, 2003, Hierro et al., 2005, Sharma et al., 2005), their spontaneous spread in the garden should not be treated too lightly.

It is difficult to predict whether the spontaneous escape of cultivated plants from sites of cultivation within the Łódź University Botanical Garden may be the beginning of their further spread outside its boundaries. The time course of observations was relatively short and it is unknown how long the escaped plants may persevere in the new sites where they grow, especially since most taxa were characterised by low frequency of occurrence.

Conclusion

Taking into account the composition of group of escaped plants (predominance of native species, high number of ergasiophygophytes among the alien species) and location of the garden in the centre of a major city, further spontaneous spread of described species seems rather doubtful. It can be supposed that the spontaneous appearance of most escaped plants was rather accidental – they appeared transiently and without a tendency for further spread. At the same time, information on first records of spontaneous occurrence of species escaping from cultivation may be valuable due to the future possibility of reconstruction of initial stages of migration (invasion) once it will have occurred.

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