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The occurrence of alien species in the agriculture landscape: the case of the Proszowice Plateau (Southern Poland)

Introduction

The phenomenon of the synanthropisation of flora and vegetation is an important issue according to the diversity of plants and animals. It can also influence a local economy (Pimentel, 2011), especially when it refers to areas that neighbour large agglomerations and serve as an agricultural service for them. The appearance of alien species in local floras is a process dating back to the beginning of agriculture (e.g., Kornaś, 1981). The European alien species database (DAISE) contains over 6.6 thousand plant species that have been recorded to date in Europe. Their origin is associated with intentional introductions connected with their use, but there is also a large group of plants unintentionally transferred. The proportion of non-native species in the floras of individual European countries is varied, and their number ranges from approx. 500 to 1.900 species (Lambdon et al., 2008; Tokarska-Guzik et al., 2011). It is assumed that the number of alien species in Poland is 939, which represents around 27% of the flora of Poland (Tokarska-Guzik et al., 2012). In the studies on the causes and mechanism of the distribution of newcomers, the detailed cartographic studies of local floras cannot be overestimated (Zając, Zając, 2003).

The Proszowice Plateau (342.23 by physico-geographical regionalisation of Poland; Małopolska Upland, southern Poland) represents a special area: neighbouring with Kraków agglomeration, one of the biggest cities in Poland and with an old tradition of agriculture dating back to the Neolithic, it was one of the earliest, dated Neolithic settlement centres in Poland (Kruk et al., 1996). Nowadays, almost 80% of the area (of the 770 km^2) is covered by arable fields, which is the consequence of the favourable natural conditions: rich soils, gentle landscape relief, and microclimatic conditions (Towpasz, 2006). Human settlements occupy a relatively small area, many of them are dispersed in the area, and a few are concentrated in several small towns.

The botanical studies in this area were started in 1995, and they have revealed the occurrence of rare and endangered plant species and vegetation types (e.g., Towpasz, 1994; 2004; Towpasz, Kotańska, 1999; 2001; Trzcińska-Tacik et al., 1998; Kotańska et al., 2001; Towpasz, Cwener, 2002; Towpasz, Stachurska-Swakoń, 2010; Towpasz et al., 2001; 2011; 2017).

The paper is devoted to the alien species occurring in the Proszowice Plateau. We concentrated on the kenophytes (species arrived in Poland after 1500 A.D., Kornaś, 1977), because the archaeophytes were analysed before (Towpasz, Kotańska, 2003). The aim of the analyses was the search for rules of the mechanism of the synanthropisation of local flora.

Methods

The floristic analysis of the flora of the Proszowice Plateau was based on a detailed inventory with the use of the cartogram method of ATPOL (Zając, 1978) with the base unit (square) of 2 km × 2 km. The results presented here are based on the published "Flora of the Proszowice Plateau" (Towpasz, 2006) with the addition of new findings from the last few years. The geographical-historical classification of the species was used (Kornaś, 1977) and the terminology follows Kornaś, Medwecka-Kornaś (2002). In this respect, the following terminology of anthropophytes (non-indigenous plant species) was used: archaeophytes – species alien to the natural indigenous flora which arrived and became permanently established before the end of the 15th century; kenophytes – species brought to the country intentionally or unintentionally from 16th century; epoecophytes – species occurred in fields or ruderal habitats; hemiagriophytes – species established in seminatural habitats like meadows; holoagriophytes – species established in naturally disturbed plant communities such as forests, marches, swamp, ponds; diaphytes – casual species; and, ergasiophytes – casual species from cultivations.

The lists of kenophytes were established after Zając et al. (1998) and Mirek et al. (2002). The obtained group of kenophytes was analysed in terms of their distribution and frequency (number of squares in which the species was noted), origin (Zając et al., 1998), life form (Raunkiaer form – Zarzycki et al., 2002), Ellenberg indicator values (Ellenberg et al., 1992), Grime's life strategies (Klotz et al., 2002), and dispersion mode (Klotz et al., 2002). The names of species used follow Mirek et al. (2002).

Results

The flora of Proszowice Plateau contained 1008 plant species, and 204 species of those were permanently established alien species, i.e. metaphytes and 27 temporally wild

diaphytes (ergasiophytes) (Appendix 1 – Table 1). Among the established species of alien origin, archaeophytes (108 species) represent the largest group, and the list of kenophytes consists of 96 species. In the last group, 44 species were classified as epoecophytes, 46 as hemiagriophytes, and 6 as holoagriophytes (Appendix 1 – Table 2). Almost half of the kenophytes are invasive species in Poland (according to Tokarska-Guzik et al., 2012).

The most frequent among kenophytes were species commonly known as weeds. They occurred in the arable fields or ruderal habitats in the investigated area. The following belong to the group of epoecophytes growing in the segetal habitats: *Galinsoga ciliata*, *G. parviflora*, *Oxalis fontana*, *Veronica persica*, *Vicia dasycarpa*. *Galinsoga parviflora* was the species most frequently noted in the area, because it occurred in 85% of the ATPOL squares (in 253 of 296). The rarest weeds were *Chenopodium strictum* and *Kochia scoparia*, which had only one location. *Amaranthus retroflexus* and *Chamomilla suaveolens* were epoecophytes widespread both in segetal and ruderal habitats. The following species should also be mentioned, as they were not rare: *Amaranthus chlorostachys* and *Sisymbrium loeselli*. *Lycium barbarum*, classified here as an epoecophyte, was noted rather frequently, i.e. in 47% of ATPOL squares. It created dense thickets on the steep field bounds.

The group of rare epoecophytes included *Amaranthus lividus*, *Salsola kali* subsp. *ruthenica*, *Sisymbrium altissimum* and *Sinapis alba*. The following belong to the rare species growing in the ruderal habitats: *Cardaria draba*, *Datura stramonium*, *Diplotaxis muralis*, *Geranium divaricatum*, *G. pyrenaicum*, and *Lepidium densiflorum*. In this group of epoecophytes, *Centaurea diffusa*, *Silene dichotoma* and *Tanacetum parthenium* were found in few locations on roadsides.

The group of species that were permanently established in natural and semi-natural habitats in Poland was numerous in the Proszowice Plateau, together 52 species. The most frequent species, according to the number of ATPOL squares in the area, was *Conyza canadensis* (71% of ATPOL squares) and *Solidago gigantea* (50% of ATPOL squares). The last species was common in abandoned fields, unmanaged meadows, as well as in riparian communities along streams. *Solidago gigantea*, like in other regions of our country, often creates large and single-species clusters.

The following group of hemiagriophytes includes several species that have recently spread in Poland, especially along river valleys: *Echinocystis lobata* and species of the genus *Heracleum*: *H. mantegazzianum* and *H. sosnovskyi*. *Acer negundo* has to be also mentioned as the species with the expansive potential on the area. It was noted mainly in forests and thickets along streams; however, when planted along roads, it could easily overgrow larger areas. Another threat to the local flora is *Parthenocissus inserta*, which very easily expands due to vegetative dispersion. The following are species that are fairly often noted in the area: *Bidens frondosa*, *Bromus carinatus*, *Erigeron annuus*,

Impatiens glandulifera, *Ligustrum vulgare*, *Medicago sativa*, *Onobrychis viciifolia*, *Rudbeckia laciniata,* and *Trifolium patens.*

In the group of holoagriophytes, six taxa were listed: *Acorus calamus*, *Cerasus mahaleb*, *Elodea canadensis*, *Impatiens parviflora*, *Quercus rubra,* and *Robinia pseudoacacia*. Among alien tree species, *Robinia pseudoacacia* were the most frequently noted in the area, and it was found in 81% of ATPOL squares. The species could be treated as a particularly expansive plant. It is already completely established in the forests, and it even creates single-species woodlands on steep slopes above the roads. The steep embankments of the Vistula River are significantly overgrown by black locust. The undergrowth of these woodlands consisted of a mixture of forest and meadow plants. Frequently, *Impatiens parviflora*, also a holoagriophyte, covered the floors beneath the tree crowns. *Impatiens parviflora* was also found in others forest and shrub communities. It was noted in 54% of ATPOL squares. Other tree species, *Quercus rubra* rarely occurred in the area, and it was found in eight ATPOL squares only. *Acorus calamus* grew in the reeds and *Elodea canadensis* in water reservoirs. These species were rarely found in the studied area, which is related to the local relief and the rarity of such habitats. The remaining four species were found in the forest communities.

Most alien species were found rarely in the studied area. 53 taxa (55% of all) were found very rarely, and they were noted in 1-10 ATPOL square (Fig. 1). Only six species occurred in more than 200 ATPOL squares: *Chamomila suaveolens* (77% of ATPOL squares), *Conyza canadensis* (71%), *Galinsoga ciliata* (79%), *G. parviflora* (85%), *Robinia pseudoacacia* (81%), and *Veronica persica* (77%).

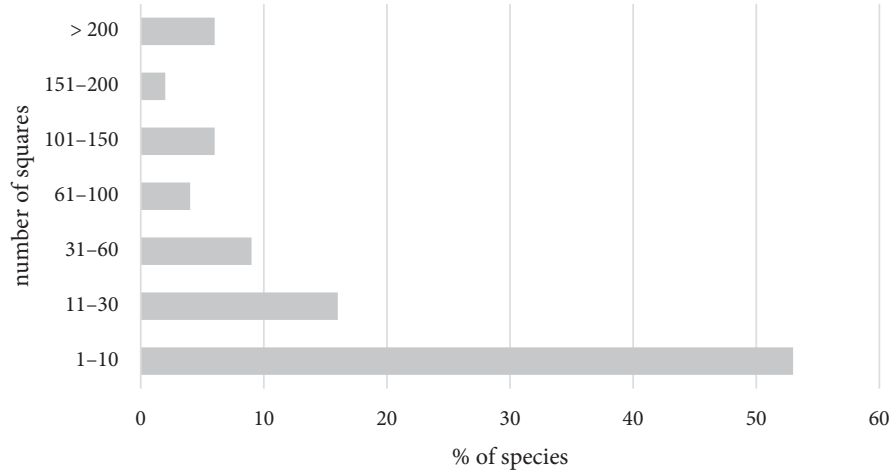

Fig. 1. The frequency of occurrence of kenophytes of the Proszowice Plateau (Southern Poland) in the ATPOL square (2 km × 2 km); a number of all squares: 296, a number of kenophytes: 96

Concerning the origin of the kenophytes that occurred in the investigated area, species originating in Northern America (33) and Europe (22) make the highest contribution (Appendix 1 – Table 2).

Therophytes (39 species) predominate when considering the main plant life form among species. There is also a significant number of hemicryptophytes (36 species). Even in the investigated areas that have an agriculture character, seventeen species had a form of phanerophyte. With the respect of the ecological indicators, most species preferred full light and a moisture indicator value between 4 and 6. Concerning the nutrient soil condition, rich soil was favourable (N = 7–8 for 50% of species). The largest group of kenophytes produced anemochorous seeds (40% of species). 16% of species were autochorous. The vegetative mode of spreading predominates among perennials (16% of all species).

The interesting issue is the allocation strategy of alien plants. 41% of species have been characterised as having the Competitor strategy, while 27% had a CR strategy (Fig. 2). However, when we take the species with an occurrence in more than 70% of ATPOL squares, most of them had the CR strategy. There were only two species with the SR strategy: *Impatiens parviflora*, *Salsola kali* subsp. *ruthenicus*. Three species used the CS strategy: *Acorus calamus*, *Hesperis matronalis* subsp. *matronalis*, *Hyssopus officinalis*.

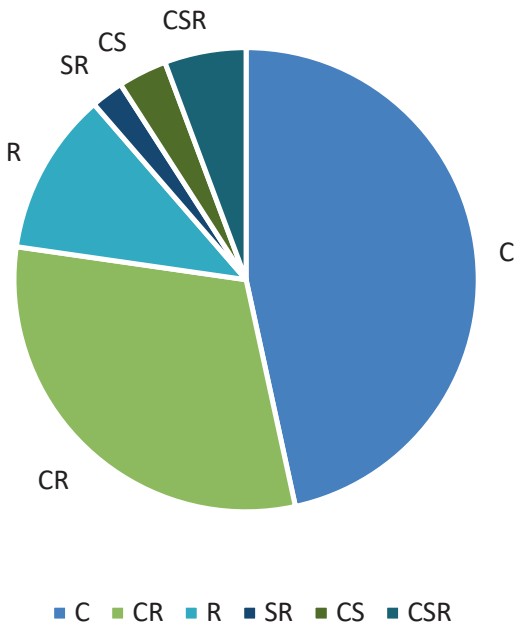

Fig. 2. The percentage contribution of Grime's life strategy in the kenophytes of the Proszowice Plateau (Southern Poland); C – competitors, R – ruderals, S – stress tolerant; a number of kenophytes: 96

The analysis of the distribution of the kenophytes indicated the role of habitat differentiation and the land use method. The special role in the landscape diversity is played by river and stream valleys. The highest concentration of hemiagryophytes and holoagriophytes was found in the Vistula River valley (Fig. 3).

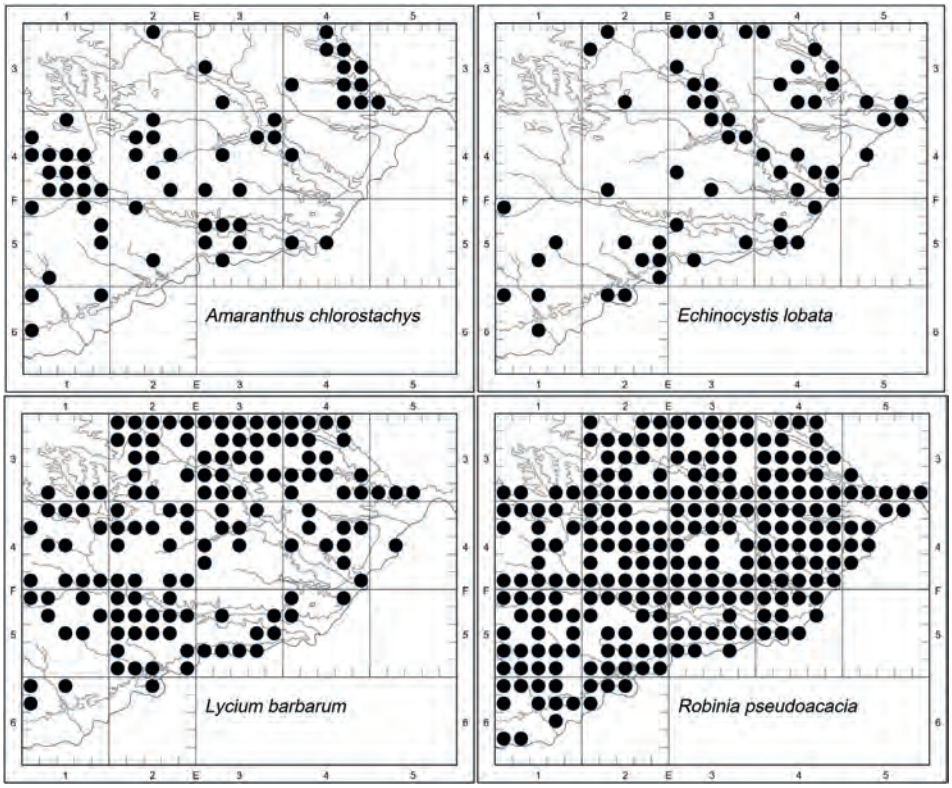

Fig. 3. The distribution of chosen kenophytes on the Proszowice Plateau (Southern Poland); ATPOL squares (2 km × 2 km)

Discussion

Detailed analyses of local floras provide a useful assessment of their synanthropisation (Faliński, 1972; Kornaś, 1977; Kornaś, Medwecka-Kornaś, 2002) and provide a good base for further considerations, particularly connected with alien species that could significantly change the diversity (e.g., Heger, Trepl, 2003; Bradley et al., 2010; Tokarska-Guzik et al., 2012; Zając, Zając, 2015). The proportion of anthropophytes in the local floras of Poland is diversified, and it often depends on the accessibility and number of anthropogenic habitats. These kinds of studies are important for the monitoring of alien species (Pyšek et al., 2008). In recent decades, different approaches have been discussed for analysing the causes and mechanisms of the encroachment

of alien species. One of them is to look for particular attributes that make if possible for species to invade (e.g., Kornaś, 1990; Faliński, 1998; Fu Dostatny, 1999; Drescher, Prots, 2003; Tokarska-Guzik, 2005; Theoharides, Dukes, 2007; Towpasz, Stachurska-Swakoń, 2011; Trzcińska-Tacik, Stachurska-Swakoń, 2011; Bartoszek, Stachurska-Swakoń, 2016). The other approach is to look for abiotic conditions that make sites resistant to invasion (e.g., Pyšek et al., 2010; Barabasz-Krasny et al., 2018).

The presented analysis of local flora gives a general view on the group of alien species occurring in the landscape that has been used intensively of a long time. The number of alien species is not very high, and they constitute about 20% of the flora of Proszowice Plateau. The main cause of this phenomenon is the lack of railroads and bigger cities or communication centres (Towpasz, 2006). The long history of agriculture and the predomination of arable fields in the landscape are visible in the prevalence of archaeophytes among alien species (Towpasz, Kotańska, 2003). Some of them are rare in Poland. The rarity of archaeophytes is connected with global change known in farmlands, i.e. larger farms, mechanization, the use of herbicides, etc. (e.g., Trzcińska-Tacik et al., 1998; Trzcińska-Tacik, Stachurska-Swakoń, 2010; Stachurska-Swakoń, Trzcińska-Tacik, 2014).

In general, some rules of occurrence of kenophytes and its features in the investigated area could be seen. Similar to other regions in Poland or adjacent countries, the alien species originated mainly from Europe and North America (Zając et al., 1998; Tokarska-Guzik et al., 2012). There are mainly therophytes and competitors (according to life strategy) predominates. This phenomenon was also noticed by Tokarska-Guzik (2003) when the alien flora of chosen Polish cities was compared. The usefulness of life strategy to estimate anthropogenic areas was described by different authors (e.g., Grime, 2002; Lososová et al., 2006). Vuković et al. (2014) pointed at the CR strategy that prevailed for invasive species in Croatia. Similarly, when we compare the list of species with a number of localities (the number of squares in which the species was recorded) and life strategy, it could be concluded that species with the CR strategy had a higher potential to invade.

The distribution of kenophytes along rivers is perceived by many authors (e.g., Dajdok, Kącki, 2003; Dajdok, Tokarska-Guzik, 2009). The river valleys serve as habitat diversification in the landscape and roads for dispersion of plant diaspores.

The local character of the area is demonstrated by the spontaneous formation of woodlands with *Robinia pseudoacacia* and the formation of dense thickets with *Lycium barbarum*. On a local scale, the last species should be treated as a hemiagriophyte, if the tendency to occupy new patches will maintain. It can be also assumed that the long list of alien species with a low number of localities is the result of the intensive use of the landscape. Both mentioned species are treated as invasive in Poland. The number of invasive plant species in the investigated area is high; almost a half of the

noticed kenophytes are found in the list of invasive plant species in Poland. Some of them are really aggressive in the area and a growing number of localities is observed. In this respect, the investigation of the local flora is still important.

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Appendix 1

Tab. 1. The historical-geographical classification of the flora of Proszowice Plateau (Southern Poland)

Name of group	Number of species	Local flora [%]
Spontaneophytes	804	79.8
Anthropophytes	231	22.9
Metaphytes	204	20.2
Archaeophytes	108	10.7
Kenophytes	96	9.5
Epoecophytes	44	4.4
Hemiagriophytes	46	4.6
Holoagriophytes	6	0.6
Diaphytes (Ergasiophytes)	27	2.7

Tab. 2. Kenophytes in the flora of the Proszowice Plateau; invasive species in Poland (according to Tokarska-Guzik et al., 2012) are marked in bold

Species	Number of squares (max 296)	0rigin	life forms	life strategy	Epoecophytes	Hemiagriophytes	Holoagriophytes
Acer negundo	72	Am N	M	C		+	
A. saccharinum	1	Am N	M	-		+	
Acorus calamus	7	Asia C & S	G, Hy	CS			+
Aesculus hippocastanum	18	Eur SE	M	C		+	
Amaranthus chlorostachys	59	Am S & C	T	CR	+		
A. lividus	12	Am S & C	T	CR	+		
A. retroflexus	185	Am N	T	CR	+		
Aster lanceolatus	1	Am N	H	C		+	
A. novae-angliae	1	Am N	H	C		+	
A. novi-belgii	20	Am N	H	C		+	
A.* × *salignus	1	Am N	H	C		+	
Bidens frondosa	47	Am N	T	CR		+	
Brassica nigra	3	Eur SW	T	CR		+	
B. rapa subsp. rapa	1	Eur S	T	CR	+		
Bromus carinatus	45	Am N	T, H	-		+	
B. japonicus	2	Eur S, Asia W	H	R	+		
B. × *pseudothominii*	4	antrop	H	-		+	
Bryonia alba	16	Eur E, Asia W	H	CR	+		
Bunias orientalis	3	Eur SE, Asia W	H	C		+	
Cardaria draba	3	Eur SE, Asia SW	G, H	CSR	+		

Centaurea diffusa	1	Eur SE, Asia SW	T, H	CSR	+		
Cerasus mahaleb	2	Eur S, Asia SW	M	C			+
Chamomilla suaveolens	227	Am N, Asia E	H	R	+		
Chenopodium strictum	10	Asia C	T	R	+		
Conyza canadensis	211	Am N	T, H	CR		+	
Cuscuta campestris	1	Am N [SE]	T, p	-	+		
Datura stramonium	14	Am N [SE]	T	CR	+		
Dianthus barbatus	1	Eur C	H	-	+		
Diplotaxis muralis	6	Eur S & W	T, H	CSR	+		
Echinocystis lobata	59	Am N	T, li	CR		+	
Echinops sphaerocephalus	7	Eur E, Asia W	H	C	+		
Elodea canadensis	6	Am N	Hy	CR			+
Elsholtzia ciliata	9	Asia E	T	R	+		
Epilobium ciliatum	7	Am N	H	-	+		
Eragrostis minor	1	Eur SE	T	R	+		
Erigeron annuus	86	Am N	H	C		+	
Galinsoga ciliata	233	Am C	T	CR	+		
G. parviflora	253	Am S & C	T	CR	+		
Geranium divaricatum	5	Eur S, Asia C	T	R	+		
G. pyrenaicum	1	Eur S	H	CSR	+		
Helianthus tuberosus	15	Am N	G	C		+	
Heracleum mantegazzianum	3	Asia C & E	H	C		+	
H. sosnovskyi	1	Asia SW	H	C		+	
Hesperis matronalis subsp. matronalis	13	Eur S	H	CS		+	
Hyssopus officinalis	1	Eur S & SE	Ch	CS	+		
Impatiens glandulifera	44	Asia C	T	C		+	
I. parviflora	161	Asia C, Asia E	T	SR			+
Juglans regia	16	Eur SE	M	C		+	
Juncus tenuis	16	Am N	H	CSR		+	
Kochia scoparia	11	Eur E, Asia W	T	CR	+		
Lepidium densiflorum	2	Am N	T	R	+		
Ligustrum vulgare	26	Eur	H	CR		+	
Lolium multiflorum	127	Eur SW, Afr N, Am SW	H, T	C		+	
Lonicera caprifolium	1	Eur SE	N	C		+	
Lupinus polyphyllos	4	Am N	H	C		+	
Lycium barbarum	138	Asia E	N	C	+		
Lycopersicon esculentum	3	Am S	T	CR	+		
Lysimachia punctata	3	Eur SE	H	C	+		
Malus domestica	12	Eur	M	C		+	
Medicago sativa	143	Asia S	H	C		+	
M. × varia	97	antrop	H	C		+	
Mentha spicata	2	antrop	H	-		+	
Oenothera depressa	2	Am N	H	CR	+		
Onobrychis viciifolia	50	Eur S, SE	H	cr		+	

Oxalis fontana	143	Am N, Asia E	T	R	+		
Padus serotina	4	Am N[E] & AmS[N]	N, M	C		+	
Parthenocissus inserta	38	Am N[E]	N, li	C		+	
Physalis alkekengi	4	Eur SE, Asia SW	H	C	+		
Prunus domestica subsp. domestica	10	Asia	M	C		+	
Pyrus communis	65	Eur	M	C		+	
Quercus rubra	10	Am N	M	C			+
Reynoutria japonica	30	Asia E	G	C		+	
Robinia pseudoacacia	240	Am N	M	C			+
Rosa rugosa	3	Asia E	N	C		+	
Rudbeckia laciniata	34	Am N	H	C		+	
Rumex confertus	3	Eur SE, Asia W	H	C		+	
Salsola kali subsp. ruthenica	1	Eur SE, Asia C	T	SR	+		
Senecio vernalis	9	Eur SE, Asia W	T, H	R	+		
Silene dichotoma	1	Eur S, SE	H	R	+		
Sinapis alba	6	Eur S	T	CR	+		
Sisymbrium altissimum	4	Eur SE, Asia C	H, T	CR	+		
S. loeselii	30	Eur SE, Asia C	H, T	CR	+		
Solidago canadensis	7	Am N	G, H	C	+		
S. gigantea	147	Am N	G, H	C		+	
Symphoricarpos albus	16	Am N	N	C		+	
Syringa vulgaris	19	Eur SE	N	C		+	
Tanacetum parthenium	5	Eur SE, Asia SW	H	C	+		
Telekia speciosa	1	Eur SE, Asia	H	C	+		
Trifolium patens	113	Eur S	T	-		+	
Typha laxmanii	1	Eur, Asia	H, Hy	-		+	
Veronica peregrina	1	Am N	T	-		+	
V. persica	229	Asia SW	T	CR	+		
Vicia dasycarpa	38	Eur S	T	CR	+		
V. grandiflora	3	Eur S, Asia SN	T	CR		+	
Xanthium albinum	3	Am N [S]	T	CR	+		
X. strumarium	1	Am S	T	CR	+		

Life forms (Raunkieur forms): Ch – chamaephyte, G – geophyte, H – hemicryptophyte, Hy – hydrophyte, li – liane, M – megaphanerophyte, N – nanophaneropyte, p – parasite, T – therophyte, Life strategy (Grime's strategy): C – competitors, R – ruderal, S – stress tolerator

Abstract

The synanthropisation of vegetation is presently a serious problem, both due to its impact on plant and animal diversity, as well as its significance through the impact on the global and local economy, both directly and indirectly. Understanding the mechanisms of new arrivals is one of the important aspects of many types of research. The presented paper concerns the analysis of selected features of kenophytes occurring on the Proszowice Plateau (Southern Poland). On the basis of long-term floristic studies, a list of kenophytes was selected. The list was subject to a detailed analysis of the frequency, origin, ecological numbers, life forms, and life strategies. The results indicate that perennial species with a CR life strategy have the greatest chance of expansion in the agricultural area, although the annual species with the C strategy predominate. Nowa-

days, 42 plant species (from 96 kenophytes of the Proszowice Plateau flora) are listed as invasive species in Poland.

Key words: flora, invasive species, kenophytes, life strategy, synanthropisation

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Występowanie gatunków obcego pochodzenia w krajobrazie rolniczym: na przykładzie Płaskowyżu Proszowickiego (Południowa Polska)

Streszczenie

Synantropizacja szaty roślinnej jest współcześnie poważnym problemem, zarówno z powodu wpływu na różnorodność roślin i zwierząt, jak również ma znaczenie poprzez oddziaływanie ekonomiczne na gospodarkę w wymiarze bezpośrednim i pośrednim. Poznanie mechanizmów wnikania nowych przybyszów jest jednym z ważnych aspektów badań nad inwazyjnością. Prezentowana praca dotyczy analizy wybranych cech kenofitów występujących na Płaskowyżu Proszowickim (Południowa Polska). Na podstawie długoletnich badań florystycznych wyłoniono listę kenofitów, którą poddano szczegółowej analizie względem częstości wystąpień, obszaru pochodzenia, liczb ekologicznych, form życiowych i strategii życiowych. Wyniki wskazują, że największe szanse ekspansji w terenie rolniczym mają gatunki wieloletnie o strategii życiowej CR, chociaż liczebnie przeważają gatunki jednoroczne o strategii C. Obecnie, 42 gatunki (spośród 96 kenofitów) występujące we florze Płaskowyżu Proszowickiego są wymienione jako inwazyjne we florze Polski.

Słowa kluczowe: flora, gatunki inwazyjne, kenofity, strategie życiowe, synantropizacja

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