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Southern European species in the flora of towns in the central Poland

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ABSTRACT: The aim of the study was to investigate the participation and conditions of occurrence of southern European species (with Mediterranean or Mediterranean-continental type of geographic range) in the synanthropic floras of major towns in central Poland. Investigations were conducted for 7 towns in the region (with population larger than 50 thousand inhabitants): Łódź, Piotrków Trybunalski, Tomaszów Mazowiecki, Zgierz, Pabianice, Bełchatów and Radomsko. They differ in size, history and dominant functions. Within the group of analysed towns, the largest is Łódź (760 thousand inhabitants) – city with the third largest population in Poland. In each of the towns, species connected with the Mediterranean area were analyzed with regard to their share and geographical-historical diversity against the background of entire synanthropic urban floras. A total of 142 southern European species were found to occur in the analysed towns (15% of their entire synanthropic flora and 30% in the flora of anthropophytes). The predominant group of species are non-naturalised anthropophytes (45%); a significant group is formed by archaeophytes (34%). The share of kenophytes is smaller (21%). In the individual towns, the number of southern European species varies from134 to 53. The share of southern European species in the flora varies from 12.2% to 16.4% for the total synanthropic flora and is the highest in Łódź i.e. the biggest city of the analyzed. The share of this group of species spreads differently among anthropophytes and metaphytes. In Łódź it is lower than in the other cities. Similarity analysis performed for entire grass floras and separately for geographical-historical groups in individual towns points to a very strong similarity between Łódź and Zgierz – two towns with a similar history and strong transport links.

Key words: urban flora, southern European plants, synanthropization, central Poland

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INTRODUCTION

The share of southern European species in the flora of Poland is small. Climate conditions and mountain chains of the Carpathians and Sudeten constitute a barrier for their northward spread from southern Europe. The native flora of Poland entirely lacks eumediterranean species (Pawłowska 1977). There are few submediterranean species as well. However, there is a larger share of species which have their centre of distribution in southern Europe among Polish anthropophytes. They constitute the vast majority not only of archaeophytes, but also kenophytes of European origin (Zając1979, Tokarska-Guzik 2005).

Changes in the geographical-historical structure of the flora are among the symptoms of anthropopressure which has a particularly considerable effect on the urban areas. Within urban territory, they lead to: formation of a flora with divergent structure from the one originally present (disturbance of natural floristic continuity in time), formation of the flora with the structure divergent from the one present in extra-urban areas (disturbance of floristic continuity in space), taxonomic, ecological and geographical uniformisation of floras in different urban areas (i.a. Wittig 1991, 2002, 2004, Jackowiak 1998, 2006, Sudnik-Wójcikowska 1998). According to the thesis presented by Jackowiak (1998), cities constitute a

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supra-regional spatial floristic system, the essence of which is the similarity of species composition of the spontaneous flora.

The aim of the study was to investigate the participation and conditions of occurrence of southern European species (with Mediterranean or Mediterranean-continental type of geographic range) in the synanthropic floras of major towns in central Poland. In each of the towns, species connected with the Mediterranean area were analyzed with regard to their share and geographical-historical diversity against the background of entire synanthropic urban floras (Bomanowska & Witosławski 2008).

MATERIALS AND METHODS

Diversity of southern European plants on synanthropic habitats in towns of central Poland was analyzed on the sample of 7 largest (with populations bigger than 50 thousand inhabitants) towns of the region: Łódź, Piotrków Trybunalski, Tomaszów Mazowiecki, Zgierz, Pabianice, Bełchatów and Radomsko (Fig. 1). The towns differ in size, history and dominant functions. The largest city within this group is Łódź (760 thousand inhabitants) with the third largest population in Poland. The selected towns, except for Tomaszów Mazowiecki, have been founded between the 14th and 18th century, but they came into being as urban centers as late as the 19th or even 20th century, thanks to the process of industrialisation which transformed them socially and economically as well as with regard to urban planning. An exception to this rule is Piotrków Trybunalski which belongs to the oldest and traditionally most significant population centers of the region. The towns under study presently differ from each other as for their size and dominant functions (Tab. 1). Zgierz and Pabianice are the main (beside Łódź) industry and services centres in the Łódź agglomeration, while Piotrków Trybunalski and Radomsko are major subregional centres of Łódź Voivodeship. Tomaszów Mazowiecki and Bełchatów have each a unique position – the former developed as an industrial centre, while the latter is a housing and service centre of the Bełchatów Industrial Region. Łódź is the regional capital of central Poland and is dominant over the remaining towns not only due to its size and number of inhabitants, but also due to the development of metropolitan functions (Koter *et al.* 2000).

Fig. 1. Location of the investigated towns in central Poland

The scope of analysis in the present study concerns the synanthropic floras of investigated towns. The complete list of vascular plant species was prepared based on floristic data derived from many years of own field studies as well as literature data (Bomanowska & Witosławski 2008 and literature quoted there). Because of differences in the scope of floristic studies at various locations, the analysis took into account only those species that occurred exclusively in synanthropic (ruderal and segetal) habitats, while data on occurrence of each species was encoded in a binary fashion (0-1, absent-present) without considering quantitative abundance.

The southern European plants species (with Mediterranean or Mediterranean-continental type of geographic range) were distinguished after data basis Phanart (Lindacher 1995) and Biolflor (Klotz *et al.* 2002).

The present study applies the mode of classification of the flora with regard to geographical-historical characteristics developed by Kornaś (1981) supplemented by Mirek (1981) and Jackowiak (1990). The status of anthropophytes was granted to those species which have no natural sites of occurrence in the central Poland. The extent of anthropophyte naturalisation was related to local conditions. In analysing the floristic composition, selected indicators of anthropogenic changes in the flora were applied (Tab. 2). Indicator values were calculated using the formulas suggested by Jackowiak (1990, 2006).

The expected share of species has been estimated basing on the formula (after Gotelli & Graves 1996):

$$E(s) = \frac{n \times m}{N}$$

where: n - the number of species in the flora of the object, m - the number of southern European species in all the objects, N - the general number of all the species in the objects

Table 1. Characteristic of cities taken under study of synanthropic floras (Bomanowska & Witosławski 2008, changed)

City	Total area [km^2]	Number of inhabitants [in thousands]	Time of bestowed of city rights	Dominant function
Łódź	294	767 600	XV	capital of voivodeship; regional center, metropolis function
Bełchatów	35	64 600	XVIII and again XX	capital of county; attentive and services functions
Pabianice	33	69 682	XIV	capital of county; industrial function
Piotrków Trybunalski	67.3	79 599	XIV	capital of county; industrial, attentive and services functions
Radomsko	51.4	50 399	XIII	capital of county; industrial function
Tomaszów Mazowiecki	41.3	67 159	XIX	capital of county; industrial function
Zgierz	42	58 400	XIII	capital of county; industrial, attentive and services functions

Source: Statistical Yearbook of the Republic of Poland 2007, Statistical Yearbook of Łódzkie Voivodship 2007, Koter et al. 2000; Liszewski 2001

Table 2. Indicators of anthropogenic changes in the flora (after Jackowiak 1990, 2006)

Indicator	Formula	
Indicators of anthropization (IAn_t – indicator of total anthropization, IAn_p – indicator of permanent anthropization)	$IAn_t = \frac{An}{Sp + An} \times 100\%$	$IAn_p = \frac{M}{Sp + Mt} \times 100\%$
Indicators of archaeophytization (IAr_t – indicator of total archaeophytization, IAr_p – indicator of permanent archaeophytization)	$IAr_t = \frac{Ar}{Sp + An} \times 100\%$	$IAr_p = \frac{Ar}{Sp + Mt} \times 100\%$
Indicators of kenophytization (IKn_t – indicator of total kenophytization, IKn_p – indicator of permanent kenophytization)	$IKn_t = \frac{Kn}{Sp + An} \times 100\%$	$IKn_p = \frac{Kn}{Sp + Mt} \times 100\%$
Indicator of modernization	$IM = \frac{Kn}{Mt} \times 100\%$	
Indicator of fluctuation changes	$IF = \frac{Df}{Sp + An} \times 100\%$	

Explanations: An – number of anthropophytes (alien species), Sp – number of spontaneophytes (native species), Mt – number of metaphytes (permanently established alien species), Ar – number of archaeophytes (established alien species introduced intentionally or unintentionally before 1500), Kn – number of kenophytes (alien species introduced intentionally or unintentionally after 1500), Df – number of diaphytes (established alien species not permanently established)

Similarity between synanthropic floras in individual towns was determined using the Jaccard similarity coefficient with object grouping by the unweighted pair group method (Dzwonko 2007).

RESULTS

Synanthropic floras of analysed cities include a total of 956 vascular plant species in this 142 of southern European species. Among southern European species only anthropophytes have occurred, including 78 metaphytes (30 kenophytes, 48 archaeophytes) and 64 diaphytes (Tab. 3, Tab. 4). The share of southern European species is 15% in whole synanthropic flora and 30% in the flora of anthropophytes of analysed towns. Therophytes (91 species) constitute a vast majority of the species in the life forms spectrum of southern European plants (Tab. 5).

Diversity of the southern European species considered against the diversity in the entire urban synanthropic flora has the following features:

- it has a relatively much higher value of indicators of total and permanent archaeophytisation (IAr_t and IAr_p), somewhat higher value of indicators of total and permanent kenophytisation (IKn_t and IKn_p), and, as a consequence, also a lower value of the indicator of modernisation (IM), moreover, it has a higher value of the indicator of fluctuation (IF; Tab. 4);
- it has a relatively much higher share of therophytes, lower share of phanerophytes, hemicryptophytes and geophytes (Tab. 5).

Unification of floras and species diversity. The southern European plants floras of investigated towns show a high degree of taxonomic uniformity As many as 27.4% species occur in all the towns (Tab. 6). Individual geographical-historical groups show varied degrees of uniformity as reflected by: the share of species that are common to the floras of all towns, the percentage presence of the total pool of species in individual towns and in similarity index values calculated for various pairs of urban floras.

The highest share of species that are common to all towns is shown by archaeophytes (54.4%), while the lowest shares are those of diaphytes (12.5%) and kenophytes (16.7%). Furthermore, the highest share of species occurring only in a single town is characteristic for diaphytes (31.3%), being much lower in other geographical-historical groups.

The actual percentage implementation of the entire species pool in the analysed floras for specific geographical-historical groups has the following minimal values: 64.6% – for archaeophytes, 33.3% – for kenophytes and 18.8% – for diaphytes (Tab. 7).

The values of Jaccard similarity coefficient calculated within individual geographical-historical groups between local floras of any two towns are never lower than: 0.689 – for archaeophytes; 0.333 – for kenophytes and 0.183 – for diaphytes.

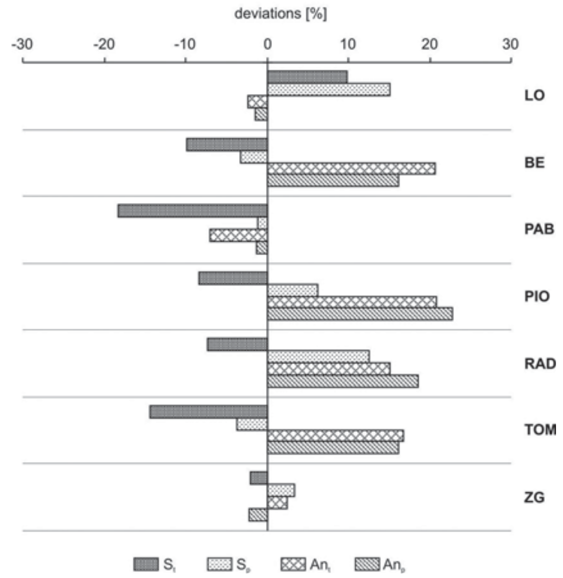

Fig. 2. Deviations in the observed number of species in the floras of the individual towns from the expected values for: total synanthropic flora (S_t), permanent synanthropic flora (S_p), total flora of anthropophytes (An_t), permanent flora of anthropophytes (An_p); LO, BE, PAB, PIO, RAD, TOM, ZG – see table 3

In the individual towns, the share of southern European species in the flora varies (Tab. 8): from 12.2% (Pabianice) to 16.4% (Łódź) for the entire synanthropic flora; from 27.6% (Pabianice) to 35.9% (Piotrków Trybunalski) - for the flora of anthropophytes; from 9.9% (Tomaszów Mazowiecki) to 11.8% (Łódź) for permanent synanthropic flora; from 21.1% (Zgierz) to 34.0% (Piotrków Trybunalski) for permanent flora of anthropophytes.

The highest number of species was recorded in Łódź (134 species) and in Zgierz (99), while the lowest number of species occurred in Radomsko (53 species). The differences between the observed and expected number of southern European species in the floras of the particular towns run differently as regards to the entire synanthropic flora, among anthropophytes, in the permanent synanthropic flora (including apophytes and metaphytes), and among permanent anthropophytes (metaphytes, Fig. 2). The number of southern European species is higher than expected: for the total synanthropic flora (only in Łódź), for the permanent synanthropic flora (in Łódź, Radomsko, Piotrków Trybunalski and Zgierz), for the flora including antropophytes only (in Piotrków Trybunalski, Bełchatów, Tomaszów Mazowiecki, Radomsko and Zgierz), for the permanent flora of antropophytes (in Piotrków Trybunalski, Radomsko, Tomaszów Mazowiecki and Bełchatów).

Similarity (cluster) analysis and classification conducted for entire floras and separately for geographical-historical

Table 3. List of southern European species occurring in synanthropic floras of largest towns in central Poland

Species	LO	BE	PAB	PIO	RAD	TOM	ZG	GHG	LF
Aesculus hippocastanum L.	+	+	+	+	+	+	+	Kn	M
Agrostemma githago L.	+	+	+		+	+	+	Ar	T, H
Alcea rosea L.	+	+	+	+		+	+	Df	H
Althaea officinalis L.	+							Df	H
Amaranthus lividus L.	+	+	+	+	+	+	+	Kn	T
Anchusa arvensis (L.) M. Bieb.	+	+	+	+	+	+	+	Ar	T, H
Anthemis arvensis L.	+	+	+	+	+	+	+	Ar	T
Anthemis cotula L.	+	+		+	+	+	+	Ar	T
Anthemis ruthenica M. Bieb.	+	+		+	+	+	+	Kn	T
Anthoxanthum aristatum Boiss.	+	+	+	+		+	+	Kn	T
Antirrhinum majus L.	+	+						Df	T, C
Aphanes arvensis L.	+	+	+	+	+	+	+	Ar	T
Aphanes inexspectata W. Lippert	+	+		+		+		Ar	T
Atriplex rosea L.	+							Ar	T
Avena sativa L.	+	+	+	+	+	+	+	Df	T
Ballota nigra L.	+	+	+	+	+	+	+	Ar	C, H
Barbarea intermedia Boreau	+							Kn	H
Beta vulgaris L.	+	+		+	+	+	+	Df	H
Borago officinalis L.	+						+	Df	T
Brassica napus L.	+	+	+	+	+	+	+	Df	T
Brassica nigra (L.) W. D. J. Koch	+		+	+		+		Kn	T
Brassica oleracea L.	+	+		+		+	+	Df	Ch
Brassica rapa L.	+		+	+		+	+	Kn	T
Briza maxima L.	+						+	Df	T
Bromus arvensis L.	+			+			+	Ar	T
Bryonia dioica Jacq.	+		+	+			+	Kn	H
Bunias orientalis L.	+		+	+	+	+	+	Kn	H
Calendula officinalis L.	+	+	+	+	+	+	+	Df	T
Carduus acanthoides L.	+	+	+	+	+	+	+	Ar	H
Carduus nutans L.	+					+		Ar	H
Centaurea cyanus L.	+	+	+	+	+	+	+	Ar	T
Cerastium tomentosum L.	+		+				+	Df	C
Chamomilla recutita (L.) Rauschert	+	+	+	+	+	+	+	Ar	T
Cheiranthus cheiri L.	+	+		+		+	+	Df	C
Chenopodium murale L.	+						+	Ar	T
Chenopodium opulifolium Schrad. ex W. D. J. Koch et Ziz.	+		+					Ar	T

Species	LO	BE	PAB	PIO	RAD	TOM	ZG	GHG	LF
Chenopodium vulvaria L.	+							Ar	T
Chrysanthemum segetum L.	+							Ar	T
Clematis vitalba L.	+		+				+	Kn	N, li
Colutea arborescens L.	+		+				+	Df	N
Consolida ajacis (L.) Schur	+	+	+	+	+	+	+	Df	T
Consolida regalis Gray	+	+	+	+	+	+	+	Ar	T
Coriandrum sativum L.	+							Df	T
Coronopus squamatus (Forssk.) Asch.	+			+			+	Ar	T
Cymbalaria muralis P. Gaertn., B. Mey. et Scherb.	+		+				+	Kn	C, H
Cynosurus echinatus L.	+						+	Df	H
Daucus carota L. subsp. *sativus* (Hoffm.) Arcang.	+	+		+		+		Df	H
Dianthus barbatus L.	+	+	+		+		+	Kn	T
Diplotaxis muralis (L.) DC.	+	+	+	+	+	+	+	Kn	T, H
Diplotaxis tenuifolia (L.) DC.	+		+				+	Kn	C, H
Dipsacus sativus (L.) Honck							+	Df	H
Echinops sphaerocephalus L.	+		+	+		+	+	Kn	H
Eragrostis minor Host	+		+	+	+	+	+	Kn	T
Euphorbia helioscopia L.	+	+	+	+	+	+	+	Ar	T
Euphorbia peplus L.	+	+	+		+		+	Ar	T
Foeniculum vulgare Mill.	+						+	Df	H, T
Fumaria officinalis L.	+	+	+	+	+	+	+	Ar	T
Galega officinalis L.	+							Kn	H
Galeopsis angustifolia (Ehrh.) Hoffm.	+		+			+	+	Kn	T
Galeopsis ladanum L.	+	+	+	+		+	+	Ar	T
Galium tricornutum Dandy			+					Ar	T
Geranium pyrenaicum Burm. f.	+			+		+		Kn	H
Glaucium corniculatum (L.) Rudolph	+						+	Df	T
Glaucium flavum Crantz	+						+	Df	T
Herniaria hirsuta L.	+	+		+		+	+	Ar	T, H
Hibiscus trionum L.	+						+	Df	T
Hordeum marinum Huds.	+							Df	T
Hyssopus officinalis L.	+						+	Kn	Ch
Iberis umbellata L.	+	+	+	+		+		Df	T
Lagurus ovatus L.	+						+	Df	T
Lamium purpureum L.	+	+	+	+	+	+	+	Ar	T, H
Lathyrus latifolius L.	+							Df	H
Leonurus cardiaca L.	+	+	+	+	+	+	+	Ar	H

Species	LO	BE	PAB	PIO	RAD	TOM	ZG	GHG	LF
Lepidium campestre (L.) R. Br.	+	+	+	+	+		+	Ar	T
Linum usitatissimum L.	+	+	+	+	+	+	+	Df	T
Lobularia maritima (L.) Desv.	+		+	+		+	+	Df	T, C
Lolium multiflorum Lam.	+	+	+	+	+	+	+	Kn	H, T
Lolium temulentum L.				+				Ar	T
Lunaria annua L.	+	+	+				+	Df	T, H
Lupinus angustifolius L.	+	+	+			+		Df	T
Lupinus luteus L.	+	+	+	+	+	+	+	Df	T
Lychnis coronaria (L.) Desv.	+						+	Df	H
Lycium barbarum L.	+		+				+	Kn	N
Malva alcea L. agg.	+	+	+			+	+	Kn	H
Malva mauritiana L.	+						+	Df	H
Malva sylvestris L.	+	+	+	+	+	+	+	Ar	H
Matthiola incana (L.) R. Br		+		+	+	+		Df	T
Matthiola longipetala (Vent.) DC. subsp. *bicornis* (Sibth. et Sm.) P. W. Ball	+						+	Df	T
Medicago arabica (L.) Huds.	+							Df	T
Medicago polymorpha L.	+						+	Df	T
Medicago rigidula (L.) All.	+							Df	T
Melandrium noctiflorum (L.) Fr.	+			+		+	+	Ar	T
Melissa officinalis L.	+		+				+	Df	H
Mentha x niliaca (Juss.) ex Jacq.	+						+	Kn	H
Narcissus poëticus L.	+							Df	G
Nigella damascena L.		+		+		+		Df	T
Nigella sativa L.							+	Df	T
Ornithogalum umbellatum L.	+	+		+	+	+	+	Kn	G
Ornithopus sativus Brot.	+	+	+	+	+	+	+	Df	T
Papaver dubium L.	+	+	+	+	+	+	+	Ar	T
Petroselinum crispum (Mill.) A. W. Hill	+	+		+		+		Df	H
Phalaris canariensis L.	+		+				+	Df	T
Phalaris paradoxa L. var. *praemosa* Cass.	+							Df	T
Philadelphus coronarius L.	+	+	+	+	+	+	+	Df	N
Physalis alkekengi L.	+						+	Kn	H
Polypogon monspeliensis (L.) Desf.	+						+	Df	T
Raphanus raphanistrum L.	+	+	+	+	+	+	+	Ar	T
Rapistrum perenne (L.) All.	+				+			Df	H
Salvia officinalis L.	+							Df	H
Salvia viridis L.	+						+	Df	T, H

Species	LO	BE	PAB	PIO	RAD	TOM	ZG	GHG	LF
Scleranthus annuus L.	+	+	+	+	+	+	+	Ar	T
Senecio vulgaris L.	+	+	+	+	+	+	+	Ar	H, T
Setaria italica (L.) P. Beauv.	+						+	Df	T
Silene armeria L.	+						+	Df	T
Silybum marianum (L.) Gaertner	+							Df	T, H
Sinapis arvensis L.	+	+	+	+	+	+	+	Ar	T
Sisymbrium officinale (L.) Scop.	+	+	+	+	+	+	+	Ar	T
Sisymbrium orientale L.	+							Df	T
Sisymbrium wolgense M. Bieb. ex E. Fourn.	+						+	Kn	H
Sonchus asper (L.) Hill	+	+	+	+	+	+	+	Ar	T
Sonchus oleraceus L.	+	+	+	+	+	+	+	Ar	H, T
Spergula arvensis L.	+	+	+	+	+	+	+	Ar	T
Stachys annua (L.) L.	+					+	+	Ar	T
Stachys byzantina K. Koch	+							Df	H
Tanacetum parthenium (L.) Sch. Bib.	+	+	+	+	+	+	+	Kn	H
Trifolium angustifolium L.	+							Df	T
Trifolium hirtum All.	+							Df	T
Trifolium incarnatum L.						+		Df	T, H
Trifolium resupinatum L.	+	+	+	+		+	+	Df	H, T
Urtica urens L.	+	+	+	+	+	+	+	Ar	T
Valerianella dentata (L.) Pollich	+		+	+		+		Ar	T
Valerianella rimosa Bastard				+				Ar	T
Veronica agrestis L.	+		+	+	+	+		Ar	T
Vicia dasycarpa Ten.	+	+		+		+	+	Kn	T
Vicia grandiflora Scop.	+	+		+		+		Kn	T
Vicia hirsuta (L.) S. F. Gray	+	+	+	+	+	+	+	Ar	T
Vicia lutea L.	+							Df	T
Vicia tetrasperma (L.) Schreb.	+	+	+	+	+	+	+	Ar	T
Vicia villosa Roth	+	+	+	+	+	+	+	Ar	T, H
Vitis vinifera L.	+	+		+	+	+		Df	N, li
Vulpia bromoides (L.) S. F. Gray	+							Df	H, T
Vulpia myuros (L.) C. C. Gmelin	+							Df	H, T

Explanations: LO – Łódź, BE – Bełchatów, PAB – Pabianice, PIO – Piotrków Trybunalski, RAD – Radomsko, TOM – Tomaszów Mazowiecki, ZG – Zgierz; GHG – geographical-historical group: Ar – archaeophyte, Kn – kenophyte, Df – diaphyte; LF – life form: M – megaphanerophyte, N – nanophanerophyte, Ch – woody chamaephyte, C – herbaceous chamaephyte, H – hemicryptophyte, G – geophyte, T – therophyte, li – liana

Table 4. Indicators of anthropogenic changes in the entire southern European plants flora of largest towns in central Poland

Indicator	Value	Difference
IAn_t	100,0	49,9
IAn_p	100,0	62,8
IAr_t	33,8	21,3
IAr_p	61,5	45,8
IKn_t	21,1	4,0
IKn_p	38,5	17,0
IM	38,5	-19,3
IF	45,1	24,5

Explanations: IAn_t – indicator of total anthropization, IAn_p – indicator of permanent anthropization, IAr_t – indicator of total archaeophytization, IAr_p – indicator of permanent archaeophytization, IKn_t – indicator of total kenophytization, IKn_p – indicator of permanent kenophytization, WM – indicator of modernization, WF – indicator of fluctuation, Value – real value of indicator, Difference – difference in value between indicator of anthropogenic changes in the southern European plants flora and the entire synanthropic flora

Table 5. The life forms in the entire southern European plants flora of largest towns in central Poland

Life form	No.	%	$Diff_S$	$Diff_{An}$
Phanerophytes	6	4.2	-7.8	-8.5
Chamaephytes	7	4.9	0.6	2.0
Hemicryptophytes	36	25.4	-15.6	-0.8
Geophytes	2	1.4	-6.6	-5.1
Therophytes	91	64.1	29.4	12.4
Total	142	100.0	-	-

Explanations: No. - number of species; $Diff_S$ - differences between the share of life forms in the southern European plants flora and the synanthropic flora $Diff_{An}$ - differences between the share of life forms in the southern European plants flora and the flora of anthropophytes

Table 6. Frequency of southern European species of largest towns in central Poland

Number of cities	1*		2		3		4		5		6		7		TOTAL	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Archaeophytes	6	12.4	3	6.2	3	6.2	3	6.2	3	6.2	4	8.4	26	54.4	48	100.0
Kenophytes	2	6.6	4	13.3	5	16.7	4	13.3	5	16.7	5	16.7	5	16.7	30	100.0
Diaphytes	20	31.3	18	28.1	5	7.8	5	7.8	5	7.8	3	4.7	8	12.5	64	100.0
TOTAL	28	19.7	25	17.5	13	9.2	12	8.5	13	9.2	12	8.5	39	27.4	142	100.0

Explanations: 1, 2 …7 – number of sites (towns) in which species occurs, 1* – species occurring only in one site (species specific to one town), 2 – species occurring in two sites, … 7 – species occurring in all sites (species common to all towns)

Table 7. Realization of pools of species belonging to different geographical-historical groups in the southern European plants floras in individual towns

Geographical-historical group	LO	BE	PAB	PIO	RAD	TOM	ZG
Archaeophytes	93.8	68.8	70.8	79.2	64.6	75.0	77.1
Kenophytes	100.0	40.0	63.3	56.7	33.3	60.0	83.3
Diaphytes	92.2	34.4	28.1	31.3	18.8	34.4	57.8
Total flora	94.4	47.2	50.0	52.8	37.3	53.5	69.7

Explanations: LO, BE, PAB, PIO, RAD, TOM, ZG – see table 3

Table 8. The number and share of southern European plants species belonging to different geographical-historical groups in the floras of individual towns

	Geographical-historical group	LO	BE	PAB	PIO	RAD	TOM	ZG
No.	Metaphytes	75	45	53	55	41	54	62
	Kenophytes	30	12	19	17	10	18	25
	Archaeophytes	45	33	34	38	31	36	37
	Diaphytes	59	22	18	20	12	22	37
	TOTAL	134	67	71	75	53	76	99
% S_t	Metaphytes	9.2	9,0	9.1	10,0	10.7	9,0	9.1
	Archaeophytes	5.5	6.6	5.8	6.9	8.1	6,0	5.4
	Kenophytes	3.7	2.4	3.3	3.1	2.6	3,0	3.7
	Diaphytes	7.2	4.4	3.1	3.6	3.1	3.7	5.4
	TOTAL	16.4	13.4	12.2	13.6	13.8	12.7	14.5
% S_p	Archaeophytes	7.1	7.3	6.5	7.6	8.8	6.6	6.3
	Kenophytes	4.7	2.7	3.6	3.4	2.8	3.3	4.3
	TOTAL	11.8	10,0	10.1	11,0	11.6	9.9	10.6
% An_t	Metaphytes	16.2	24,0	20.6	26.3	26.5	24.6	19.1
	Archaeophytes	9.7	17.6	13.2	18.2	20,0	16.4	11.4
	Kenophytes	6.5	6.4	7.4	8.1	6.5	8.2	7.7
	Diaphytes	12.8	11.8	7.0	9.6	7.7	10,0	11.4
	TOTAL	29,0	35.8	27.6	35.9	34.2	34.6	30.5
% An_p	Archaeophytes	16.4	23.6	17.5	23.5	24.8	21.4	16.2
	Kenophytes	10.9	8.6	9.8	10.5	8,0	10.7	10.9
	TOTAL	27.3	32.2	27.3	34.0	32.8	32.1	27.1

Explanations: No. - number of species; % S_t – share in total synanthropic flora; % S_p – share in permanent synanthropic flora (apophytes+metaphytes), % An_t – share in total flora of anthropophytes, % - permanent flora of anthropophytes (metaphytes); LO, BE, PAB, PIO, RAD, TOM, ZG – see table 3

Table 9. Value of indicators of anthropogenic changes in the southern European plants floras in individual towns

Indicator	LO	BE	PAB	PIO	RAD	TOM	ZG
IAn_t	100.0	100.0	100.0	100.0	100.0	100.0	100.0
IAn_p	100.0	100.0	100.0	100.0	100.0	100.0	100.0
IAr_t	33.6	49.3	47.9	50.7	58.5	47.4	37.4
IAr_p	60.0	73.3	64.2	69.1	75.6	66.7	59.7
IKn_t	22.4	17.9	26.8	22.7	18.9	23.7	25.3
IKn_p	40.0	26.7	35.8	30.9	24.4	33.3	40.3
IM	40.0	26.7	35.8	30.9	24.4	33.3	40.3
IF	44.0	32.8	25.4	26.7	22.6	28.9	37.4

Explanations: see table 3 and 4

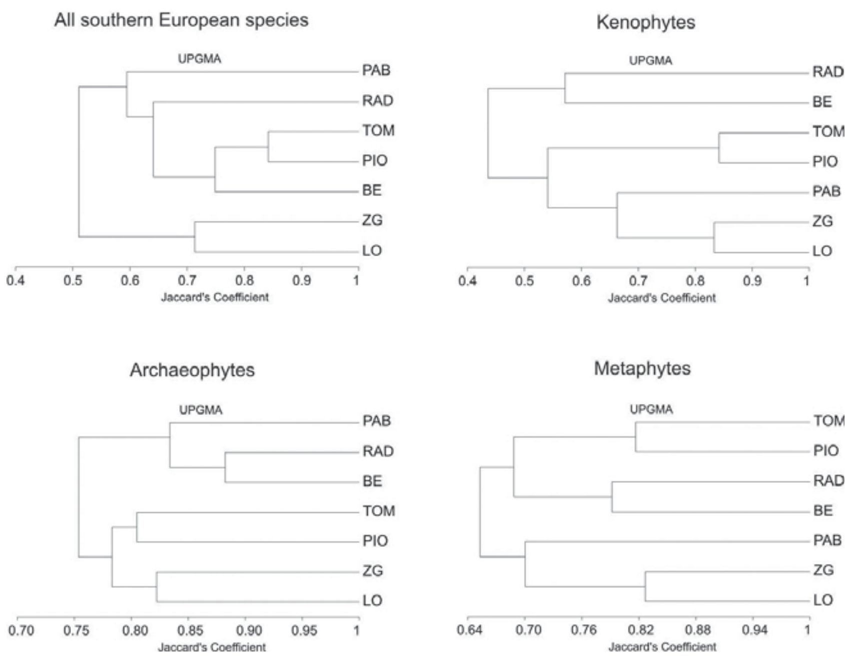

Fig. 3. Similarity of southern European plants flora of largest towns in central Poland measured by Jaccard coefficient; LO, BE, PAB, PIO, RAD, TOM, ZG – see table 3

groups in individual cities has always led to the distinction of two groups of objects: the first one is always composed of the territorially neighbouring Łódź and Zgierz; the other one of Bełchatów, Piotrków Trybunalski, Tomaszów Mazowiecki, Radomsko and Pabianice. Is has, however, to be stressed that classification of cities with regard to archaeophytes is based on significantly smaller differences in similarities than in the case of remaining geographical-historical groups (Fig. 3).

Anthropogenic structure of the southern European species floras in individual towns has been characterised using relevant indicator values based on the share of geographical-historical groups in flora (Tab. 9). In all investigated towns, archaeophytes dominate over kenophytes, as reflected in the indicator values of modernization of flora (IM). The highest share of archaeophytes (IAr_t and IAr_p) is displayed by the floras of Piotrków Trybunalski, Radomsko and Bełchatów, with only slightly lower values in the floras of Tomaszów Mazowiecki i Pabianice. The highest share of kenophytes (IKn_t and IKn_p) is characteristic for southern European floras in Zgierz, Łódź and Pabianice, i.e. in the adjacent towns closely connected by structural and functional links and actually forming a common urban centre.

The highest share of diaphytes (measured by IF) is strongly visible in Łódź where they are by 1/3 more numerous than in Zgierz and more than twice so than in any other town within the study.

Deviations of the observed values of anthropogenic transformation indexes from expected values are similar to the classification of towns with regard to their floristic similarity: (i) Łódź is distinguished from remaining towns by the lower than expected value of IAr_t; (ii) Łódź and Zgierz are distinguished from remaining towns by the lower than expected value of IAr_p, and the higher than expected value of IM (Fig. 4).

DISCUSSION

Among the effects of human impingement on the flora are the exchange of the species between the regions separated by biogeographical barriers and activating the selection that prefers the species of foreign origin showing the characteristics that facilitate new territorial occupancy (Jackowiak 1999). Foreign species undergo twofold selection. The first kind is constituted by the climactic factors, the second by the biotic ones, mainly represented by competition. The impact of the climactic factors is visible in the fact that the species that manage to settle permanently originate from the areas of the climate similar to the one of the new habitat. The exception is a considerable share of southern European species in the flora of the middle Europe. Those plants are mainly therophytes that originally go through their developmental cycle during the spring. In the middle Europe their vegetation season is shifted towards the summer when the weather corresponds to the Mediterranean spring (Kornaś 1981) The spectrum of life forms of the southern European species in the analyzed flora display a considerable share of therophytes. The characteristics shown by this group of plants prove

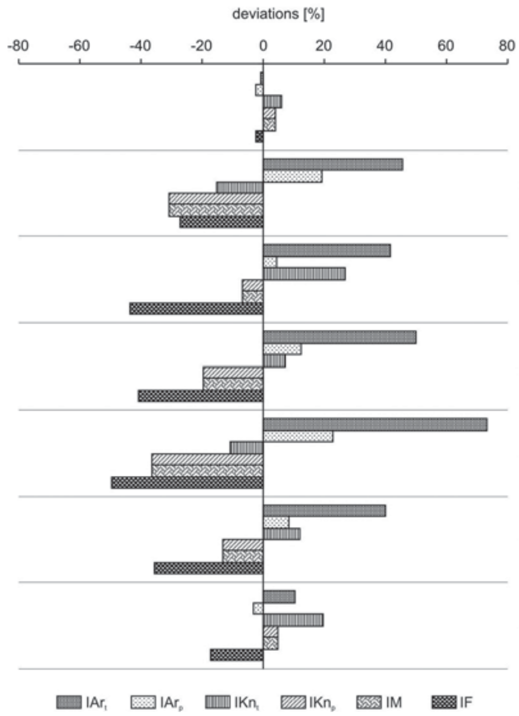

Fig. 4. Deviations in the observed values of anthropogenic transformation indexes in the floras of the individual towns from the expected values; IA_{rt}, IA_{rp}, IK_{nt}, IK_{np}, IM, IF – see table 4; LO, BE, PAB, PIO, RAD, TOM, ZG – see table 3

to be particularly useful in the process of spreading of synanthropic species on the new areas (Bazzaz 1986, Noble 1989, Pyšek 1993, Roy 1990, Jackowiak 1998).

The southern European anthropophytes living in the research area belong chiefly to archaeophytes, whereas kenophytes are definitely less numerous. Therefore, those species present in the investigated cities are mostly connected with their first influx received from the Neolithic until late 19th Century. Later adventives usually come from different that southern European geographical areas. The above geographical-historical picture of floristic diversity in the southern European species is characteristic for the entire Polish flora (Zając 1979, Tokarska-Guzik 2005).

Variability of the number of southern European species as well as richness of their complete floras occurring in the particular cities is determined mostly by their functional divergence and, accordingly, it implies heterogeneity of habitats. The positive impact of habitat diversity and moderately strong anthropogenic disturbances on the increase of floristic richness of urban areas has been addressed i.a. by Peet *et al.* (1983), Kowarik (1988), Sudnik-Wójcikowska (1998), Pyšek (1993, 1998a), Jackowiak (1998), Roy *et al.* (1999); Wołkowycki (2000), Kim *et al.* (2002), Kühn *et al.* (2004). It seems that these particular factors influence the following observations:

- the high and relatively similar richness of floras in Łódź and Zgierz – cities which have a several-fold difference in area and more than ten-fold difference in the number of inhabitants;
- small differences in floristic richness between Tomaszów Mazowiecki, Piotrków Trybunalski and Pabianice which are cities of different size and number of inhabitants, but have similar functional diversity;
- relative floristic poverty of Bełchatów which constitutes mainly a social backdrop and living quarters for employees of the nearby mine and power plant.

However, basing on these precepts it is difficult to explain the relative poverty of the flora of Radomsko, albeit the smallest town among those analysed, but still one with diversified functions.

The share of southern European species in the complete floras cities in central Poland, their geographical-historical and biological diversity does not differ from the one observed in another local Polish floras (i.a. Krawiecowa & Rostański 1976, Kornaś 1977 and literature quoted there, Sudnik-Wójcikowska 1991, 1998, Wittig 1991, 2002, 2004, Wołkowycki 2000). Just as expected, the share of southern European species in the complete flora is the biggest in Łódź, i.e. the largest city among analyzed. By contrast, the share of this group of species spreads differently among anthropophytes and methaphytes. In Łódź it is smaller than in the majority of other cities. A decrease in the share of southern European species may stem from the growing influx of diaspore of foreign species, due to the relatively stronger transportation bonds and developing industrialization and also the decrease of significance of archaeophytes of which southern European species constitute a substantial group and increase of significance of kenophytes in which the share of southern European species is considerably lower. The floras of small towns encompass relatively small number of kenophytes and diaphytes which additionally originate from different than southern European species geographical areas (Krawiecowa & Rostański 1976, Kornaś 1977, Kowarik 1990, 1995, Jackowiak 1998, Sudnik-Wójcikowska 1991, 1998), among others has been drawing attention to the changes in the relationship between archaeophytes and kenophytes with regard to the size of the urban centre.

The degree of uniformity of the local floras encompassing southern European species in the individual cities develops differently among kenophytes and archaeophytes. The varying degree of unification of local floras in separate geographical-historical groups is the expression of: natural conditions, time which have passed since their naturalisation, their biology and mode of dispersal (Bazzaz 1986, Noble 1989, Pyšek 1993, Roy 1990, Wołkowycki 2000, Bomanowska & Witosławski 2008).

High uniformity of local archaeophyte floras originates from the characteristics of their spreading, their long period of naturalisation and the source of dispersal. Archaeophytes spread in segetal habitats by diffusion, therefore there are currently no significant environmental barriers which would isolate individual cities in this regard. It is of no significance for the eventual uniformity of archaeophyte floras that nearly all studied cities (except Piotrków Trybunalski) adopted urban characteristics no sooner than during the first half of the 19^{th} century, while earlier, despite having city rights, they were in fact rural centres isolated by forests and segetal species from surrounding fields contributed to their ruderal floras – also predominantly archaeophytes. They lost their isolated character to a large extent only in the first half of the 19^{th} century with the transformation of urban function, development of transport pathways, increase in goods trade and above all the increase of area of agriculturally utilised land. It may thus be presumed that local fields and fallows were initially the main source of diaspores for the settlement of ruderal habitats in the cities, and with time they became corridors which facilitated the migration of species. The late loss of isolation of individual cities was of no significance for preservation of separate character of archaeophyte floras in view of high saturation of archaeophytes from respective neighbouring agricultural areas.

Kenophytes appeared in larger numbers only with the development of industry in the first half of the 19^{th} century and with the concurrent functional transformations in the individual cities. The relatively small uniformisation of local kenophyte floras results from different than in the case of archaeophytes secondary sources of dispersal (located within individual cities) and from the stronger isolation of separate centres with regard to this group of plants. As opposed to archaeophytes, for the most of kenophytes the arable fields connecting cities are environmental barriers which may be surmounted only by leaps.

The observed relations between floristic unification and geographical-historical affiliation of species, as well as the resulting conclusions, find corroboration in studies on ruderal floras in north-east Poland (Wołkowycki 2000).

The present state of anthropogenic diversity in the southern European species in the analysed towns is mainly related to their modern social and economic development: population size, level of industrialisation, spatial and functional links. Geographical-historical diversity of the southern European floras in individual towns in central Poland reflect the observed tendencies as recorded in the floras of towns of various size in other areas of Central Europe (Krawiecowa & Rostański 1976, Kornaś 1977, Kowarik 1995, Jackowiak 1998, Pyšek 1998 b, Sudnik-Wójcikowska 1998).

CONCLUSIONS

Conducted studies confirmed the thesis that towns constitute a supra-regional spatial floristic system, the essence of which is the similarity of species composition of the spontaneous flora.

The southern European species floras of the largest towns in central Poland, despite their detectable taxonomic and geographical-historical distinctness, display conspicuous similarity.

Łódź occupies a special position among the compared cities. This city is distinguished from the remaining cities of the region by the higher number of inhabitants, total area, built-up area and level of industrialisation. These differences are reflected in the structure of the flora.

REFERENCES

Bazzaz FA. 1986. Life history of colonizing plants: some demographic genetic and physiological features. In: Mooney HA & Drake JA (eds.), Ecology of biological invasions of North America and Hawaii. Ecological Studies, pp. 96-110. Springer Verlag, New York.

Bomanowska A & Witosławski P. 2008. Selected aspects of diversity of synanthropic flora in selected cities of central Poland. *Biodiv. Res. Conserv*. **9**: 36-42.

Dzwonko Z. 2007. Przewodnik do badań fito-socjologicznych. Instytut Botaniki Uniw. Jagiellońskiego, Wyd. Sorus. Poznań – Kraków.

Gotelli NJ & Graves G R.1996. Null models in ecology. Smithsonian Institution Press, Washington, London.

Jackowiak B. 1990. Antropogeniczne przemiany flory roślin naczyniowych Poznania. *Wyd. Naukowe Uniwersytetu A. Mickiewicza w Poznaniu*, ser. Biol. **42**: 1-208.

Jackowiak B. 1998. Struktura przestrzenna flory dużego miasta. Studium metodyczno-problemowe. *Prace Zakładu Taksonomii Roślin Uniwersytetu im. A. Mickiewicza w Poznaniu* **8**: 1-228.

Jackowiak B. 2006. Methodological proposals for studies on the structure and dynamics of urban flora. *Pol. Bot. Stud*. **22**: 251-260.

Kim Y-M, Zerbe S & Kowarik I. 2002. Human impact on flora and habitats in Korean rural settlements. *Preslia* **74**: 409-419.

Klotz S, Kühn I & Durka W. 2002. Biolflor – Eine Datenbank mit biologisch-ökologischen Merkmalen zur Flora von Deutschland. Landwirtschaftsverlag, Bundesamt für Naturschutz. Schriftenreihe für Vegetationskunde. Bd. 38.

Kornaś J. 1977. Analiza flor synantropijnych. *Wiad. Bot*. **21**: 85-91.

Kornaś J. 1981. Oddziaływanie człowieka na florę: mechanizmy i konsekwencje. *Wiad. Bot.* **25**: 165-182.

Koter M, Liszewski S & Suliborski A. 2000. Łódź i region Polski Środkowej. Łódzkie Towarzystwo Naukowe, Łódź.

Kowarik I. 1988. Zum menschlichen Einfluss auf Flora und Vegetation. Theoretische Konzepte und ein Quantifizierungssansatz am Beispiel von Berlin (West). Landschaftsentw. u. Umweltforsch. TU Berlin **56**: 1-280.

Kowarik I. 1990. Some responses of flora and vegetation to urbanization in central Europe. In: Sukopp H, Hejny S & Kowarik I (eds.), Urban ecology: plants and plant communities in urban environments, pp. 45-74. SPB Academic Publ.

Kowarik I. 1995. On the role of alien species in urban flora and vegetation In: Pyšek P, Prach K, Rejmánek M & Wade M (eds.), Plant invasions: general aspects and special problems, pp. 85-103. SPB Academic Publ.

Krawiecowa A & Rostański K. 1976. Zależność flory synantropijnej wybranych miast polskich od ich warunków przyrodniczych i rozwoju. *Acta Univ. Wratisl.*, Pr. Bot. **21**: 5-61.

Kühn I., Brandl R. & Klotz S. 2004. The flora of German cities is naturally species rich. *Evol. Ecol. Res.* **6**: 749-764.

Lindacher R. (ed.) 1995. Phanart. Datenbank der Gefässpflanzen Mitteleuropas, Erklarung der Kennzahlen, Aufbau und Inhalt (Phanart, Database of Centraleuropean Vascular Plants, Explanation of codes, Structure and Contents). *Veröffentlichungen Geobotanischen Institut der ETH Stiftung Rubel* **125**: 1-436.

Liszewski S. (ed.). 2001. Zarys monografii województwa łódzkiego. Łódzkie Towarzystwo Naukowe, Łódź.

Mirek Z. 1981. Problemy klasyfikacji roślin synantropijnych. *Wiad. Bot.* **25**: 45-54.

Noble IR 1989. Attributes of invaders and the invading process: terrestrial and vascular plants. In: Drake JA, Mooney HA, di Castri F, Groves RH, Kruger FJ, Rejmánek M & Williamson M (eds.), Biological invasions: a global perspective, pp. 301-313. SCOPE 37. John Wiley and Sons Ltd., Chichester.

Pawłowska S. 1977. Charakterystyka statystyczna i elementy flory polskiej. In: Szafer W. & Zarzycki K. (eds.), Szata roślinna Polski **1**, pp. 129-206. PWN, Warszawa.

Peet RK, Gleen-Lewin DC & Walker-Wolf J. 1983. Prediction of man's impact on plant species diversity. In: Holzner W, Werger MJA & Ikusima I (eds.), Man's impact on vegetation, pp. 41-54. Dr W. Junk Publishing, the Hague, Boston, London.

Pyšek P. 1993. Factors affecting the diversity of flora and vegetation in Central European settlements. *Vegetatio* **106**: 89-100.

Pyšek P. 1998a. Alien plants in Czech village flora: an analysis of species numbers. *Feddes Repert.* **109**: 139-146.

Pyšek P. 1998b. Alien and native species in Central European urban floras: a quantitative comparision. *J. Biogeogr*. **25**: 155-163.

Roy J. 1990. In search of the characteristics of plant invaders. In: di Castri F, Hansen AJ & Debussche M (eds.), Biological invasions in Europe and Mediterranean Basin, pp. 335-352. Kluwer Academic Publishing, Dordrecht.

Roy DB, Hill MO & Rothery P. 1999. Effects of urban land cover on the local species pool in Britain. *Ecography* **22**: 507-515.

Sudnik-Wójcikowska B. 1991. Synanthropization indices of urban floras – an attempt at definition and assessment. *Acta Soc. Bot. Pol.* **60**: 163-185.

Sudnik-Wójcikowska B. 1998. Czasowe i przestrzenne aspekty procesu synantropizacji flory na przykładzie wybranych miast Europy Środkowej. Wydawnictwo Uniwersytetu Warszawskiego, Warszawa.

Tokarska-Guzik B. 2005. The establishment and spread of alien plant species (kenophytes) in the flora of Poland. Wydawnictwo Uniwersytetu Śląskiego, Katowice.

Wittig R. 1991. Ökologie der Großstadtflora. Gustav Fischer Verlag. Stuttgart.

Wittig R. 2002. Siedlungsvegetation. Verlag Eugen Ulmer, Stuttgart.

Wittig R. 2004. The origin and development of the urban flora of Central Europe. *Urban Ecosystems* **7**: 323–339.

Wołkowycki D. 2000. Różnicowanie i ujednolicanie się flor ruderalnych w warunkach izolacji środowiskowej. *Monogr. Bot*. **87**: 1-157.

Zając A. 1979. Pochodzenie archeofitów występujących w Polsce. *Rozprawy habilitacyjne Uniwersytetu Jagiellońskiego* **29**: 1–213.

REZIME

Južno-evropske vrste u flori gradova centralne Poljske

Piotr Witosławski, Anna Bomanowska

Cilj ovog rada bio je da se istraži prisustvo i uslovi pojavljivanja južno-evropskih vrsta (sa mediteranskim ili mediteransko-kontinentalnim tipom rasprostranjenja) u sinantropnoj flori većih gradova u centralnoj Poljskoj. Istraživanja su vršena u 7 gradova (sa populacijom od preko 50.000 stanovnika) i to: Łódź, Piotrków Trybunalski, Tomaszów Mazowiecki, Zgierz, Pabianice, Bełchatów i Radomsko. Oni se razlikuju po veličini, istoriji i dominantnim aktivnostima u okviru njih. Medju ispitivanim gradovima, največi je Łódź (760.000 stanovnika) – ujedno i treći po veličini grad u Poljskoj.

U svakom od gradova, vrste vezane za područje Mediterana su analizirane u odnosu na čitavu sinantropnu urbanu floru. Ukupno je zabeleženo 142 južno-evropske vrste u istraživanim gradovima (što je oko 15% čitave sinantropne flore i oko 30% antropofita).

Dominantna grupa su ne-naturalizovane antropofite (45%); a značajna je i grupa arheofita (34%). Udeo kenofita je manji (21%). U pojedinačnim gradovima broj južno-evropskih vrsta varira od 134 to 53, a njihov udeo od 12.2% do 16.4% ukupne sinantropne flore i najviši je u gradu Łódź koji je i najvceći analizirani grad. Udeo ove grupe varira nejednako medju antropofitama i metafitama. U gradu Łódź on je manji nego u drugim gradovima. Analiza sličnosti povezuje Łódź i Zgierz – dva grada sa sličnom istorijom I jakim transportnim vezama.

Ključne reči: urbana flora, južno-evropske biljke, sinantropizacija, centralna Poljska