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Alien plants in field margins and fields of southwestern Poland

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Abstract: Field margins are generally considered as important semi-natural habitats in intensive agricultural landscapes. Also, they are areas of regular and extensive disturbance by anthropogenic factors. As such, field margins are likely to be dominated by alien plants, including invasive species. This paper examines the relative abundance of alien and native plant species occurring in seventy field margins and adjacent crop fields in SW Poland, as well as the mutual relationship between different groups of alien species. Anthropophytes constituted 22.5% of the 435 vascular plants recorded in 1319 phytosociological relevés. They were twice as abudant in crop fields than in field margins. Most of the alien species identified were archaeophytes, the percentage of neophytes was much lower, and ergasiophygophytes were found sporadically. Archaeophytes were substantially more frequent in the peripheral (adjacent to crop fields) zones of the margins than in their interior. This suggests the direction in which these species disperse - from cultivated fields to field margins. Neophytes were more evenly distributed throughout the various zones. Only six alien species (all of them archaeophytes) recorded in the relevés are considered endangered in the studied region. The habitats examined were also only slightly colonized by the most invasive alien species. This suggests that plant communities of the field margins are still resistant to invasion. Results indicate, that field margins play only a minor role in the distribution and dispersion of alien species and are far more important reservoir of native plants. Although low number of plant species of special conservation value was located in field margins, they should deserve special protection in intensive agro-ecosystems because they harbour a suite of plants not found in other farmland habitats.

Key words: field margins, archaeophytes, neophytes, invasive alien plants, arable weeds

CHOROLOGY AND ECOLOGY

1. Introduction

Anthropophytes are alien plant species that have become naturalized in a given area as a result of either prehistoric human migration or later human activity. Hence, the local floras may include many cosmopolitan species from different parts of the world. Anthropophytes can be divided into two basic groups, depending on when they first colonized the area in question: archaeophytes and neophytes *sensu* Thellung (1915, 1918/1919), Savulescu (1927) and Meusel (1943 after Sudnik-Wójcikowska & Koźniewska 1988). Neophytes are also called kenophytes (Kornaś 1968). There has recently been a great deal of interest in the relationships between native and alien species, as well as in the spread of invasive alien species (e.g. Callaway & Aschehoug 2000; Houlahan & Findlay 2004; Rodriguez 2006; Tokarska-Guzik 2005; Hulme 2007; Theoharides & Dukes 2007; Lambdon *et al*. 2008). Another problem is the mutual relationship between different groups of alien species in areas outside their natural ranges.

Studies on archaeophytes that have been carried out in agricultural areas have mainly focused on cultivated fields. There have been many studies of this kind in Poland, as attested by a recently published three-volume bibliography (Jackowiak & Latowski 1996; Latowski & Jackowiak 2001, 2006), while a much smaller number of studies have focused on other habitats in agricultural areas, such as ponds and woodlots adjacent to cultivated fields (Koc & Polakowski 1990; Dąbrowska-Prot 1991; Loster 1991; Wójcik & Wasiłowska 1994; Ratyńska & Szwed 1998; Ratyńska 2003a). These semi-natural habitats are of great importance to the diversity of various groups of organisms in agricultural areas (Stuchlikowa 1979; Olaczek 1990; Loster & Dubiel 1985; Loster 1991; Chmielewski & Węgorek 2003; Karg 2004; Kujawa 2006). Nevertheless, no study has been carried out to date on the distribution of both archaeophytes and neophytes in the most common form of semi-natural habitats which are field margins. Greaves & Marshall (1987) defined field margin as the whole of the crop edge, any margin strip present and the semi-natural habitat associated with the boundary, such as a hedge, grass bank, or ditch. For the purpose of the present study we adopted this definition, however: (*i*) in the studied farmland do not exist margin strips managed for conservation such as a sown wild flower strips, set-aside margins, conservation headland or beetle banks (see Marshall & Moonen 2002 for detailsBRC); (*ii*) to compare the anthropophytes composition in cultivated and non-cultivated parts of the margin, we separated data collected in the seminatural habitat (= field margin) and in the crop edge (= crop, cultivated field).

The aims of the present study were as follows:

- to discuss the relative abundance of anthropophytes in the present-day vegetation of field margins, comparing the relative abundances of archaeophytes and neophytes;
- to compare the species composition of the anthropophyte component in field margins and adjacent cultivated fields;
- to determine the distribution of anthropophytes in various zones of field margins; and
- to determine whether field margins serve as a haven for endangered anthropophytes or as a reservoir from which invasive species can spread.

2. Material and methods

Field studies in agricultural areas of the Sudetic Foreland (Fig. 1) were carried out during the growing season from 2004 to 2007. 70 sites were included in the study, i.e. marked out 500 m long sections of separate field margins. The sites represented strips of vegetation adjacent to cultivated fields, escarpments, stream banks, ditches, rural roads and abandoned railroad tracks. They ranged in width from 4.9 to 29 meters, with an average value of 11.7 m. In the present study, the crop types adjacent to field margins were representative for the Sudetic Foreland as a whole. The main crops currently cultivated in the region are wheat, maize, rye and oilseed rape (Table 1).

Table 1. Crops represented in the collected samples

Cultivated plant	No of samples (relevés)	Percentage of samples
Triticum aestivum	152	39.9
Zea mays	77	20.2
Hordeum vulgare	66	17.3
Brassica napus	60	15.7
Beta vulgaris	12	3.1
Secale cereale	5	1.3
Avena sativa	4	1.0
Solanum tuberosum	3	0.8
Fragaria ×ananassa	1	0.3
Phaseolus vulgaris	1	0.3

The studied strips consisted of distinct vegetation zones that were designated as follows: D – field track (roads and paths); K – shrub zone; L – tree zone; Z – herbaceous zone on slopes, berms and crop edges (Fig. 2); O – marginal verges and R – riparian zone. Data were also collected in the areas immediately adjacent to the sites, including: U – cultivated fields; and Tm – fallow fields and meadows.

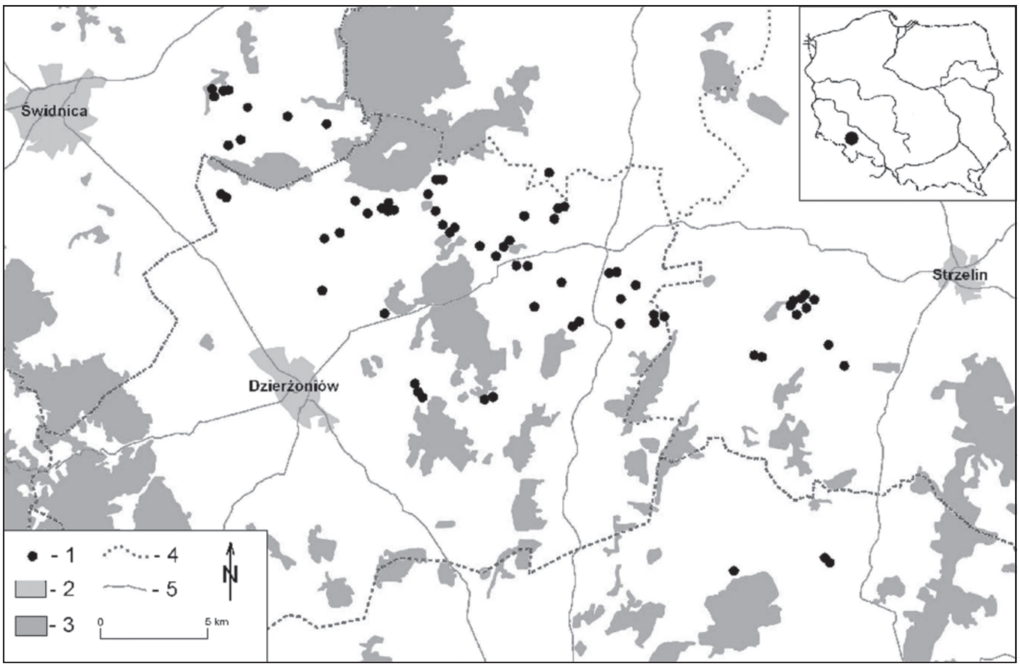


Fig. 1. Situation of the field margins studied in the area of research
Explanations: 1 – locality of the margin, 2 – main towns, 3 – forests, 4 – administrative borders, 5 – main roads

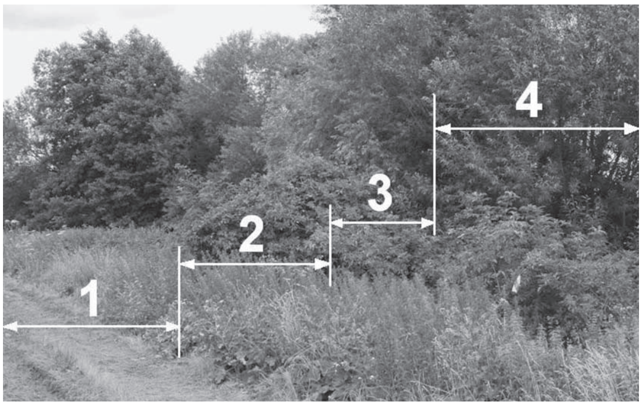


Fig. 2. An example of the field margin division into vegetation zones
Explanations: 1 – field track (D), 2 – herbaceous (Z), 3 – shrub zone (K), 4 – tree zone (L)

At each site, floristic data were collected from three transverse transects, each 10 meters wide. Two of the transects were laid out a 100 meters from either end of the studied section of the field margin, and the third ran across the middle of the section (Fig. 3). Each transect continued into adjacent crops, meadows or pasture.

Phytosociological relevés were collected at each transect using standard methods (Pawłowski 1972). In total, 1319 relevés were collected. The relevés were situated within the boundaries of individual zones. In fields and meadows, they always covered an area of two meters wide and ten meters long. Within the field margins, the surface area of the relevés depended on the width of the individual zones.

The relative abundances of individual species were determined for each relevé (Table 2). The data from the relevés were compiled into a database using the Turboveg for Windows software package (Hennekens & Schaminee 2001). The relevés were then classified and quantified using the Juice software package (Tichy 2002).

Plants nomenclature was unified in accordance with the "Flowering Plants and Pteridophytes of Poland" (Mirek *et al.* 2002). The anthropophytes identified were

Table 2. Cover degrees and their mean values (after Pawłowski 1972)

Cover degree	Mean value of cover degree (%)
5	87.5
4	62.5
3	37.5
2	17.5
1	5.0
+	0.1

further categorized as either archaeophytes (Zając 1979) or neophytes (Zając *et al.* 1998; Tokarska-Guzik 2005).

The coefficient of group constancy (***S***) of archaeophytes and neophytes was calculated for each zone within the field margin and in the surrounding fields or meadows in accordance with the following formula (Tüxen & Ellenberg 1937 in Pawłowski 1972):

$$S = (g/z \cdot n)\ 100\%$$

where: g – the total number of occurrences of the species from the group; z – the number of species from the group; and n – the number of relevés in the table.

To measure the association between anthropophyte species and the vegetation zones, the coefficient of fidelity (Φ=phi) for individual species was calculated. It was done for each zone within the field margin and in adjacent crop, using a model available in the Juice software program (Chytrý *et al.* 2002):

$$\Phi = \frac{N \cdot n_p - n \cdot N_p}{\sqrt{n \cdot N_p \cdot (N - n) \cdot (N - N_p)}}$$

where: N – the number of relevés in the data set; N_p – the number of relevés in the particular vegetation zone; n – the number of occurrences of the species in the data set; and n_p – the number of occurrences of the species in the particular vegetation zone.

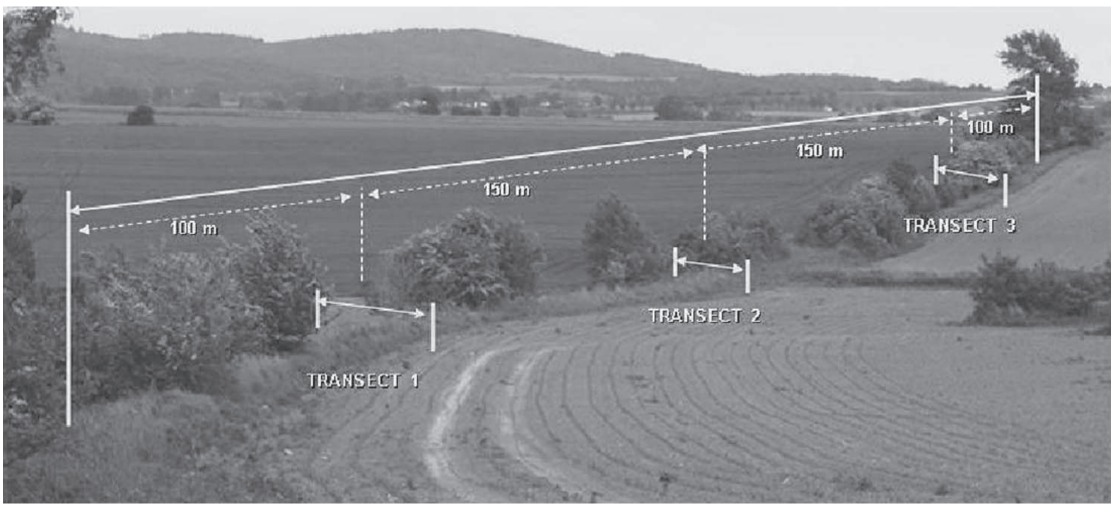


Fig. 3. Division of field margin into sections where transverse transects were delimited

The values of Φ range from -1 to 1, but for convenience, they are multiplied by 100 in the program, therefore they range from -100 to 100. Positive values indicate that the species and the vegetation zone co-occur more frequently than would be expected by chance. Larger values indicate a greater degree of joint fidelity. Fidelity was calculated for presence/absence data. To remove the dependence of the fidelity measures on the sample size (i.e. the number of relevés in the particular vegetation zone), the size of all groups was standardized to equal size. Fisher's exact test was calculated to check the statistical significance of the phi coefficients obtained. Both, standardization and the test, are options available in Juice.

3. Results

3.1. Number of species

In a sample of 1319 relevés 435 species of vascular plants were identified. Out of these, 22.5% were alien species. The number of alien species was very similar both in cultivated fields and field margins (Table 3). Nevertheless, their collective share in the total flora was twice as high in cultivated fields as in field margins. This was because the total number of species of vascular plants was far higher in field margins than in cultivated fields.

Most of the alien species identified were archaeophytes. In cultivated fields they made up about 25% of the species identified. The percentage of neophytes was much lower. They made up 6.1% of the species identified in field margins, and 7.5% of the species identified in cultivated fields. Ergasiophygophytes were found sporadically, and made up 2.5% of the species identified (Table 3).

3.2. Coverage

In cultivated fields, the species with the highest values for the coefficient of coverage (amounted to 3) were *Vicia tetrasperma* and *Lactuca serriola*. In field margins, the species with the highest values for the coefficient of coverage were *Reynoutria japonica* (5), *Impatiens parviflora* (3), and *Solidago gigantea* (3). These three plants are invasive species that often form dense, uniform phytocoenoses (Table 4).

Table 4. Plants classified as invasive (after Tokarska-Guzik 2005) recorded in the field margins studied

Species	Frequency (total No = 1319)	Max. cover
Amaranthus retroflexus	24	3
Aster novi-belgii	1	+
Bidens frondosa	5	+
Bryonia alba	4	+
Chamomilla suaveolens	50	2
Conyza canadensis	19	1
Galinsoga ciliata	13	2
Galinsoga parviflora	33	2
Impatiens parviflora	72	3
Juncus tenuis	6	+
Lupinus polyphyllus	4	2
Oxalis fontana	46	1
Padus serotina	1	+
Quercus rubra	2	0.1
Reynoutria japonica	1	5
Solidago canadensis	14	3
Solidago gigantea	12	2
Veronica persica	126	2

3.3. Species composition

The anthropophytes, identified in the cultivated fields and field margins, examined in the present study were mainly common cosmopolitan species. Nevertheless, archaeophytes and neophytes differed greatly in terms of coverage, constancy and fidelity (Table 5).

Archaeophytes were far more common in cultivated fields than in field margins. In field margins, only one species (*Apera spica-venti*) was found in more than 10% of the relevés. In cultivated fields, on the other hand, 22 species were found in more than 10% of the relevés. Of these species, the most common were *Apera spica-venti*, *Viola arvensis* and *Myosotis arvensis*.

The differences between field margins and cultivated fields may be attributed to the difference in the number

Table 3. Participation of alien species in the flora of studied habitats

Habitat	Number of relevés	Number of vascular plants	Archaeophytes		Neophytes		Cultivated plants (ergasiophygophytes)		Anthropophytes in total	
			No of species	%	No of species	%	No of species	%	No of species	%
Field margins	912	411	51	12.4	25	6.1	4	1.0	80	19.5
Crops	381	214*	54	25.2	16	7.5	11	5.1	81	37.9
Fallow and meadows	26	158	16	10.1	7	4.4	1	0.6	24	15.1
All habitats combined	1319	435	60	13.8	27	6.2	11	2.5	98	22.5

Explanation: *including cultivated plants

Table 5. Frequency of archaeophytes and neophytes in relevés made in fields and field margins

Frequency index	Habitat	Archaeophytes		Neophytes	
		No of species	%	No of species	%
Species present in >10% of relevés	Fields	22	36.7	1	3.7
	Field margins	1	1.7	-	-
Species with fidelity index >20	Fields	18	30.0	1	3.7
	Field margins	1	1.7	4	14.8
Exclusive species*	Fields	7	11.7	2	7.4
	Field margins	4	6.7	8	29.6

Explanation: *species present only in crops or only in field margins

of relevés collected in these areas (912 and 407 respectively), as well as to the fact that field margins are very diverse habitats, whereas cultivated fields are uniform and homogeneous. This is confirmed by the values for the coefficient of fidelity, which were higher for archaeophytes found in cultivated fields than for those found in field margins (Table 6). The archaeophytes that were most common in cultivated fields were also found in field margins but in lower abundance. Most of these were annuals that were found only in the peripheral zones of the field margins.

Neophytes, in contrast, were commonly found both in cultivated fields and field margins. There were four times as many species with high values for the coefficient of fidelity in field margins than in cultivated fields. There were also four times as many species that were found exclusively in field margins than species that were found exclusively in cultivated fields (Table 5). The neophytes most commonly found in field margins were *Impatiens parviflora*, *Chamomilla suaveolens* and *Veronica persica*. None of the 27 neophytes identified, however, was found in more than 10% of the relevés collected in field margins. This is probably because neophytes were generally not abundant in the areas included in the study. The neophytes most commonly found in cultivated fields were *Veronica persica*, *Oxalis fontana* and *Galinsoga parviflora*. *Veronica persica* was found in 26% of the relevés collected in cultivated fields, whereas the other species were significantly less common.

3.4. Habitat preferences of anthropophytes

Both archaeophytes and neophytes preferred cultivated fields. However, many were also frequently found in field margins, especially in the periphery zones, i.e. herbaceous verges, and field tracks, which were usually located by the margin side. For archaeophytes, values of the coefficient of group constancy (S) were high and about the same, both in herbaceous verges and roads (Fig. 4). Similarly, neophytes preferred the field tracks, but also the zone of trees (Fig. 4). Nevertheless, habitat preferences were less distinct in neophytes and they were more evenly distributed in vegetation zones.

Individual species had even more distinct habitat preferences as determined on the basis of the fidelity coefficient (Table 6). Most archaeophytes highly preferred cultivated fields. This was true for *Anagallis arvensis*, *Lamium purpureum* and *Viola arvensis*. For about half of the archaeophytes found, the fidelity coefficient was also positive in field margins, although the value was statistically significant for only one species: *Apera spica-venti*. Some archaeophytes were found on field tracks in addition to either field margins or cultivated fields. These included *Matricaria maritima* subsp. *inodora* and *Capsella bursa-pastoris*. Among species that were found in field margins, but not in cultivated fields, the only archaeophyte species with high fidelity coefficients were those that grew along field tracks, such as *Cichorium intybus* and *Lepidium ruderale*. Furthermore, the only archaeophyte species that highly preferred the shaded habitats of the tree and shrub zones was *Ballota nigra*.

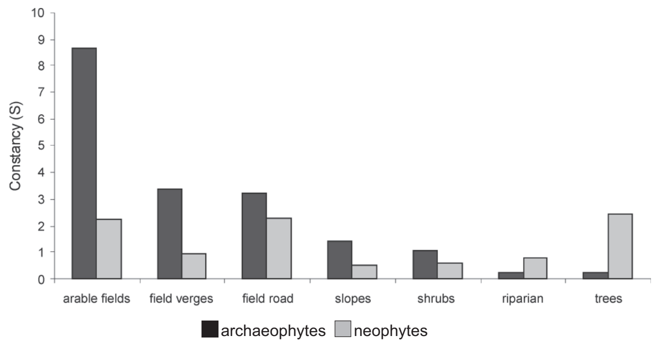


Fig. 4. Group constancy of archaeophytes and neophytes within cultivated fields and zones of field margins

Among the neophytes found in cultivated fields, the species with the highest fidelity coefficients were *Oxalis fontana* and *Veronica persica*. These species were found at many of the sites examined. Among species found along field tracks, the neophyte species with the highest fidelity coefficients were *Chamomilla suaveolens* and *Juncus tenuis*. Several neophyte species preferred shaded habitats. Of these, *Bryonia alba* and *B. dioica* preferred the shrub zone, and *Impatiens parviflora* and *Solidago gigantea* preferred the tree zone.

Table 6. Fidelity measures of archaeophyte and neophyte species associated with the vegetation zones in the field margins and adjoining fields

Species	Habitat zone						
	field	margin verges	field tracks	herbaceous zone	riparian zone	shrub zone	tree zone
	No of relevés						
	383	203	88	381	99	98	43
	Archaeophytes						
Anagalis arvensis	●●●●	.	.	.	.	.	.
Lamium purpureum	●●●●	.	.	.	.	.	.
Veronica arvensis	●●●	.	○	.	.	.	.
Melandrium noctiflorum	●●●	.	.	.	.	.	.
Euphorbia peplus	●●	○	.	.	.	.	.
Veronica agrestis	●●	.	.	.	.	.	.
Geranium dissectum	●●	.	.	.	.	.	.
Sherardia arvensis	●●	.	.	.	.	.	.
Scleranthus annuus	●	.	.	.	.	.	.
Bromus secalinus	●	.	.	.	.	.	.
Lithospermum arvense	○	.	.	.	.	.	.
Fumaria vaillantii	○	.	.	.	.	.	.
Papaver argemone	○	.	.	.	.	.	.
Vicia villosa	○	.	.	.	.	.	.
Hyoscyamus niger	○	.	.	.	.	.	.
Apera spica-venti	●●●●	●●	.	.	.	.	.
Viola arvensis	●●●●●●	○	.	.	.	.	.
Myosotis arvensis	●●●●●	○	.	.	.	.	.
Thlaspi arvense	●●●●	○	.	.	.	.	.
Fallopia convolvulus	●●●●	○	.	.	.	○	.
Papaver rhoeas	●●●	○	.	.	.	.	.
Fumaria officinalis	●●●	○	.	.	.	.	.
Euphorbia helioscopia	●●●	○	.	.	.	.	.
Centaurea cyanus	●●●	○	.	.	.	.	.
Sinapis arvensis	●●	○	.	.	.	.	.
Aphanes arvensis	●●	○	.	.	.	.	.
Avena fatua	●●	○	.	.	.	.	.
Lamium amplexicaule	●	○	.	.	.	.	.
Euphorbia exigua	●	○	.	.	.	.	.
Neslia paniculata	○	○	.	.	.	.	.
Galium spurium	○	○	.	.	.	.	.
Bromus sterilis		○	.	.	.	.	.
Matricaria maritima subsp. *inodora*	●●●●	+	●●	.	.	.	.
Capsella bursa-pastoris	●●●	○	●●	.	.	.	.
Chamomilla recutita	●●		●●	.	.	.	.
Vicia tetrasperma	●	○	●●	+			
Descurainia sophia	●●	○	○	.	.	.	.
Spergula arvensis	●	○	○	.	.	.	.
Sonchus asper	○	○	○	.	.	.	.
Vicia angustifolia	○	○	○	.	.	.	.
Echinochloa crus-galli	●●●	.	○	.	.	.	.
Solanum nigrum	●●●	.	○	.	.	.	.
Setaria pumila	●●●	.	○	.	.	.	.
Geranium pusillum	●●	.	○	.	.	.	.
Vicia sativa	●	.	○	.	.	.	.
Anthemis cotula	●	.	○	.	.	.	.
Cichorium intybus	.	.	●●●●	.	.	.	.
Lepidium ruderale	.	.	●●	.	.	.	.
Malva sylvestris	.	+	●●	.	.	.	.
Consolida regalis	●	.	.	+	.	.	.
Vicia hirsuta	●	○	○	+		○	
Lathyrus tuberosus	○	○	.	●	.	.	.
Lamium album	○	○	.	○	.	.	.
Sisymbrium officinale	○	.	○	○	.	.	.
Bromus tectorum	+	.	○	+	.	.	.
Sonchus oleraceus	○	○	.	.	○	.	.
Lactuca serriola	.	○	○	○	.	○	.
Armoratia rusticana	.	○	.	.	○	○	.

Urtica urens	.	.	.	○	.	.	.
Ballota nigra	.	.	.	+	.	●●	+
				Neophytes			
Oxalis fontana	●●	.	.	.	.	.	.
Amaranthus chlorostachys	○	.	.	.	.	.	.
Brassica nigra	○	.	.	.	.	.	.
Veronica persica	●●●●	●	.	.	.	.	.
Amaranthus retroflexus	●●	○	.	.	.	.	.
Sinapis alba	○	○	.	.	.	.	.
Galinsoga parviflora	●●	○	○	.	.	.	.
Galinsoga ciliata	●●	.	○	.	.	.	.
Lolium multiflorum	+	○	.	+	.	.	.
Lupinus polyphyllus	○	○	.	.	.	○	.
Aster novi-belgii	.	○	.	.	.	.	.
Sisymbrium loeselii	.	○	.	.	.	.	.
Medicago sativa	.	○	○	.	.	.	.
Bromus carinatus	.	○	○	.	.	.	.
Conyza canadensis	.	○	○	.	○	○	.
Chamomilla suaveolens	.	.	●●●●●●	.	.	.	.
Juncus tenuis	.	.	●●	.	.	.	.
Malva alcea	.	.	.	○	.	.	.
Reynoutria japonica	.	.	.	○	.	.	.
Bryonia alba	.	.	.	○	.	●●	.
Bryonia dioica	.	.	.	+	.	●●	.
Solidago canadensis	.	.	.	●	.	.	○
Impatiens parviflora	.	.	.	.	●	.	●●●●●
Bidens frondosa	.	.	.	.	●	.	●●●
Solidago gigantea	.	.	.	.	+	.	●●●
Quercus rubra	+	.	.	.	.	○	.
Padus serotina	.	.	.	.	.	○	.
				Cultivated plants (ergasiophygophytes)			
Triticum aestivum	●●●●●●	.	.	.	.	.	.
Zea mays	●●●●●	.	.	.	.	.	.
Hordeum vulgare	●●●	.	.	.	.	.	.
Solanum tuberosum	●●	.	.	.	.	.	.
Beta vulgaris	●●	.	.	.	.	.	.
Brassica napus	●●●●	○	○	.	.	.	.
Avena sativa	●●	○	○	.	.	.	.
Secale cereale	●	.	○	.	.	.	.
Pisum sativum	○	.	.	.	.	.	.
Fragaria x ananasa	○	.	.	.	.	.	.
Phaseolus species	○	.	.	.	.	.	.

Explanations: symbols indicate the following values of the phi coefficient + – <1.0, ○ or ● – 1.1-10.0, ●● – 10.1-20.0, ●●● – 20.1-30.0, ●●●● – 30.1-40.0, ●●●●● – 40.1-50.0, ●●●●●● – 50.1-60.0, values lower than 0 indicating negative fidelity were omitted by the program. Filled symbols denote significant phi values ($p<0.05$, Fisher's exact test)

3.5. Life forms

Most of the alien species identified in both cultivated fields and field margins were therophytes (Fig. 5). The percentage of therophytes was approximately the same in the case of archaeophytes recorded in both types of habitat. The group of neophytes was also dominated

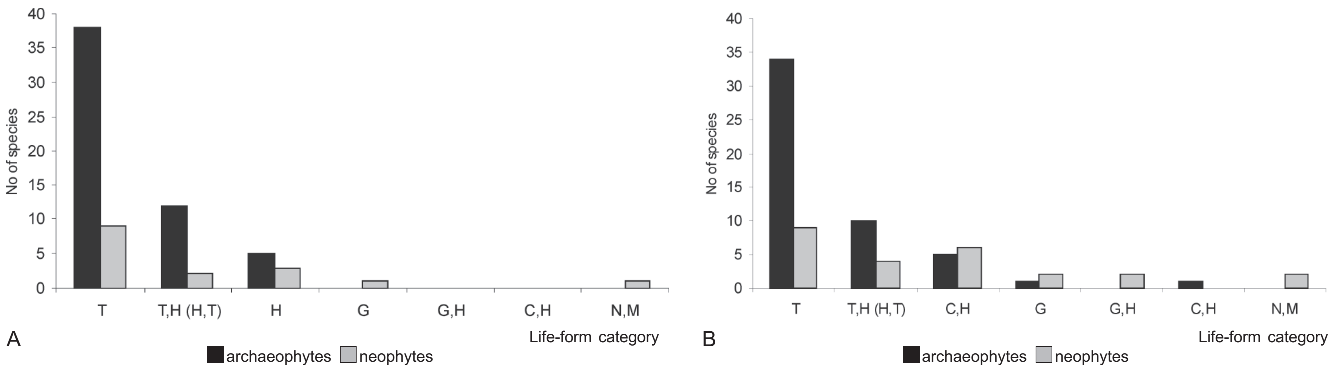
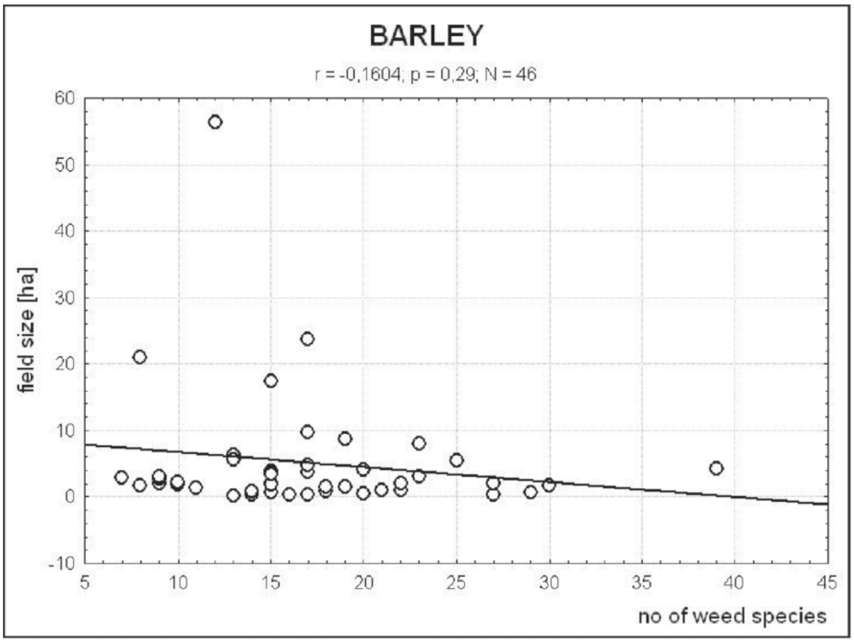
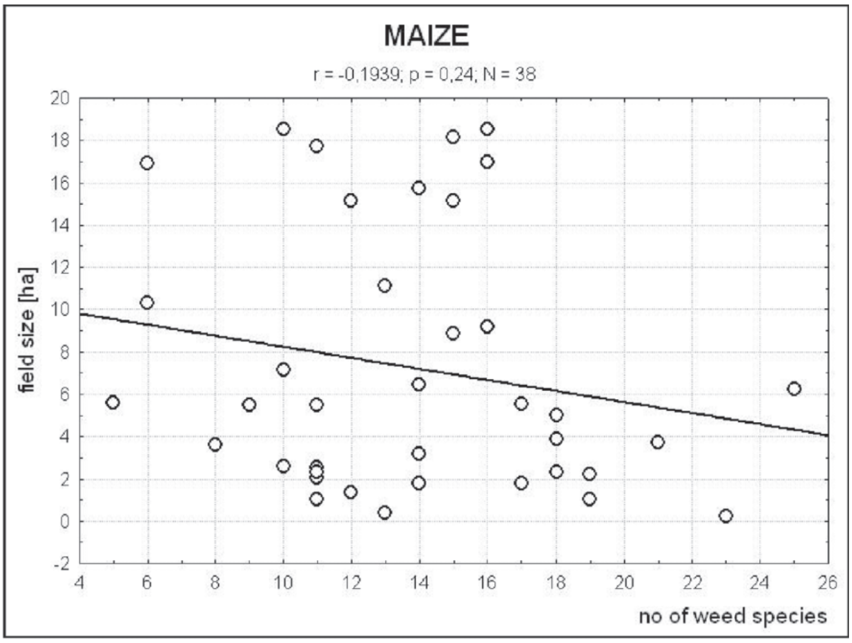
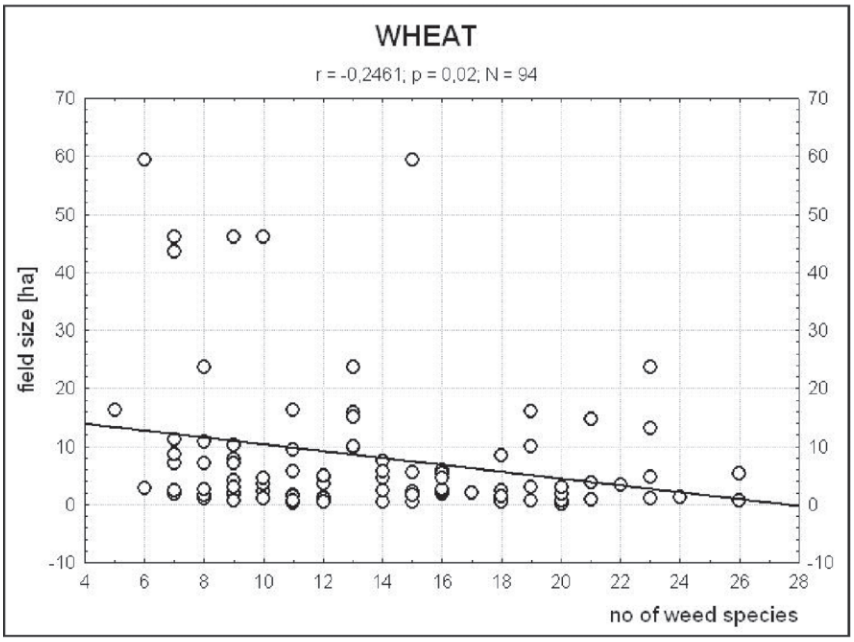


Fig. 5. Number of anthropophyte species from different life-form categories in fields (A) and field margins (B)

Explanations: see Appendix 1


BARLEY
r = -0,1604; p = 0,29; N = 46
field size [ha]
no of weed species


MAIZE
r = -0,1939; p = 0,24; N = 38
field size [ha]
no of weed species


WHEAT
r = -0,2461; p = 0,02; N = 94
field size [ha]
no of weed species

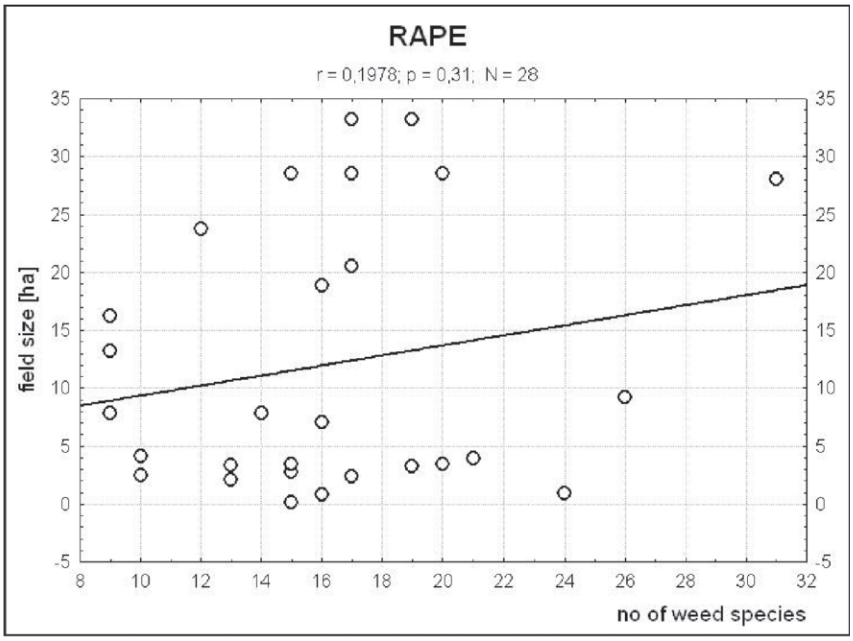


Fig. 6. Relationships between the number of vascular plants in relevés and the field area in four types of crops: barley (*Hordeum vulgare*), maize (*Zea mays*), wheat (*Triticum aestivum*) and rape (*Brassica napus*)

by therophytes which amounted to nine species in both types of habitat. Because of difference in the number of neophytes in cultivated fields (16 species) and in field margins (25), the predominance of therophytes was stronger in the former habitat.

3.6. Effect of crop type and field size on diversity of weed flora

In terms of the number of species found, the weed flora varied widely among the various types of habitat examined in the present study (Table 7). The communities with the highest level of biodiversity were well-established phytocoenoses that developed on arable land that was not cultivated on a yearly basis, such as fallow fields and meadows. The level of biodiversity was also high in two winter crops – rye and oats. These crops, however, represent only a small portion of the total crops cultivated in the study area, which explains small sample sizes. In fields planted with wheat and maize, the weed flora was represented by the smallest number of species among the habitat types examined in this study. This is probably due to the high intensity of farming in fields of these crops.

We expected the lower number of weed species in larger fields than in smaller fields, because larger fields tend to be subject to more intensive cultivation. In the present study, however, this relationship was only partly confirmed. Data from the main crops grown in the area showed weak significant and negative correlation for wheat, and negative but insignificant correlation for maize and barley. On the other hand, the correlation was positive for oilseed rape (Fig. 6).

Table 7. Weed richness in samples from different fields adjacent to field margins

Habitat/Crop type	Sample size /No of relevés/	No of weed species /mean ± SD/
Fallow	11	24.2 ± 4.45
Avena sativa	3	24.0 ± 4.36
Meadow	7	23.9 ± 5.21
Secale cereale	5	23.0 ± 3.46
Solanum tuberosum	3	18.7 ± 10.0
Hordeum vulgare	46	17.1 ± 6.56
Brassica napus	28	16.3 ± 5.19
Beta vulgaris	8	14.2 ± 3.99
Zea mays	39	13.8 ± 4.48
Triticum aestivum	95	13.7 ± 5.17
Total	245	15.8 ± 6.10

4. Discussion

Anthropophytes make up part of plant communities found in different habitats, where interactions between them determine the relative abundances of individual species in the community. The implications of this are not clear and affect the ecology of the community and the distribution of species within it. This also has to be taken into consideration when designing programs to protect particular plant communities. As far as plant communities in cultivated fields are concerned, the results of this study are similar to those of previous studies, carried out in other regions, in which the relative abundance of apophytes was higher than that of alien species, and the relative abundance of archaeophytes was higher than that of neophytes (Jackowiak & Latowski 1996; Latowski 2002; Latowski & Jackowiak 2001, 2006).

Field margins, on the other hand, often consist of a mosaic of different ruderal habitats, such as field tracks and railroad beds, interspersed with semi-natural habitats like roadsides, ditch banks and other habitats in which regenerative plant succession is underway. The relationships between alien and native species in these habitats are not completely understood. There have not been any exhaustive studies with which the results of the present study can be compared. In the seventy field margins examined in this study, the anthropophytes made up 19.5% of plant species, about half of what it was in the cultivated fields adjacent to these sites (37.9%). This difference seems to indicate that marginal habitats play only a minor role in the distribution and dispersion of alien species, and that cultivated fields are a far more important reservoir, especially, because they have been decidedly more altered by human activity.

By far, most of the archaeophytes identified in the present study are species that are characteristic for segetal habitats. They were typically found in relevés collected from cultivated fields. In field margins, on the other hand, they were more often found in the peripheral zones than in the interior zones. This suggests that the normal direction in which these species disperse is from cultivated fields to field margins. Low abundance of the archaeophytes in the interior zones, especially in the shrub and tree zones, was probably caused by the habitat conditions, which were not favorable for many of these species. Most of them are therophytes, which can not successfully compete with the perennial plants that dominate the vegetation of these zones. Corresponding results were obtained in riparian habitats located between cropfields in eastern Canada. More weedy and, in particular, introduced species were recorded in the samples near cropfields than in the interior, where, in contrast, native wetland species dominated (Boutin *et al.* 2003).

Neophytes were more evenly distributed in the transects, i.e. throughout the various zones of field margins and in adjacent fields. It is therefore difficult to determine the normal direction in which these species spread. Some neophytes strongly preferred cultivated fields over field margins, such as *Oxalis fontana* and *Veronica persica*. Nevertheless, most of them preferred field margins and were rarely found in crops. This was true for such species as *Impatiens parviflora* and *Chamomilla suaveolens* (Appendix 1, Table 6).

Some alien species are listed as threatened or endangered in Poland. All of these are archaeophytes that have become completely naturalized and were formerly widely distributed in the country. They have become far less abundant now because of improvements in agricultural technology and weed control. Some species are considered rare or endangered on a local scale, and others on a national scale (Kucharczyk & Wójciak 1995; Żukowski & Jackowiak 1995; Zając & Zając 1998; Bernacki *et al.* 2003; Nowak *et al.* 2003; Markowski & Buliński 2004; Zarzycki & Szeląg 2006; Jackowiak *et al.* 2007). Some archaeophyte species were included in the second edition of the Polish Red Book of Plants (Kaźmierczakowa & Zarzycki 2001). The elaborations of endangered plant species that occur exclusively in segetal and synanthropic habitats indicate that most of them are archaeophytes (e.g. Warcholińska 1986/1987; Anioł-Kwiatkowska 2003; Ratyńska 2003b; Nowak 2004).

Out of the sixty archaeophyte species found in field margins and cultivated fields in the Sudetic Foreland, six are considered endangered in the province of Lower Silesia (Kącki *et al.* 2003). They were noticed mostly in relevés from cultivated fields (Table 8) and only three species were also found in relevés from field margins: *Consolida regalis*, *Euphorbia exigua* and *Geranium dissectum*. This is significant in light of the ongoing discussion on conserving endangered segetal weed species (Warcholińska 1986/1987; Anioł-Kwiatkowska 2003; Ratyńska 2003b; Siciński 2003; Nowak 2007). Sporadic occurrence of endangered anthropophytes in field margins suggests that in the present form they are not important refuges for these species. Except for the peripheral zones, field margins rarely contain patches of bare ground exposed to the sun on which therophytes can grow without being overshadowed by taller plant

Table 8. Archaeophytes included in the local red list of plants (Kącki *et al.* 2003)

Species	Category of threat	Frequency (total no = 1319)	Relevés per habitat zone
Bromus secalinus	VU	3	U-3
Consolida regalis	LC	6	U-5; Z-1
Euphorbia exigua	LC	5	U-4; O-1
Fumaria vaillantii	CR	1	U-1
Geranium dissectum	LC	16	U-14; O-1; Z-1
Sherardia arvensis	LC	5	U-5

Explanations: CR – critically endangered, VU – vulnerable, LC – least concern, O – field margin verges, U – fields, Z – herbaceous zone on slopes, balks and edges species. Unfortunately, the peripheral zones are particularly susceptible to contamination by herbicides applied to the adjacent cultivated fields. This probably also limits the occurrence of rare anthropophyte species in this habitat. In many countries, a hands-off policy has been proposed as the best solution for maximizing the role of field margins as reservoirs for rare and endangered weed species. One of the solutions is isolating field margin habitats from nearby cultivated fields with a buffer zone planted with a mixture of grasses and papilionaceous plants. Reducing or eliminating the use of fertilizers and herbicides at the edges of cultivated fields has also been proposed (Moonen & Marshall 2001). Some of these methods should be considered for implementation in Poland.

Some neophytes are invasive and readily form xenospontaneus communities (Faliński 1969, 1998; Jackowiak 1999; Tokarska-Guzik 2005). These species may reduce plant diversity on a local scale (Tokarska-Guzik & Dajdok 2004; Tokarska-Guzik *et al.* 2005). From among the invasive species listed by Tokarska-Guzik (2005), eighteen were found in the relevés collected in the present study (Table 4). Some invasive species can have a particular negative impact on the other components of the plant communities they invade. These include *Reynoutria japonica*, *Solidago gigantea* and *Solidago canadensis*. *Reynoutria japonica* is currently not a serious threat to the margin communities studied because it is still not widely distributed. In the present study, it was found in only one relevé. It was also recorded in other parts of the habitats examined (outside the transects), especially near the sites at which garbage has been illegally dumped. Alien *Solidago* species, on the other hand, pose a more serious threat because they are commoner and spread very rapidly. Over the four years during which the present study was carried out, there was a visible increase in the area covered by these species. In one of the field margins examined, the area covered by alien *Solidago* species increased from about 10% in 2004 to about 30% in 2007. Two other invasive neophytes have also recently entered the field margin habitats examined in the present study: *Impatiens glandulifera* and *Echinocystis lobata*. These species, however, grew outside the transects from which relevés were collected. In the study area, they did not form dense thickets that they often do in other habitats, such as river valleys and ruderal sites.

Another invasive neophyte, *Impatiens parviflora*, can dominate the understory of certain types of forest (Obidziński & Symonides 2000; Chmura & Sierka 2006). In the present study, *Impatiens parviflora* was found in 72 relevés, including 13 relevés collected from cultivated fields. Six of these were planted with wheat, three with rye, two with sugar beets, one with oilseed rape and one with maize. The species was mainly found in shaded edges of fields along rows of trees and shrubs but also of reed and nettle.

Interestingly, no neophytes, including invasive species, were found on abandoned railroad beds, even though these sites are usually colonized by anthropophytes. In one study on the flora of railroad beds in Silesia, anthropophytes represented from 70% to 80% of the total flora (Krawiecowa 1968). Most of these were archaeophytes, although neophytes made up more than 10% of the flora at some sites. In a more recent study, segetal species were found to make up a large part of the ruderal flora of railroad beds and yards (Latowski 2004). In the present study, four of the sites examined contained stretches of railroad beds that were abandoned in the last ten or fifteen years. In transects running through these railroad beds, the only alien species found were archaeophytes, such as *Vicia tetrasperma*, *Lathyrus tuberosus*, *Viola arvensis* and *Sisymbrium officinale*.

The habitats examined in the present study were therefore only slightly colonized by the most invasive alien species. These species had little effect on the level of biodiversity in these habitats. The level of biodiversity was, however, often reduced by apophyte species that form dense, almost monospecific thickets, especially *Phragmites australis* and *Urtica dioica*. These species thrive in both segetal and ruderal habitats (Zając & Zając 1992). In the present study, *Phragmites australis* was recorded in 225 relevés and had a coverage of over 60% in 42 relevés. *Urtica dioica* was recorded in 761 relevés, and had a coverage of over 60% in 45 relevés. Species diversity was significantly lower in relevés containing these species (Fig. 7). Plant communities dominated by *Phragmites australis* were usually found near streams and drainage ditches. Communities dominated by *Urtica*

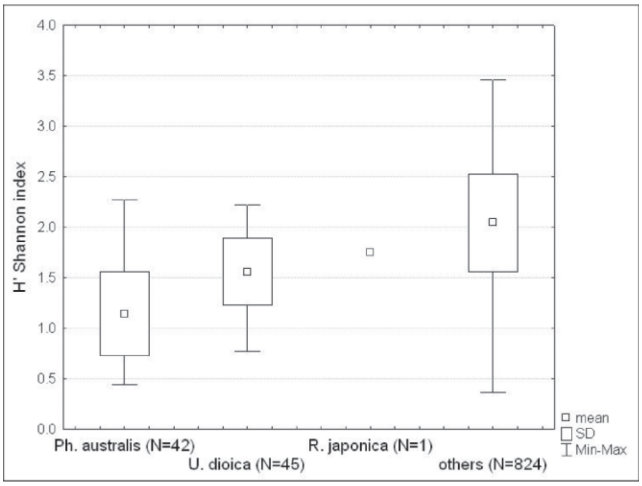


Fig. 7. Values of the Shannon index calculated for phytocoenoses dominated by *Phragmites australis, Urtica dioica*, *Reynoutria japonica* and others. Mean values are calculated from the sets of relevés in which the particular species amounted more than 60% of cover. The sample of the remaining 824 relevés done in the field margins is used as a control

dioica were usually found in places with a high content of nutrients derived from fertilizers, such as the base of escarpments, vegetation strips along drainage ditches, and slopes oriented toward drainage ditches (Dajdok 2004).

Anthropophytes made up only a small proportion of the plant communities of the field margin habitats examined in the present study. Invasive species were especially not abundant, which indicates that the plant communities examined were probably resistant to invasion. In contrast, field margins appeared to be refuges mostly for native plant species. Because a suite of these plants is not found in other farmland habitats, field margins should deserve special protection as biodiversity refuges in the areas of intensive agriculture.

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Appendix 1. Frequency of anthropophytes in the field margins and adjacent crops (assignment of species to life-form categories in Raunkiaer system after Rutkowski 2004)

Species	Life form	No of occurrence (frequency) of the species in habitat / vegetation zone							Field margins (%)	Fields (%)	Total no of relevés
		U	O	D	Z	R	K	L			
					Archaeophytes						
Anagalis arvensis	T	66	5	-	-	-	-	-	0.5	17.3	71
Anthemis cotula	T	6	1	2	1	-	-	-	0.4	1.6	10
Apera spica-venti	T, H	179	73	15	48	1	4	1	15.6	47.2	324
Aphanes arvensis	T	18	3	-	-	-	-	-	0.3	4.7	21
Armoracia rusticana	G	-	1	-	-	1	1	-	0.3	-	3
Avena fatua	T, H	23	5	-	4	-	-	-	1.0	6.0	32
Ballota nigra	C, H	-	3	1	9	1	6	1	2.3	-	21
Bromus secalinus	T, H	3	-	-	-	-	-	-	-	0.8	3
Bromus sterilis	T	-	1	-	-	-	-	-	0.1	-	1
Bromus tectorum	T	1	-	1	1	-	-	-	0.2	0.3	3
Capsella bursa-pastoris	H, T	106	24	21	12	-	1	-	6.4	27.8	168
Centaurea cyanus	T	52	14	2	2	1	1		2.2	13.9	75
Chamomilla recutita	T	29	6	8	5	-	-	-	2.1	7.6	48
Cichorium intybus	H	-	-	16	10	-	1	-	3.0	-	27
Consolida regalis	T	5	-	-	1	-	-	-	0.1	1.3	6
Descurainia sophia	T	31	10	4	8	1	2	-	2.7	8.1	56
Echinochloa crus-galli	T	69	7	8	2	-	-	-	1.9	18.1	86
Euphorbia exigua	T	4	1	-	-	-	-	-	0.1	1.0	5
Euphorbia helioscopia	T	45	6	-	1	-	-	1	0.9	11.8	54
Euphorbia peplus	T	8	2	-	-	-	-	-	0.2	2.1	12
Fallopia convolvulus	T, H	118	19	-	13	1	9	1	4.7	31.2	165
Fumaria officinalis	T	44	5	-	2	-	-	-	0.8	11.5	51
Fumaria vaillantii	T	1	-	-	-	-	-	-	-	0.3	1
Galium spurium	T	2	1	-	-	-	-	-	0.1	0.5	3
Geranium dissectum	T	14	1	-	1	-	-	-	0.2	3.7	16
Geranium pusillum	T	40	7	5	10	-	2	-	2.6	10.8	65
Hyoscyamus niger	H, T	1	-	-	-	-	-	-	-	0.3	1
Lactuca serriola	H	11	9	3	14	-	4	1	3.4	2.9	42
Lamium album	H	1	1	-	1	-	-	-	0.2	0.3	3
Lamium amplexicaule	T	5	1	-	-	-	-	-	0.1	1.3	6
Lamium purpureum	T, H	72	4	-	2	-	1	1	0.9	18.9	82
Lathyrus tuberosus	H	24	12	2	27	1	-	-	4.6	6.3	66
Lepidium ruderale	H, T	-	-	2	1	-	-	-	0.3	-	3
Lithospermum arvense	T	1	-	-	-	-	-	-	-	0.3	1
Malva sylvestris	H	1	1	2	1	-	-	-	0.4	0.3	5
Matricaria maritima subsp. *inodora*	H, T	153	31	26	22	-	3	1	9.1	40.4	242
Melandrium noctiflorum	T	41	1	-	1	-	-	-	0.2	10.8	43
Myosotis arvensis	T, H	174	31	3	25	2	5	-	7.2	45.9	246
Neslia paniculata	T	5	2	-	1	-	-	-	0.3	1.3	8
Papaver argemone	T	1	-	-	-	-	-	-	-	0.3	1
Papaver rhoeas	T	68	14	1	6	-	1	-	2.4	17.8	90
Scleranthus annuus	T	4	-	-	-	-	-	-	-	1.0	4
Setaria pumila	T	33	2	2	-	-	-	-	0.4	8.7	37
Sherardia arvensis	T	5	-	-	-	-	-	-	-	1.3	5
Sinapis arvensis	T	10	2	-	1	-	-	-	0.3	2.6	14
Sisymbrium officinale	T	3	-	2	3	-	-	-	0.5	0.8	8
Solanum nigrum	T	39	1	3	-	-	-	-	0.4	10.2	44
Sonchus asper	T	4	3	1	-	-	-	-	0.4	1.0	8
Sonchus oleraceus	H, T	2	1	-	-	1	-	-	0.2	0.5	4
Spergula arvensis	T	18	3	2	-	-	-	-	0.5	4.7	24
Thlaspi arvense	T, H	94	16	1	5	1	1	-	2.6	24.9	122
Urtica urens	T	-	-	-	1	-	-	-	0.1	-	1
Veronica agrestis	T	13	-	-	-	-	-	-	-	3.4	13
Veronica arvensis	T	53	4	3	-	-	-	-	0.8	14.2	63
Vicia angustifolia	T	3	3	1	2	-	-	-	0.7	0.8	9
Vicia hirsuta	T	36	14	8	24	1	8	-	6.0	9.4	99
Vicia sativa	T	9	1	3	3	-	-	-	0.8	2.3	16
Vicia tetrasperma	T	49	20	13	29	4	1	-	7.3	13.1	124
Vicia villosa	T, H	1	-	-	-	-	-	-	-	0.3	1
Viola arvensis	T	236	35	5	19	-	9	-	7.5	62.2	308
No of archaeophytes in the zone		54	45	30	37	12	18	7			

Neophytes											
Amaranthus chlorostachys	T	3	-	-	-	-	-	-	-	0.3	3
Amaranthus retroflexus	T	19	4	1	-	-	-	-	0.5	5.2	24
Aster novi-belgii	H	-	1	-	-	-	-	-	0.1	-	1
Bidens frondosa	T	-	-	-	-	2	-	3	0.5	-	5
Brassica nigra	T	1	-	-	-	-	-	-	-	0.3	1
Bromus carinatus	T, H	-	1	1	1	-	-	-	0.3	-	3
Bryonia alba	H	-	-	-	2	-	2	-	0.4	-	4
Bryonia dioica	H	1	-	-	2	-	2	-	0.4	0.3	5
Chamomilla suaveolens	T	9	3	38	-	-	-	-	4.5	2.4	50
Conyza canadensis	T, H	6	4	2	1	3	2	-	1.3	1.6	19
Galinsoga ciliata	T	11	1	1	-	-	-	-	0.2	2.9	13
Galinsoga parviflora	T	24	5	2	2	-	-	-	1.0	6.3	33
Impatiens parviflora	T	13	4	-	21	11	4	19	6.5	3.4	72
Juncus tenuis	H	-	-	3	1	-	-	-	0.4	-	6
Lolium multiflorum	H, T	1	2	-	1	-	-	-	0.3	0.3	5
Lupinus polyphyllus	H	2	1	-	-	-	1	-	0.2	0.5	4
Malva alcea	H	-	-	-	1	-	-	-	0.1	-	1
Medicago sativa	H	1	2	1	1	-	-	-	0.4	0.3	5
Oxalis fontana	G	33	3	-	5	-	1	-	1.0	8.9	46
Padus serotina	N, M	-	-	-	-	-	1	-	0.1	-	1
Quercus rubra	M	1	-	-	-	-	1	-	0.1	0.3	2
Reynoutria japonica	G	-	-	-	1	-	-	-	0.1	-	1
Sinapis alba	T	1	1	-	-	-	-	-	0.1	0.3	2
Sisymbrium loeselii	H, T	-	1	-	-	-	-	-	0.1	-	1
Solidago canadensis	G, H	-	1	-	9	1	1	1	1.4	-	14
Solidago gigantea	G, H	-	2	-	3	2	-	4	1.2	-	12
Veronica persica	T	98	16	3	2	1	1	-	2.5	26.0	126
No of neophytes in the zone		16	17	9	15	6	10	4			
Cultivated plants (ergasiophygophytes)											
Avena sativa	T	21	4	3	1	-	-	-	0.9	5.5	29
Beta vulgaris	H	12	-	-	-	-	-	-	-	3.1	12
Brassica napus	T (C)	74	9	4	4	-	-	-	1.9	19.4	91
Fragaria ×ananassa	H	1	-	-	-	-	-	-	-	0.3	1
Hordeum vulgare	T	66	4	2	2	-	1	-	1.0	17.8	76
Phaseolus vulgaris	T	1	-	-	-	-	-	-	-	0.3	1
Pisum sativum	T	1	-	-	-	-	-	-	-	0.3	1
Secale cereale	T	6	1	1	1	-	-	-	-	1.6	10
Solanum tuberosum	G	12	-	-	-	-	-	-	-	3.1	12
Triticum aestivum	T	155	4	3	4	-	-	-	-	40.9	166
Zea mays	T	76	2	-	-	-	-	-	0.1	20.5	78
No of cultivated plants in the zone		11	6	5	5	0	1	0			

Explanations: D – field tracks, K – shrub zone, L – tree zone, O – margin verges, R – riparian zone, U – field, Z – herbaceous zone; C – chamaephytes, G – geophytes (cryptophytes), H – hemicryptophytes, M – megaphanerophytes, N – nanophanerophytes, T – therophytes