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OCCURRENCE OF NEOPHYTES IN AGROPHYTOCOENOSES – FIELD SURVEY IN THE CZECH REPUBLIC

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Abstract

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Neophytes belong to a group of non-native plants, which were introduced by man either intentionally or unintentionally in different ways. The discovery of America is a historical milestone for non-native plant research. Most scientists use the term neophyte for species introduced after the year 1500. Neophytes became progressively more numerous in arable fields and their proportion significantly increased during the second half of the 20th century. The aim of this study was to assess the occurrence of neophytes in arable fields in the Czech Republic in terms of applied management systems, crops, and environmental site conditions at different altitudes. In the years 2006 to 2008, a phytocoenological survey was conducted on selected farms across the Czech Republic under various climate and soil conditions in spring and winter cereals and in wide-row crops. Totally, 172 weed species were found. Among these species, 8 % were considered as neophytes (13 species). In respect of their stage of invasiveness, 6 neophytes were considered as invasive, 6 species as naturalized and 1 species was considered as casual. Frequencies of neophyte species we found ranged between 0.3–31 % from all relevés. Environmental site conditions associated with altitude were the most important factors correlated with the occurrence of neophytes. The incidence of neophytes is primarily concentrated at lower altitudes and is mainly associated with stands of spring wide-row crops, especially root crops and vegetables. A higher proportion of neophytes was found in organic farming.

Keywords: arable land, weed communities, conventional and organic farming, cereals, wide-row crops, altitude

INTRODUCTION

Neophytes belong to a group of non-native plants, which were imported by man either intentionally or unintentionally in different ways. According to the arrival time, non-native species can be divided into an archeophytes group introduced already in prehistoric times and neophytes introduced just in the historical period (Preston *et al.*, 2004). As a central milestone, the year of the discovery of America has been considered, i. e. 1492, as since this event voyages of discovery started and therefore possibilities of plants' dispersal greatly increased (roughly then this limit is determined by the year of 1500). The definition of a neophyte, however, requires more information. Holub and Jirásek (1967) e.g. regard only unintentionally introduced species as neophytes. For simplicity and compatibility reasons, we use the term without any relation to whether the given species arrived accidentally at a new habitat or was brought intentionally by humans. It only respects the residence time (species introduced after the year 1500) regardless of the mean of introduction (Pyšek *et al.*, 2002).

According to the status of invasiveness of neophytes, Richardson *et al.* (2000) distinguish the casual, naturalized and invasive ones. The casuals are those species which can grow and flourish in an area, but do not form self-replacing populations. The naturalized ones reproduce consistently and sustain populations over more than one life cycle without direct intervention by humans. Invasive plants are naturalized plants that produce reproductive offsprings, often in very large numbers, at considerable distances from parent plants.

The alien flora of the Czech Republic consists of 1454 taxa, made up by 350 archaeophytes (24.1 %) and 1104 neophytes (75.9 %), which represent in addition to about 2945 native taxa known from the country and form 33.1 % of the total plant diversity ever recorded there (Pyšek *et al.*, 2012b). Danihelka *et al.* (2012) mention that the flora of the Czech Republic includes 3557 species. Of these, 2256 species are regarded as native, 464 naturalized (228 archaeophytes and 236 neophytes) and 837 casual aliens (62 archaeophytes and 775 neophytes).

Habitats with the greatest proportion of aliens belong to two groups, anthropogenic habitats (arable land, ruderal vegetation, trampled areas) and coastal, littoral and riverine habitats. Neophytes are commonly found in habitats also occupied by archaeophytes. Thus, the number of archaeophytes can be considered as a good predictor of the neophyte invasion risk. However, neophytes seem to have a stronger affinity to wet habitats and disturbed woody vegetation while archaeophytes tend to be more common in dry to mesic open habitats (Chytrý *et al.*, 2008). In terms of field conditions, aliens are most common in lowland agricultural and urban areas, whereas they are sparsely represented in mountainous areas. At middle altitudes, agricultural areas are more invaded than forested areas. General similarity of the invasion maps for archaeophytes and neophytes reflects the high correlation between occurrences of these two groups of aliens. There are, however, some fine-scale differences between them, contrary to the similarity revealed at a coarse scale. For example, neophytes more strongly respond to altitude, being more concentrated in the lowlands than archaeophytes. Also, neophytes seem to invade river corridors more heavily than archaeophytes in the Czech Republic (Chytrý *et al.*, 2009; Pyšek *et al.*, 2012a, Marini *et al.*, 2013).

Representation of neophytes in agrophytocoenoses is related to the intensity of farming and crop structure. Intensification of agriculture (e.g. large amounts of fertilizer) may promote the invasion of neophytes (Soukup *et al.*, 2004; Kovács-Hostyánszki *et al.*, 2011). Lososová and Cimalová (2009) stated that cereal stands were richer in archaeophytes and root crop stands were richer in neophytes. Archaeophytes are common in old crops introduced with the beginning of agriculture (as for example cereals), but are poorly represented in relatively recently introduced crops (rape, maize), where neophytes are most numerous (Pyšek *et al.*, 2005).

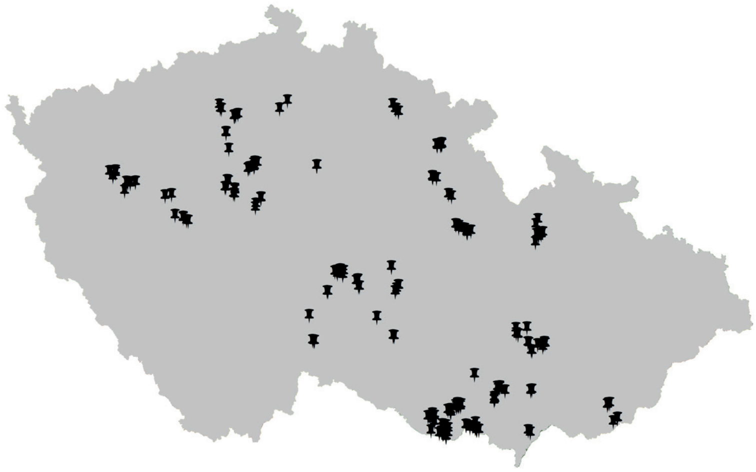
Neophytes are progressively more numerous in arable fields and their proportion significantly increased during the second half of the 20th century (Pyšek *et al.*, 2003, 2005; Šilc and Čarni, 2005). Also Lososová *et al.* (2004) indicate a decline in archaeophytic annuals (e.g. *Papaver argemone*, *Neslia paniculata*, *Raphanus raphanistrum*) and an increase in neophytes.

Economically the most important group of neophytes are usually invasive species which can spread easily and cause serious agricultural losses. Pyšek *et al.* (2012b) state that there are 50 invasive taxa of neophytes in our country. Hejný *et al.* (1973) deal with the issue of adventitious plants classified into groups of quarantine weeds. Jehlík (1998) discloses 40 foreign expansive weeds, of which 88 % are neophytes. Holec *et al.* (2004) list current most important invasive weed species spreading on arable land.

The aim of this study was to assess the current situation in the occurrence of neophytes in arable fields in representative areas of the Czech Republic in terms of (i) applied management systems (conventional and organic farming), (ii) crops (winter cereals, spring cereals, wide-row crops), and (iii) environmental site conditions which are for this purpose roughly represented by altitude.

MATERIALS AND METHODS

In the years 2006 to 2008, a phytocoenological survey was conducted on selected farms across the Czech Republic at various climate and soil conditions. Totally, 62 farms (27 conventional farms with common chemical weed control and 35 organic farms applying methods according to appropriate valid legislation without the use of herbicides and at least 2 years of organic management practices) were chosen for the research. The altitude varied between 175–650 m above sea level. The observation was conducted in winter cereals (winter wheat, winter barley, rye, spelt, triticale), spring cereals (spring barley, oat, naked oat, spring wheat) and wide-row spring crops (sugar beet, potatoes, maize, oil pumpkin, feeding carrots, fodder beet, beet-root). The weediness was evaluated in June and July in cereals and in late July, August, September and at the beginning of October in wide row crops. Each field was investigated once during the surveyed period. In total, 290 relevés were recorded (Fig. 1) – 113 relevés at altitudes lower than 250 m, 89 relevés at 250–350 m, and 88 relevés at levels higher than 350 m. Among them, 158 relevés represented conventionally farmed fields (53 relevés in winter cereals, 50 relevés in spring cereals and 55 relevés in wide-row crops) and 132 relevés represented organic fields (54 relevés in winter cereals, 38 relevés in spring cereals and 40 relevés in wide-row crops). (Fig. 1). The cover was estimated using the nine-degree Braun-Blanquet scale (Braun-Blanquet, 1964; modified by Barkman *et al.*, 1964). The size of the surveyed phytocoenological relevés was 100 m^2. Fungi, non-vascular plants and self-seeded seedlings of trees were not evaluated. The native/alien status was classified for each taxon



1: *Map of the Czech Republic showing recorded relevés.*

(Pyšek *et al.*, 2012b). The nomenclature followed that of Kubát *et al.* (2002). For individual species, frequencies of occurrences were calculated. Just the presence of species in a relevé was taken into account for frequency calculations.

The neophyte occurrence at different altitudes, in crops and farming types was analysed using multivariate analyses in the CANOCO 4.5 software (ter Braak and Šmilauer, 2002). The Braun-Blanquet scale values were transformed to an ordinal scale (van der Maarel, 1979). Due to long gradients on the first canonical axis (5.115 SD units) in the compositional turnover in a detrended correspondence analysis (DCA), the canonical correspondence analysis (CCA) was subsequently applied. In the CCA, net effects of explanatory variables on neophytes occurrence were determined. The altitude, crop (winter cereals, spring cereals and wide-row crops) and type of farming (organic, conventional) were used as explanatory variables. The net effects of a particular variable were obtained after the exclusion of the effects shared with other variables. The net effects were tested using partial CCAs, when only one explanatory variable was used and the other variables were used as covariables (Lososová *et al.*, 2004). The ratio of a certain canonical eigenvalue to the sum of all eigenvalues (total inertia) was used to estimate the proportion of the explained variation (Borcard *et al.*, 1992). The effects were evaluated using Monte Carlo permutation tests for the first or all canonical axes (999 permutations were used).

RESULTS AND DISCUSSION

Totally, 172 weed species were found (volunteer crops were not included). Among the observed species, 50 % were considered as archaeophytes (86 species), 42 % as apophytes (73 species) and 8 % as neophytes (13 species). Pyšek *et al.* (2012b) state that the alien flora of the Czech Republic forms 33.1 % of the total plant diversity. Similarly Danihelka *et al.* (2012) declare representation of alien flora as 36.6 %. A high proportion of non-native flora in our research (58 %) relate to the nature of the studied areas which undergo yearly disturbances and influence by man as a grower (Chytrý *et al.*, 2008). This finding correlates with the data reported by Holec *et al.* (2008), who mentioned approximately 30 % of apophytes, 60 % of archaeophytes, and 10 % of neophytes among arable weeds occurring in the Czech Republic. In individual European countries numbers of neophytes as weeds on arable land usually do not exceed 10 species, with only 3–5 of them having significant importance (Soukup *et al.* 2004).

The following frequencies were found for individual species: *Veronica persica* (31.38 %),

Amaranthus retroflexus (21.03 %), *Amaranthus powellii* (16.90 %), *Matricaria discoidea* (7.24 %), *Galinsoga parviflora* (4.83 %), *Conyza canadensis* (4.48 %), *Datura stramonium* (4.14 %), *Galinsoga quadriradiata* (3.79 %), *Oxalis fontana* (1.72 %), *Consolida orientalis* (1.03 %), *Solanum physalifolium* (0.69 %), *Abutilon theophrasti* (0.34 %), *Kochia scoparia* (0.34 %). Species frequencies in relation to individual factors are shown in Tab. I.

In respect of the status of invasiveness (Pyšek *et al.*, 2012b), 6 neophytes were considered as invasive (*Amaranthus powellii*, *Amaranthus retroflexus*, *Conyza canadensis*, *Galinsoga parviflora*, *Galinsoga quadriradiata*, *Kochia scoparia*). Six species were naturalized (*Abutilon theophrasti*, *Consolida orientalis*, *Datura stramonium*, *Matricaria discoidea*, *Oxalis fontana*, *Veronica persica*). One species was considered as casual (*Solanum physalifolium*). *Solanum physalifolium* has occured in the Czech Republic as a neophyte since 1975. On arable land, it has occurred in vegetable crops and potatoes. As the number of known locations is increasing, independent and selfreproductive populations had been created. Therefore, *S. physalifolium* can be classified in the Czech Republic as an invasive weed (Holec *et al.*, 2006).

I: *Species frequencies (%) related to studied factors*

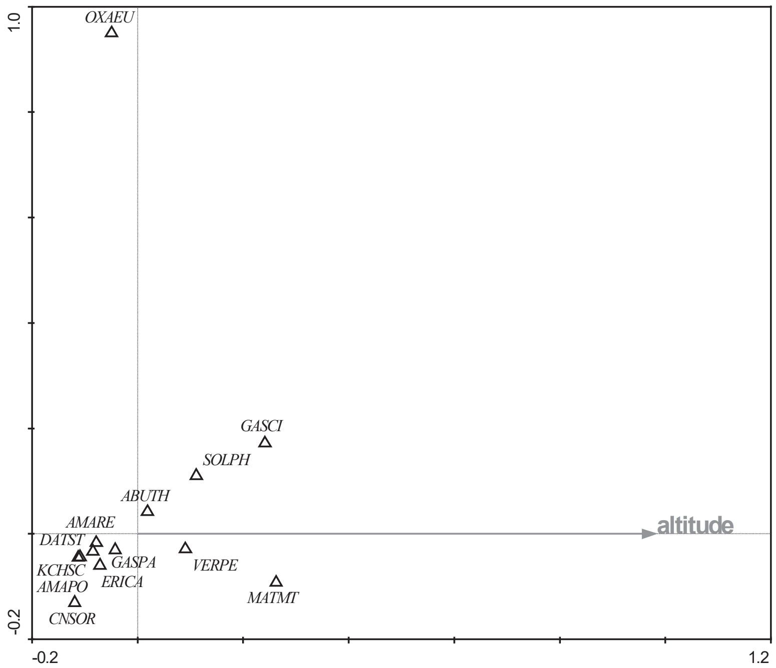
	All	Type of farming		Altitude (m a.s.l.)			Crop		
		conv	org	<250	250–350	>350	WC	SC	WRC
Veronica persica	31.38	29.75	33.33	15.93	42.70	39.77	30.84	28.41	34.74
Amaranthus retroflexus	21.03	19.62	22.73	33.63	23.60	2.27	3.74	13.64	47.37
Amaranthus powellii	16.90	8.23	27.27	34.51	11.24	0.00	9.35	14.77	27.37
Matricaria discoidea	7.24	3.16	12.12	0.00	5.62	18.18	8.41	9.09	4.21
Galinsoga parviflora	4.83	1.90	8.33	6.19	6.74	1.14	0.00	5.68	9.47
Conyza canadensis	4.48	1.27	8.33	6.19	5.62	1.14	2.80	3.41	7.37
Datura stramonium	4.14	1.90	6.82	7.08	4.49	0.00	0.00	2.27	10.53
Galinsoga quadriradiata	3.79	1.27	6.82	0.88	3.37	7.95	1.87	1.14	8.42
Oxalis fontana	1.72	1.27	2.27	0.88	4.49	0.00	1.87	3.41	0.00
Consolida orientalis	1.03	0.63	1.52	1.77	1.12	0.00	0.93	2.27	0.00
Solanum physalifolium	0.69	0.63	0.76	0.88	0.00	1.14	0.00	0.00	2.11
Abutilon theophrasti	0.34	0.63	0.00	0.00	1.12	0.00	0.00	0.00	1.05
Kochia scoparia	0.34	0.00	0.76	0.00	1.12	0.00	0.93	0.00	0.00

conv – conventional farming; org – organic farming; WC – winter cereals; SC – spring cereals; WRC – wide-row crops

II: *Net effects of explanatory variables on the occurrence of neophytes*

	Eigenvalue	%	F-ratio	p-value
All	0.804	14.20	7.111	0.001
Altitude	0.424	7.49	14.990	0.001
Crop	0.220	3.88	3.888	0.001
Type of farming	0.116	2.05	4.090	0.001

Eigenvalue – sum of all canonical eigenvalues (total inertia = 5.664); % – percentage of explained variance; F-ratio for the test of significance of all (first) canonical axes; p-value – corresponding probability value obtained using the Monte Carlo permutation test (999 permutations)



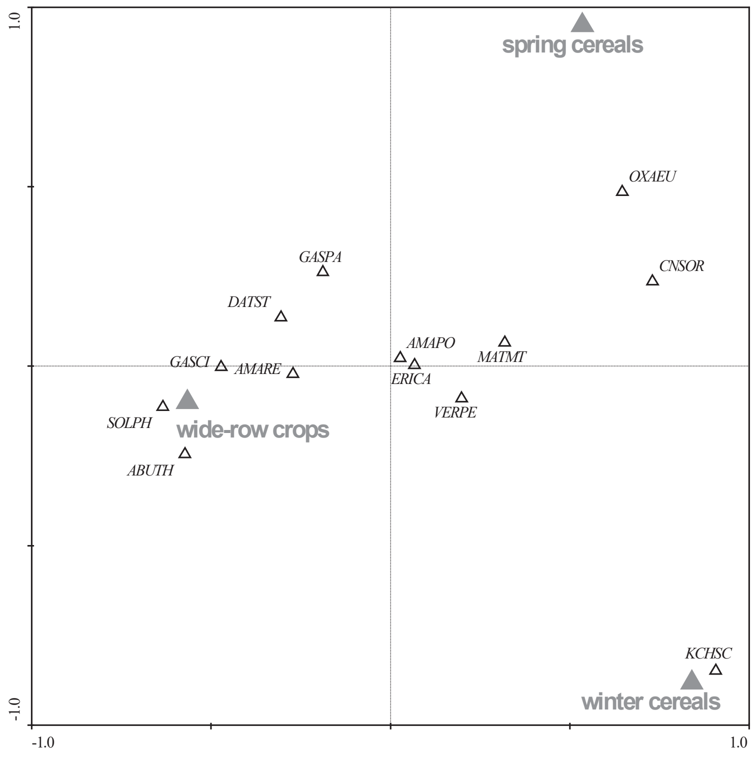
2: *Ordination diagram, pCCA. Occurrence of neophytes at different altitudes.*
Abbreviations: ABUTH – *Abutilon theophrasti*; AMAPO – *Amaranthus powellii*; AMARE – *Amaranthus retroflexus*; CNSOR – *Consolida orientalis*; ERICA – *Conyza canadensis*; DATST – *Datura stramonium*; GASPA – *Galinsoga parviflora*; GASCI – *Galinsoga quadriradiata*; KCHSC – *Kochia scoparia*; MATMT – *Matricaria discoidea*; OXAEU – *Oxalis fontana*; SOLPH – *Solanum physalifolium*; VERPE – *Veronica persica*.

Four found neophytes have the status of alien expansive weeds (sensu Jehlík, 1998): *Abutilon theophrasti*, *Amaranthus powellii*, *Kochia scoparia* and *Consolida orientalis*. These species are regularly introduced into the Czech Republic, having a high level of ecological adaptability and reproductive ability in synanthropic ecotopes, especially on cultivated arable land.

The net effects of all variables (altitude, crop, type of farming) on the occurrence of neophytes were statistically significant (Tab. II). Together, these variables explained 14.2 % of the total variability in the studied species data. The majority of the variation was explained by altitude (7.49 %), followed by crop (3.88 %) and type of farming (2.05 %).

The ordination diagram in Fig. 2 clearly shows that the incidence of neophytes is primarily concentrated in lower altitudes. Most neophytes species were found in warm lowland areas (Jehlík, 1998; Chytrý *et al.*, 2009; Pyšek *et al.*, 2012a). In terms of altitude the incidence of *Veronica persica*, *Matricaria discoidea* and *Galinsoga quadriradiata* is slightly higher at higher elevation. These findings seem to be additional characteristics to so far reported specific factors such as site conditions (wider ecological amplitude, tolerance of colder locations) partially linked to a longer period of occurrence in our country, a gradual process of naturalisation and spread to other regions. The incidence of *Solanum physalifolium* with increasing altitude is a rather random affair related to a rare occurrence in the Bohemian-Moravian Highlands at an altitude of 500 m a. s. l. probably due to the introduction by horticultural activities from the warm lowland locations. In the past, *Solanum physalifolium* was restricted to warm climates, particularly the lowlands around Prague and the Elbe river basin (Holec *et al.*, 2006; Jursík *et al.*, 2011).

The ordination diagram in Fig. 3 clearly shows that the incidence of neophytes is mainly associated with stands of spring wide-row crops, especially root crops and vegetables. This confirms reports of Lososová and Cimalová (2009) about a higher incidence of neophytes in wide-row crops. Jehlík (1998) lists the largest group of neophytes with optimal development in root crops. Pyšek *et al.* (2005) also report that neophytes are most numerous in relatively recently introduced crops. In addition, the affinity of monitored neophytes to cultivated crops is related to the biological characteristics of these plants. Most of these weeds belong to a biological group called late spring annual weeds (*Galinsoga parviflora*, *Galinsoga quadriradiata*, *Datura stramonium*, *Amaranthus retroflexus*, *Amaranthus powellii*, *Solanum physalifolium*, *Abutilon theophrasti*), whose germination is concentrated in the period from May to June, when the soil is sufficiently warm, and their growth and development match with root crops planted in warm late spring/summer months of the year (Kohout, 1997; Jursík *et al.*, 2011). The ordination diagram in Fig. 3 shows a low connection of neophytes with cereals. The incidence of overwintering annual weed species is related to cereals (*Veronica persica*, *Matricaria discoidea*, *Consolida orientalis*) which demonstrate adapted life cycles,

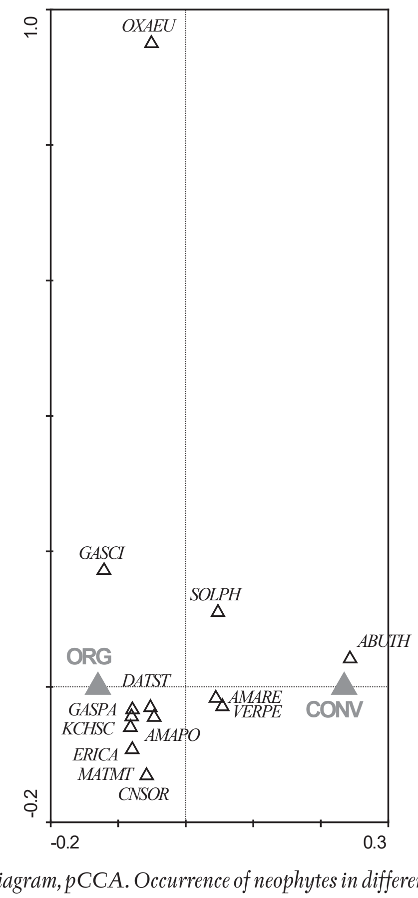


3: *Ordination diagram, pCCA. Occurrence of neophytes in different crops.*

especially winter cereals. *Consolida orientalis* has been a frequent weed in winter cereals in warm areas on chernozem soils in recent years (Jehlík, 1998). A tendency of *Oxalis fontana* occuring in spring cereals is likely in relevés taken in spring barley on a damp location near a watercourse, where optimal conditions for a strong development of this weed exist (Deyl and Ušák, 1956; Holzner and Glauninger, 2005). The ordination diagram in Fig. 3 shows the connection of the occurrence of *Kochia scoparia* with winter cereals, while most often it is found in parallel with other neophytes in cultures of root crops (Jehlík, 1998). One explanation is based on only one finding of *K. scoparia* in a relevé taken in winter wheat in Southern Moravia in a maize production area, where the weed has been strongly spreading on arable land in recent times (Holec *et al.*, 2004).

The ordination diagram in Fig. 4 shows the occurrence of neophytes in conventional and organic farming systems. Borysiak (2015) found 6 neophytes on very extensively organically cultivated arable lands in Poland (*Veronica persica, Galinsoga parviflora, Oxalis fontana, Matricaria discoidea, Conyza canadensis, Erigeron annuus*). All of them contributed to weediness only at a small degree. Intensification of agriculture may promote the invasion of neophytes (Chytrý, 2001; Soukup *et al.*, 2004, Kovács-Hostyánszki *et al.*, 2011). Our results, however, show a higher proportion of neophytes in organic farming. The occurrence of neophytes, therefore, does not necessarily relate only to the declared management system, but it will be affected also by the application of intensive farming.

There were also seen organic fields where a high intensity of permitted farming methods and weed control (e. g. intensive mechanical cultivation) strongly reduced the overall level of weed infestation and created so the "space" for the invasion of neophytes. The high level of weed infestation of arable lands prevented the migration of neophytes in Poland (Borysiak, 2015). Simultaneously, organic fields allow the occurrence even of weeds which are sensitive to commonly used herbicides and so on organic fields, these weeds have better conditions for their survival (e. g. *Galinsoga* spp., *Consolida orientalis*). *Abutilon theophrasti* was noticed just under conventional farming, which might be related to its almost exclusive incidence in sugar beet which is rarely grown in organic farming system.



4: *Ordination diagram, pCCA. Occurrence of neophytes in different types of farming.*

CONCLUSION

We found 13 neophytes (8 % of all species) in the monitored agrophytocoenoses of the Czech Republic. Their occurrence is mainly concentrated in lower altitudes. Except for four very common species, we can conclude that the neophyte species we identified are still not widespread on agricultural land (a frequency less than 5 %). On the other hand, several species have been common on arable land for a long time and caused significant problems in grown crops regardless of lower frequencies (*Amaranthus retroflexus* in root crops, *Galinsoga parviflora* in vegetables, *Abutilon theophrasti* in sugar beet, and *Veronica persica* in winter crops). Some species are invading new areas and we predict an increase in their harmfulness in the near future (*Galinsoga quadriradiata*, *Amaranthus powellii*, *Solanum physalifolium*). Our results show a higher proportion of neophytes in organic farming. The occurrence of neophytes, therefore, does not necessarily relate only to intensive agriculture and lower species diversity but it is very likely more affected by the type of crops grown and related farming practices. Most neophytes were associated with stands of wide-row crops, especially root crops and vegetables.

Acknowledgements

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