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Occurrence of native weed species on arable land – Effect of different environmental factors

*Luděk Tyšer, Michaela Kolářová**

Department of Agroecology and Crop Production, Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences Prague, Prague, Czech Republic

**Corresponding author: mkolarova@af.czu.cz*

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Abstract: Native species form a substantial part of arable weed communities. The objective of this survey was to study the occurrence of native species in arable fields in the Czech Republic related to applied management systems (conventional and organic farming), crops (winter cereals, spring cereals, wide-row crops) and environmental conditions at different altitudes. In 2006–2018, a phytocoenological survey (320 relevés) was performed across the Czech Republic. In total, 180 weed species were recorded, of which 43.33% were considered as native (78 species). The net effects of all the studied variables on the occurrence of native species were found as statistically significant. Most of the variability was explained by the altitude, followed by the crop and type of farming. The highest occurrence of native weeds was noticed in organic farming and cereals and increased with an increasing altitude. The higher incidence in higher elevations can be connected to the more intensive agriculture in the lowlands.

Keywords: apophytes; *Chenopodium album*; species frequencies; *Viola arvensis;* weed communities

Native species form one of the richest groups in plant communities (Danihelka et al. 2012). Pyšek et al. (2012) define native species as those that have evolved in a given area or that arrived there by natural means without any intentional or accidental intervention of humans from an area where they are native.

Native species of weed communities are essentially annual and perennial species that historically come from regularly disturbed habitats with very diverse conditions (disturbed sites in floodplains of rivers, alluviums, erosion grooves, incineration sites, habitats strongly influenced by animals, etc.). Former communities contained many of the weeds of today (Holzner & Immonen 1982; Arlt et al. 1991).

During the historical development of plant communities, there was a stable and repeated enrichment of native vegetation with alien species, first by archaeophytes (before 1500 A.D.), then by neophytes (taxa introduced after 1500 A.D.) (Preston et al. 2004; Pyšek et al. 2012). Thus, there are several contrasting processes that can be observed: the introduction of often ubiquitous alien plant species (i.e., biological invasion), the decline or extirpation of native species, and a remaining high species richness of native species, based on those that are common (Kühn & Klotz 2006).

Many types of native species have a strong potential for their spread. Prach & Wade (1992) suggested not to use the term invasion for the spreading of native species (which remains reserved for spreading of non-native species), but expansion. Since the 1950s, occurrences of native species have been increasing in number and distribution (Sukopp 2006). Sádlo & Pokorný (2003) gave an overview of the main expansive species present, classified according to their original habitats in the ancient and medieval landscape. Widespread, nitrophilous and shadow tolerating species, mostly native species, rise

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in importance and form weed groups poor in species, but partly very rich in individuals (Hilbig 1982). The expansion of native species can be much faster in some cases than that of alien species because native species have a higher number of diaspores or a shorter period of adaptation in new localities (Zajac & Zajac 2009).

The phenomenon of native species is widespread, but little studied. Therefore, the role of native species in the studies of synanthropic flora has often been underappreciated (Sukopp 2008). This raises a number of questions. Are native species currently an important component of our arable communities? Are dangerous and widely harmful species represented here? Are endangered species represented here? How do various environmental factors affect the representation of native weed species? According to the long period of their action in our conditions, it could be concluded that their distribution will be, in contrast to alien species (especially neophytes) (Chytrý et al. 2009), widespread and not very dependent on environmental factors. Native species usually have optimal conditions (climatic optimum) for their existence in the territory of their origin and primary location. For neophytes, as well as archaeophytes, the climate still remains a major obstacle to their wider distribution (Lososová et al. 2004).

The aim of this study is to evaluate the occurrence of native species in arable weed communities in the Czech Republic on the basis of the following parameters (*i*) applied farming types (conventional and organic), (*ii*) crops (winter cereals, spring cereals, wide-row crops), and (*iii*) environmental site conditions (represented by altitude).

MATERIAL AND METHODS

A phytocoenological survey was performed on selected farms in representative areas of the Czech Republic with different climate and soil conditions from 2006 to 2018 (Figure 1). The farms were chosen according to three criteria: (1) farming type used: conventional (use of herbicides) and organic (methods following the appropriate valid legislation with no herbicides and applying organic practices for at least 2 years) farms were selected; (2) crops: winter cereals (winter wheat, winter barley, rye, spelt, triticale), spring cereals (spring barley, oat, naked oat, spring wheat, spring rye, spring triticale) and wide-row spring crops (sugar beet, potatoes, maize, oil pumpkin, feeding carrots, fodder beet, beetroot, sunflower, onion);

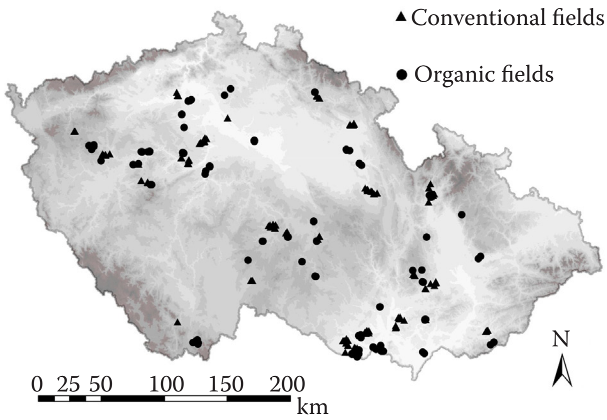

Figure 1. Map of the Czech Republic showing the recorded relevés

(3) altitude between 170 and 681 m a.s.l. Totally, we recorded 320 phytocoenological relevés, of which 163 were farmed in conventionally managed fields and 157 in organic fields. Regarding the crops, 107 relevés were recorded in winter cereals, 108 in spring cereals and 105 in wide-row crops. The assessments were undertaken in June and July for the cereals and in late July, August, September and the beginning of October in the wide row crops. Concerning the altitude, 116 relevés were recorded at altitudes lower than 250 m, 92 relevés at 250–350 m, and 112 relevés at levels higher than 350 m.

The nine-degree Braun-Blanquet scale was used for the visual assessment of the cover (Braun-Blanquet 1964, modified by Barkman et al. 1964) on plots of 100 m^2 (phytocoenological relevés). The relevés were laid out in the central parts of the individual fields. For each taxon, the native/alien status was classified (Pyšek et al. 2012). The nomenclature followed Kubát et al. (2002). Endangered weed species were classified according to Grulich (2012).

The species frequencies were calculated (only the presence of the species in a relevé was considered). The total frequency (%) is calculated as the share of the sum of the presences of the native species in the relevés (inside the individual factors) to the sum of the presences of the native species in all the relevés.

The obtained data on the occurrence of native species in the different studied factors was examined by multivariate statistics in the CANOCO software (version 4.5) (ter Braak & Šmilauer 2002). The Braun-Blanquet values were converted to an scale 1–9 (van der Maarel 1979). Due to the rather long gradient on the first canonical axis [(5.303 SD units;

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SD – species turnover units, derived from the 'standard deviation' (width) of a species response curve (Hill & Gauch 1980)] in the compositional turnover in a detrended correspondence analysis (DCA), the canonical correspondence analysis (CCA) was chosen as a direct analysis. As environmental variables, the type of farming, crop and altitude were used. The net effects of all the explanatory variables on the occurrence of native species were determined in the pCCAs after excluding the effects shared with other variables (only one explanatory variable was used and the other variables were used as covariables) (Lososová et al. 2004). The ratio of an individual canonical eigenvalue to the sum of all eigenvalues (total inertia) was used to assess the proportion of the explained variation (Borcard et al. 1992). The effects were tested by Monte Carlo permutation tests (ter Braak & Šmilauer 2002) (999 permutations were used). In ordination diagrams, the species are marked according to the European and Mediterranean Plant Protection Organization (EPPO) Codes (EPPO 2019).

RESULTS

Totally, 180 weed species were recorded (volunteer crops were not included), where 43.33% were considered as native (78 species), 48.89% as archaeophytes (88 species) and 7.78% as neophytes (14 species).

The species frequencies of native weeds in relation to the individual factors are shown in Table 1. The table shows that the most frequent weed species in the Czech Republic are *Chenopodium album*, *Viola arvensis*, *Polygonum aviculare*, *Elytrigia repens*, *Stellaria media*, *Galium aparine* and *Taraxacum* sect. *Ruderalia*.

Some endangered species of native weeds have also been found: *Aphanes arvensis* (C3), *Odontites vernus* (C2t), *Rhinanthus alectorolophus* (C3). Their occurrence was fully or mainly concentrated in the organic farming and at higher altitudes.

The net effects of all the examined variables (type of farming, crop, altitude) on the occurrence of native species were found as statistically significant (Table 2). These variables altogether explained 10.0% of the total variation in the species data. The majority of the variability can be linked to the altitude (5.3%), followed by the crop (2.8%) and the type of farming (1.6%).

In relation to the altitude (Table 1, Figure 2), an increase in the representation of weed taxa at higher altitudes in the Czech Republic was recorded. The occurrence of native weed species in crops (Table 1, Figure 3) shows that, overall, their highest representation is in spring cereals. Individual species, however, show some different tendencies. In relation to the farming systems, native weed species were mostly found in the organic farming (Table 1, Figure 4).

DISCUSSION

In the plant communities of the Czech Republic, the proportion of native species is 66.9% (Pyšek et al. 2012) or 63.4% (Danihelka et al. 2012). The relatively low proportion of native species and the high share of alien flora in our study (56.67%) is associated with the character of the studied areas, which have been under permanent human disturbance each year (Chytrý et al. 2008). The highest proportion of alien species can be found on the arable land (Küzmič & Šilc 2017). As reported by Lososová and Simonová (2008), the representation of native species in weed vegetation in Moravia is 49%.

Concerning the most represented native species of weeds, a similar composition to our weed vegetation has been reported by Lososová et al. (2008). Native species of weeds are often significantly economically harmful weeds (Schroeder et al. 1993). Some native weed species are also registered among the current expansive species of our flora. In particular, *G. aparine*, *V. arvensis*, *E. repens*, *T.* sect. *Ruderalia*, *A. vulgaris* are spreading (Sádlo & Pokorný 2003; Mikulka et al. 2009; Šarić et al. 2011). They spread strongly even outside the arable land, from where they enrich the adjacent field cultures with their diasporas (e.g., *Taraxacum* sect. *Ruderalia*).

Only a lower number of endangered native weeds (3 species) were found, which may be related to the fact that the species whose occurrence is decreasing in weed communities mainly include archaeophytes (Lososová et al. 2004). The majority of the threatened species in Western and Central Europe have a Mediterranean origin (Pyšek et al. 2002).

With respect to the net effects of all the examined variables, Lososová et al. (2004) also confirm the primary importance of the altitude in the weed species composition. They emphasised that, on a broad geographical scale, the vegetation of a man-made habitat with a large proportion of alien species that is strongly subjected to a management system is more affected by primary environmental factors than human activities.

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Table 1. Species frequencies (%) related to the studied factors (30 species with the highest frequency)

Species	All	Type of farming		Crop			Altitude (m a.s.l.)		
		conv.	org.	WC	SC	WR	< 250	250–350	> 350
Chenopodium album L.	72.81	60.74	85.35	52.34	81.48	84.76	80.17	68.48	68.75
Viola arvensis Murray	58.75	53.99	63.69	65.42	67.59	42.86	33.62	65.22	79.46
Polygonum aviculare L.	55.31	47.24	63.69	61.68	71.30	32.38	55.17	52.17	58.04
Elytrigia repens (L.) Nevski	41.88	33.13	50.96	39.25	35.19	51.43	19.83	38.04	67.86
Stellaria media (L.) Vill.	40.94	22.09	60.51	40.19	41.67	40.95	25.86	41.30	56.25
Galium aparine L.	40.63	27.61	54.14	48.60	50.93	21.90	28.45	47.83	47.32
Taraxacum sect. *Ruderalia* Kirschner, H. Øllgaard & Štěpánek	39.06	38.65	39.49	46.73	41.67	28.57	30.17	32.61	53.57
Plantago major L.	23.13	14.72	31.85	14.02	25.93	29.52	7.76	21.74	40.18
Persicaria lapathifolia (L.) Delarbre	20.00	9.82	30.57	10.28	22.22	27.62	18.97	19.57	21.43
Galeopsis tetrahit L.	16.88	8.59	25.48	13.08	22.22	15.24	0.00	3.26	45.54
Vicia hirsuta (L.) S. F. Gray	15.31	3.68	27.39	16.82	17.59	11.43	0.86	10.87	33.93
Chenopodium hybridum L.	13.44	9.82	17.20	8.41	9.26	22.86	31.90	6.52	0.00
Aethusa cynapium L.	13.44	11.04	15.92	14.02	18.52	7.62	7.76	22.83	11.61
Rumex obtusifolius L.	13.44	6.13	21.02	10.28	10.19	20.00	6.03	11.96	22.32
Persicaria maculosa S. F. Gray	12.50	4.29	21.02	13.08	15.74	8.57	2.59	15.22	20.54
Vicia tetrasperma (L.) Schreber	12.19	4.91	19.75	13.08	19.44	3.81	0.00	13.04	24.11
Poa annua L.	11.25	11.04	11.46	11.21	15.74	6.67	0.00	11.96	22.32
Chenopodium polyspermum L.	10.63	2.45	19.11	6.54	11.11	14.29	13.79	10.87	7.14
Artemisia vulgaris L.	10.31	6.13	14.65	6.54	12.96	11.43	2.59	9.78	18.75
Rumex crispus L.	8.44	3.07	14.01	8.41	12.96	3.81	2.59	9.78	13.39
Gnaphalium uliginosum L.	7.81	4.91	10.83	6.54	8.33	8.57	0.00	2.17	20.54
Arabidopsis thaliana (L.) Heynh.	7.19	1.23	13.38	7.48	6.48	7.62	0.86	4.35	16.07
Stachys palustris L.	6.56	0.61	12.74	4.67	10.19	4.76	0.86	5.43	13.39
Equisetum arvense L.	6.56	4.91	8.28	4.67	8.33	6.67	0.86	6.52	12.50
Mentha arvensis L.	5.63	0.61	10.83	6.54	4.63	5.71	0.00	7.61	9.82
Arenaria serpyllifolia L.	4.06	0.61	7.64	4.67	4.63	2.86	1.72	5.43	5.36
Scleranthus annuus L.	4.06	0.61	7.64	3.74	7.41	0.95	0.00	1.09	10.71
Persicaria hydropiper (L.) Delarbre	4.06	1.84	6.37	3.74	6.48	1.90	0.00	1.09	10.71
Tussilago farfara L.	3.13	0.00	6.37	2.80	3.70	2.86	0.86	5.43	3.57
Urtica dioica L.	3.13	0.61	5.73	3.74	2.78	2.86	1.72	5.43	2.68
The total frequency (%)	100.00	33.30	66.70	31.97	38.37	29.66	22.66	27.64	49.70

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

Table 2. Net effects of the explanatory variables on the occurrence of native species

Explanatory variables	Covariables	Eigenvalue	%	*F*-ratio	*P*-value
All	–	0.327	10.0	8.525	0.001
Type of farming	crop, altitude	0.053	1.6	5.576	0.001
Crop	type of farming, altitude	0.092	2.8	4.795	0.001
Altitude	type of farming, crop	0.175	5.3	18.303	0.001

Eigenvalue – sum of all the canonical eigenvalues (total inertia = 3.276); % – percentage of the explained variance; *F*-ratio for the test of significance of all the (first) canonical axes; *P*-value – the corresponding probability value obtained using the Monte Carlo permutation test (999 permutations)

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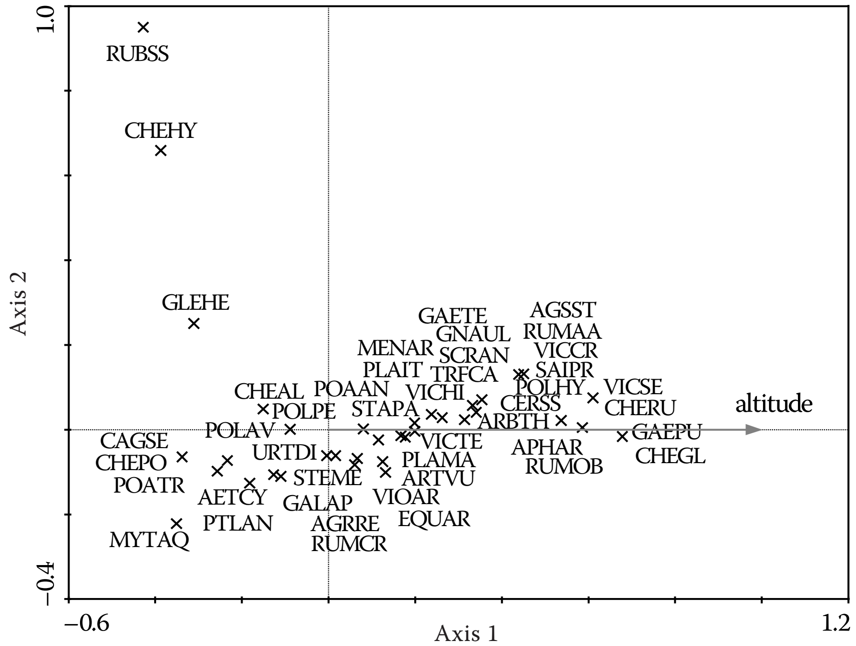

Figure 2. Ordination diagram, pCCA (eigenvalues of axis 1: 0.175, axis 2: 0.226); occurrence of native species at different altitudes

Minimum species fit 1% – 44 species out of 78; AETCY – *Aethusa cynapium*; AGRRE – *Elytrigia repens*; AGSST – *Agrostis stolonifera*; APHAR – *Aphanes arvensis*; ARBTH – *Arabidopsis thaliana*; ARTVU – *Artemisia vulgaris*; CAGSE – *Calystegia sepium*; CERSS – *Cerastium* spp.; CHEAL – *Chenopodium album*; CHEGL – *Chenopodium glaucum*; CHEHY – *Chenopodium hybridum*; CHEPO – *Chenopodium polyspermum*; CHERU – *Chenopodium rubrum*; EQUAR – *Equisetum arvense*; GAEPU – *Galeopsis pubescens*; GAETE – *Galeopsis tetrahit*; GALAP – *Galium aparine*; GLEHE – *Glechoma hederacea*; GNAUL – *Gnaphalium uliginosum*; MENAR – *Mentha arvensis*; MYTAQ – *Myosoton aquaticum*; PLAIT – *Plantago uliginosa*; PLAMA – *Plantago major*; POAAN – *Poa annua*; POATR – *Poa trivialis*; POLAV – *Polygonum aviculare*; POLHY – *Persicaria hydropiper*; POLPE – *Persicaria maculosa*; PTLAN – *Potentilla anserina*; RUBSS – *Rubus* spp.; RUMAA – *Rumex acetosella*; RUMCR – *Rumex crispus*; RUMOB – *Rumex obtusifolius*; SAIPR – *Sagina procumbens*; SCRAN – *Scleranthus annuus*; STAPA – *Stachys palustris*; STEME – *Stellaria media*; TRFCA – *Trifolium campestre*; URTDI – *Urtica dioica*; VICCR – *Vicia cracca*; VICHI – *Vicia hirsuta*; VICSE – *Vicia sepium*; VICTE – *Vicia tetrasperma*; VIOAR – *Viola arvensis;* pCCA – partial canonical correspondence analysis

In our survey, the altitude positively affected the representation of the weed taxa. Kolářová et al. (2013), describe a significant increase in the number of weed species with an increasing altitude as well. This may be related to a more intensive form of farming (and stronger regulatory pressure on weed communities) in fertile lowlands. Lososová and Cimalová (2009) state that the richness of the native species increased with an increasing altitude and the precipitation. Unlike alien plants (mainly neophytes), which are mainly bound to lower altitudes (Chytrý et al. 2009), native species are found throughout the whole country. In the lowlands, there are mainly thermophilous weed species (e.g., *Chenopodium hybridum*), while, in the foothill areas, there are species bound to humid climatic conditions and more acidic soils (e.g., *Gnaphalium uliginosum*, *Persicaria hydropiper*).

In our observations, the highest representation of native weed species was seen in the spring cereals. The individual species, however, show some different tendencies. Lososová and Cimalová (2009) state that the number of native species was similar in cereal fields and in root crops fields. In cereals, the most frequent weed species found are the annual winter and early spring species (e.g., *V. arvensis*, *P. aviculare*, *G. aparine*, *P. annua*, *Vicia* spp.). On the contrary, annual species germinating later in the spring predominate in the wide-row crops and are often tied to root crops (e.g., *Chenopodium* spp., *P. lapathifolia*). Also, Lososová et al. (2004) record thermophilous and nutrient-demanding weeds more frequently in root crops.

In relation to the farming systems, native weed species were mostly found in the organic farming. Their

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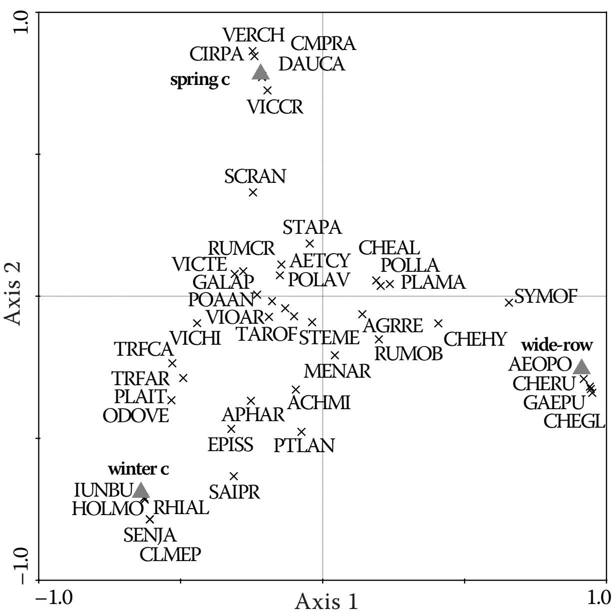

Figure 3. Ordination diagram, pCCA (eigenvalues of axis 1: 0.077, axis 2: 0.015), occurrence of native species in the different crops

Minimum species fit 1% – 43 species out of 78; ACHMI – *Achillea millefolium*; AEOPO – *Aegopodium podagraria*; AETCY – *Aethusa cynapium*; AGRRE – *Elytrigia repens*; APHAR – *Aphanes arvensis*; CHEAL – *Chenopodium album*; CHEGL – *Chenopodium glaucum*; CHEHY – *Chenopodium hybridum*; CHERU – *Chenopodium rubrum*; CIRPA – *Cirsium palustre*; CLMEP – *Calamagrostis epigejos*; CMPRA – *Campanula rapunculoides*; DAUCA – *Daucus carota*; EPISS – *Epilobium* spp.; GAEPU – *Galeopsis pubescens*; GALAP – *Galium aparine*; HOLMO –*Holcus mollis*; IUNBU – *Juncus bufonius*; MENAR – *Mentha arvensis*; ODOVE – *Odontites vernus*; PLAIT – *Plantago uliginosa*; PLAMA – *Plantago major*; POAAN – *Poa annua*; POLAV – *Polygonum aviculare*; POLLA – *Persicaria lapathifolia*; PTLAN – *Potentilla anserina*; RHIA – *Rhinanthus alectorolophus*; RUMCR – *Rumex crispus*; RUMOB – *Rumex obtusifolius*; SAIPR – *Sagina procumbens*; SCRAN – *Scleranthus annuus*; SENJA – *Senecio jacobaea*; STAPA – *Stachys palustris*; STEME – *Stellaria media*; SYMOF – *Symphytum officinale*; TAROF – *Taraxacum* sect. *Ruderalia*; TRFAR – *Trifolium arvense*; TRFCA – *Trifolium campestre*; VERCH – *Veronica chamaedrys*; VICCR – *Vicia cracca*; VICHI – *Vicia hirsuta*; VICTE – *Vicia tetrasperma*; VIOAR – *Viola arvensis;* pCCA – partial canonical correspondence analysis

higher prevalence is probably related to the lower intensity of the regulatory interventions against weeds, the generally diverse crop rotations in organic farming and sometimes to the thinner crop stands also. The higher species richness is also undoubtedly related to the more diversified spatial structure of the fields and landscape elements in organic farming. The growing heterogeneity of the landscape usually leads to an increase in species richness (Deutschewitz et al. 2003; Fried et al. 2008). Besides, other species sensitive to herbicides may be represented, e.g., *Vicia* spp. (Eisele 1996), some species of the surrounding plant communities may enter and many perennial species occur more frequently. In conventional farming in particular, species resistant to massively used herbicides and species that were recently highly spreading have a relatively high proportion (e.g., *V. arvensis*, *Taraxacum* spp.).

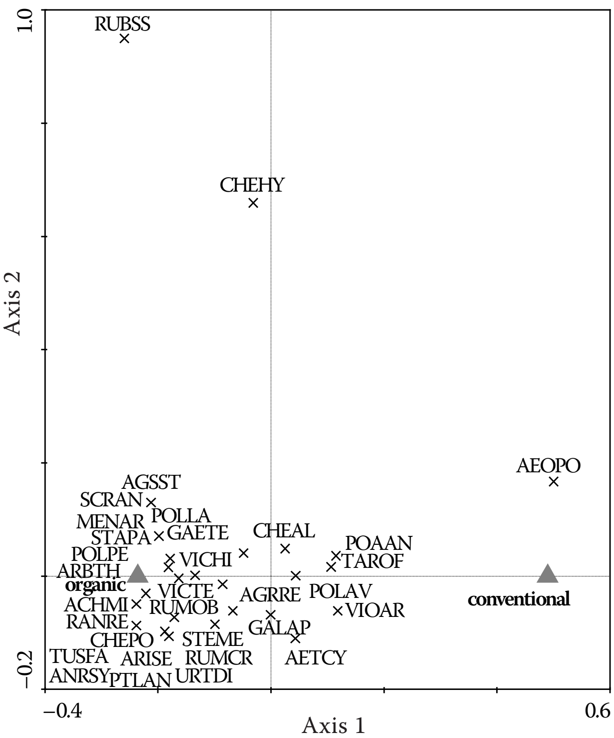

Figure 4. Ordination diagram, pCCA (eigenvalues of axis 1: 0.053, axis 2: 0.226); occurrence of native species in the different farming types

Minimum species fit 1% – 32 species out of 78; ACHMI – *Achillea millefolium*; AEOPO – *Aegopodium podagraria*; AETCY – *Aethusa cynapium*; AGRRE – *Elytrigia repens*; AGSST – *Agrostis stolonifera*; ANRSY – *Anthriscus sylvestris*; ARBTH – *Arabidopsis thaliana*; ARISE – *Arenaria serpyllifolia*; CHEAL – *Chenopodium album*; CHEHY – *Chenopodium hybridum*; CHEPO – *Chenopodium polyspermum*; GAETE – *Galeopsis tetrahit*; GALAP – *Galium aparine*; MENAR – *Mentha arvensis*; POAAN – *Poa annua*; POLAV – *Polygonum aviculare*; POLLA – *Persicaria lapathifolia*; POLPE – *Persicaria maculosa*; PTLAN – *Potentilla anserina*; RANRE – *Ranunculus repens*; RUBSS – *Rubus* spp.; RUMCR – *Rumex crispus*; RUMOB – *Rumex obtusifolius*; SCRAN – *Scleranthus annuus*; STAPA – *Stachys palustris*; STEME – *Stellaria media*; TAROF – *Taraxacum* sect. *Ruderalia*; TUSFA – *Tussilago farfara*; URTDI – *Urtica dioica*; VICHI – *Vicia hirsuta*; VICTE – *Vicia tetrasperma*; VIOAR – *Viola arvensis;* pCCA – partial canonical correspondence analysis

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In conclusion, although a relatively low proportion of native plant species is represented on the arable land compared to other plant communities, native species are an important and irreplaceable component of weed vegetation. Some species are among the most widespread and also the most economically important weeds on our farmland. Their control in the fields is usually necessary and desirable (e.g., *G. aparine*, *E. repens*). It is necessary to choose the appropriate means for regulation with regard to their specific species distribution and management system. The care for neighbouring natural habitats is also important. On the other hand, some native weed species belong to the endangered taxa of our flora and deserve appropriate measures for their protection (among other things to support species diversity). One of the measures is, for example, organic farming. It turns out that the intensity of the agricultural management can also be reflected in the spatial vertical distribution of native weed species, where, at higher altitudes, due to generally lower regulatory pressure, these species have a higher chance of existing.

REFERENCES

Arlt K., Hilbig W., Illig H. (1991): Ackerunkräuter – Ackerwildkräuter. Wittenberg Lutherstadt, Ziemsen Verlag.

Barkman J.J., Doing H., Segal S. (1964): Kritische Bemerkungen und Vorschläge zur quantitativen Vegetationsanalyse. Acta Botanica Neerlandica, 13: 394–419.

Borcard D.P., Legendre P., Drapeau P. (1992): Partialling out the spatial component of ecological variation. Ecology, 73: 1045–1055.

Braun-Blanquet J. (1964): Pflanzensoziologie. Wien, Springer.

Chytrý M., Maskell L.C., Pino J., Pyšek P., Vilà M., Font X., Smart S.M. (2008): Habitat invasions by alien plants: A quantitative comparison among Mediterranean, subcontinental and oceanic regions of Europe. Journal of Applied Ecology, 45: 448–458.

Chytrý M., Wild J., Pyšek P., Tichý L., Danihelka J., Knollová I. (2009): Maps of the level of invasion of the Czech Republic by alien plants. Preslia, 81: 187–207.

Danihelka J., Chrtek J. Jr., Kaplan Z. (2012): Checklist of vascular plants of the Czech Republic. Preslia, 84: 647–811.

Deutschewitz K., Lausch A., Kühn I., Klotz S. (2003): Native and alien plant species richness in relation to spatial heterogeneity on a regional scale in Germany. Global Ecology & Biogeography, 12: 299–311.

Eisele J.-A. (1996): *Vicia hirsuta* (L.) S.F.Gray – Problemunkraut des Organischen Landbaus. Journal of Plant Diseases and Protection, 15: S225–S231.

EPPO (2019): EPPO Global Database. Available at https://gd.eppo.int

Fried G., Norton L.R., Reboud X. (2008): Environmental and management factors determining weed species composition and diversity in France. Agriculture, Ecosystems and Environment, 128: 68–76.

Grulich V. (2012): Red List of vascular plants of the Czech Republic: 3rd edition. Preslia, 84: 631–645.

Hill M.O., Gauch H.G. (1980): Detrended correspondence analysis, an improvedordination technique. Vegetatio, 42: 47–58.

Hilbig W. (1982): Preservation of agrestal weeds. In: Holzner W., Numata M. (eds): Biology and Ecology of Weeds. The Hague, W. Junk Publishers: 57–59.

Holzner W., Immonen R. (1982): Europe: An overview. In: Holzner W., Numata M. (eds): Biology and Ecology of Weeds. The Hague, W. Junk Publishers: 203–226.

Kolářová M., Tyšer L., Soukup J. (2013): Diversity of current weed vegetation on arable land in selected areas of the Czech Republic. Plant Soil and Environment, 59: 208–213.

Kubát K., Hrouda L., Chrtek J. Jr., Kaplan Z., Kirschner J., Štěpánek J. (2002): Klíč ke květeně České republiky. Praha, Academia.

Kühn I., Klotz S. (2006): Urbanization and homogenization – Comparing the floras of urban and rural areas in Germany. Biological Conservation, 127: 292–300.

Küzmič F., Šilc U. (2017): Alien species in different habitat types of Slovenia: Analysis of vegetation database. Periodicum Biologorum, 119: 199–208.

Lososová Z., Cimalová Š. (2009): Effects of different cultivation types on native and alien weed species richness and diversity in Moravia (Czech Republic). Basic and Applied Ecology, 10: 456–465.

Lososová Z., Simonová D. (2008): Changes during the 20th century in species composition of synanthropic vegetation in Moravia (Czech Republic). Preslia, 80: 291–305.

Lososová Z., Chytrý M., Kühn I. (2008): Plant attributes determining the regional abundance of weeds on central European arable land. Journal of Biogeography, 35: 177–187.

Lososová Z., Chytrý M., Cimalová Š., Kropáč Z., Otýpková Z., Pyšek P., Tichý L. (2004): Weed vegetation of arable land in Central Europe: Gradients of diversity and species composition. Journal of Vegetation Science, 15: 415–422.

Mikulka J., Korčáková M., Burešová V., Andr J. (2009): Changes in weed species spectrum of perennial weeds on arable land, meadows and pastures. Plant Protection Science, 45: S63–S66.

Prach K., Wade P.M. (1992): Population characteristics of expansive perennial herbs. Preslia, 64: 45–51.

Preston C.D., Pearman D.A., Hall A.R. (2004): Archaeophytes in Britain. Botanical Journal of the Linnean Society, 145: 257–294.

https://doi.org/10.17221/79/2020-PPS

Pyšek P., Sádlo J., Mandák B. (2002): Catalogue of alien plants of the Czech Republic. Preslia, 74: 97–186.

Pyšek P., Danihelka J., Sádlo J., Chrtek J. Jr., Chytrý M., Jarošík V., Kaplan Z., Krahulec F.,Moravcová L., Pergl J., Štajerová K., Tichý L. (2012): Catalogue of alien plants of the Czech Republic (2nd edition): Checklist update, taxonomic diversity and invasion patterns. Preslia, 84: 155–255.

Sádlo J., Pokorný P. (2003): Rostlinné expanze a vývoj krajiny v holocénní perspektivě. Zprávy České botanické společnosti, příloha, 19: 5–16.

Schroeder D., Mueller-Schaerer H., Stinson C.S.A. (1993): A European weed survey in 10 major crop systems to identify targets for biological control. Weed Research, 33: 449–458.

Sukopp H. (2006): Apophytes in the flora of Central Europe. Polish Botanical Studies, 22: 473–485.

Sukopp H. (2008): Apophyten in der Flora von Mitteleuropa. Braunschweiger Geobotanische Arbeiten, 9: 443–458.

Šarić T., Ostojić Z., Stefanović L., Milanova S.D., Kazinczi G., Tyšer L. (2011): The changes of the composition of weed flora in Southeastern and Central Europe as affected by cropping practices. Herbologia, 12: 5–27.

ter Braak C.J.F., Šmilauer P. (2002): Canoco 4.5. Wageningen, Biometris.

van der Maarel E. (1979): Transformation of cover-abundance values in phytosociology and its effect on community similarity. Vegetatio, 39: 97–114.

Zajac M., Zajac A. (2009): Apophytes as invasive plants in the vegetation of Poland. Biodiversity Research and Conservation, 15: 35–40.

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