Diversity of current weed vegetation on arable land in selected areas of the Czech Republic

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ABSTRACT

This paper reports on the within-habitat (α) and on the between-habitat (β) diversity of weed vegetation on arable land in the Czech Republic, influenced by management systems, crops grown and altitude. A phytocoenological survey was conducted from 2006 to 2008 during a vegetation period using relevés that were 100 m^2 in size, placed in the central part of fields. The species richness and the mean Sørensen dissimilarity were calculated. The statistically significant effects of the type of farming and altitude on species richness were recorded. The average species numbers in one relevé reached 9.17 and 21.17 in conventional and organic farming, respectively. In both management systems, an increasing number of species was recorded with increasing altitude. Statistically significant effects of all the variables were observed when evaluating β-diversity. Higher β-diversity was found in conventional farming.

Keywords: altitude; farming system; weed diversity; wide-row crops; winter cereals

Weed communities have been influenced by humans throughout the entire history of agriculture. However, the most significant impacts occurred in the 20th century as a consequence of intensive farming that was characterised particularly by simple crop rotations, reduced soil tillage, effective seed cleaning technology, intensive use of fertilizers and lime, combined harvest and the usage of herbicides for weed control (Hilbig and Bachthaler 1992). The changes in weed communities in Europe were analysed in many published works (e.g. Baessler and Klotz 2006, Lososová and Simonová 2008, Tyšer et al. 2009). The results presented in these studies identify significant changes in weed communities, such as the species impoverishment of weed communities and the increasing occurrence of difficult-to-control weed species. Many weeds have become rare throughout the decades and can be found on the national 'red lists' (Holub and Procházka 2000).

The main instruments for promoting sustainable agriculture beneficial for biodiversity are currently various agri-environmental measures and organic farming. The area of organically cultivated land in the Czech Republic is on a constant rise. At the end of 2008, the share of organic farming in total agricultural land area was 8.04%. The largest areas are concentrated in the category of permanent grasslands, but also organically cultivated areas of arable land have a strong upward trend. Agricultural subjects in organic farming are paid by financial supports (Veinert 2009). The aim of these programmes is to reduce pressures on biodiversity of agricultural ecosystems and to provide farmers the opportunity to farm nature-friendly. However, evaluation of sustainability is not possible without long-term monitoring. One of the approaches of sustainability assessment is comparing of different farming systems, especially conventional practice with those environment-friendly (Vačkář 2005).

Supported by the Ministry of Education, Youth and Sports of the Czech Republic, Project No. MSM 6046070901, and by the Grant S.

Research conducted so far, primarily in Western countries, generally confirms the positive effect of organic management on biodiversity of weed communities (e.g. Callauch 1981, Azeez 2000, Salonen and Hyvönen 2000, Van Elsen 2000, Menalled et al. 2001). In the Czech Republic, similar studies on arable land are still rather rare.

Adjacent weed vegetation is strongly influenced by the share of crops that are grown in a crop rotation (Kohout et al. 2003). The impact of adjacent weeds is primarily determined by the specific growth and competitiveness of the crop during its vegetation period and by the specific crop farming practices that are typically used. The calendar parameter, characterised by a sowing period, is often responsible for the prevalent composition of agrophytocoenosis (Hallgren et al. 1999). Thus, winter crops usually dominate the overwintering weed taxa and root and vegetable crops dominate warm summer weeds. Natural site conditions (e.g. soil, climate) influence the occurrence of weed species in agrophytocoenoses. One of the priority factors considered in this regard is the effect of altitude, which is associated with many other ecological habitat parameters and the types of farming used in certain regions (Lososová et al. 2004). However, Cimalová and Lososová (2009) show that on regional scale, the relative importance of different crop types and their associated management on changes in arable weed species composition is higher than the relative importance of climatic variables.

The aim of this study was to assess α- and β-diversity on arable land in selected areas of the Czech Republic in terms of applied management systems, crops and environmental site conditions characterised by altitude.

MATERIAL AND METHODS

A three-year phytocoenological survey was undertaken from 2006 to 2008 in the Czech Republic. The data presented in this study were obtained from 27 conventional farms (with common herbicide weed control) and 35 registered organic farms (organic farming methods according to appropriate valid legislation without herbicide use). Organic management practices were used for at least 2 years in all organic farms. The winter cereals, i.e., winter wheat (*Triticum aestivum*), winter barley (*Hordeum vulgare*), rye (*Secale cereale*), spelt (*Triticum spelta*) and triticale (× *Triticosecale rimpaui*), and wide-row crops, i.e., sugar beet (*Beta vulgaris* subsp. *vulgaris* var. *altissima*), potatoes (*Solanum tuberosum*), maize (*Zea mays*), oil pumpkin (*Cucurbita pepo* subsp. *pepo*), feeding carrots (*Daucus carota*), fodder beet (*Beta vulgaris* subsp. *vulgaris* var. *rapacea*) and beet-root (*Beta vulgaris* subsp. *vulgaris* var. *vulgaris*) fields were selected for weed sampling. At each site, one phytocoenological relevé with a standard size of 100 m^2 was recorded in the central part of the field. The coverage of species was estimated using a nine-degree Braun-Blanquet cover-abundance scale (Braun-Blanquet 1964). This method uses the following scale intervals: r – rare, solitary, with small cover; + – < 1%; 1 – cover 1–5%; 2 m – many individuals, but cover < 5%; 2a – cover 5–12.4%; 2b – cover 12.5–25%; 3 – cover 25–50%; 4 – cover 50–75% and 5 – cover 75–100%. The nomenclature follows that of Kubát et al. (2002).

In total, 202 relevés of agricultural vegetation across the Czech Republic (Figure 1) were recorded (i.e. 202 different fields were monitored).

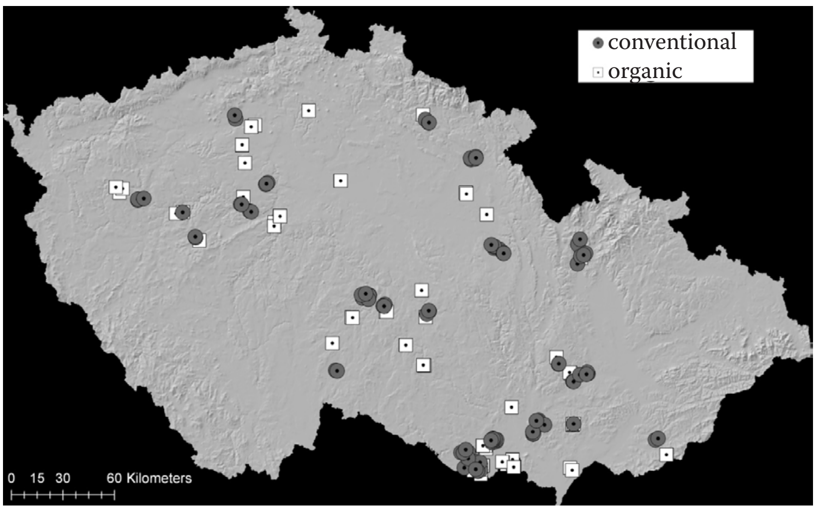


Figure 1. Map of the Czech Republic that shows the relevés taken

Table 1. Characteristics of natural conditions (Němec 2001)

Altitude	< 250 m	250–350 m	> 350 m
Average annual air temperature (°C)	9–10	8–9	5–8
Average annual rainfall (mm)	500–600	500–650	550–900
Sum of temperatures above 10°C	2 800–3 100	2 400–2 800	2 000–2 800
Main soil units	Chernozems, Phaeozems, Fluvisols	Chernozems, Haplic Luvisols	Cambisols
Percentage of arable land (%)	> 80	> 80	> 60

Of these, 108 and 94 relevés were constructed on conventionally farmed fields (53 in winter cereals and 55 in root crops) and organic fields (54 in winter cereals and 40 in wide-row crops), respectively. The fully developed vegetation period was monitored (cereals, mainly June and July and root crops, mainly August and September).

The elevation ranged from 175 to 650 m a.s.l., representing a fundamental region of arable land in the Czech Republic. From the viewpoint of altitude, the relevés were divided into 3 groups: < 250 m a.s.l., 77 relevés; 250–350 m, 66 relevés and > 350 m, 59 relevés, characterising a complex of environmental conditions that are suitable for growing concrete crops (Table 1) and the occurrence of certain weed species.

The number of species per plot was used as a measure of the species richness (α-diversity). The effect of the explanatory variables on species richness was tested by one-way ANOVA or simple regression in Statistica 9 (www.statsoft.com).

The β-diversity assessment (i.e., the mean difference in weed species composition among the relevés) was performed according to Lososová et al. (2004) in Juice 6.5 software (Tichý 2002). We partitioned the dataset along the different identified gradients (i.e. type of farming, crop and altitude). For each partition, we calculated β-diversity as the mean Sørensen dissimilarity between all pairs of relevés (1-S, where S is Sørensen similarity (Magurran 2004)). From the relevés that belonged to an individual partition, we determined the confidence intervals using 500 bootstrap samples and generated box-whisker plots. The statistical significance was tested using one-way ANOVA or simple regression in Statistica 9.

RESULTS AND DISCUSSION

α-diversity. In total, 189 weed species were found, some of which can be described as volunteers. Statistically significant effects of management type and altitude on species richness were observed; however, the effect of crops was not proven (Table 2). In the conventional type of farming, species richness was substantially lower (9.17) than in organic farming, where it was approximately two-fold higher (21.17). Similar data were also reported by Manhoudt et al. (2005), who found from 7 (winter wheat) to 15 (late potato) species in one relevé (100 m^2) under conventional farming. From a field center, Van Elsen (2000) reported the discovery of 18 weed species in a biodynamic field and only 2 species under conventional farming conditions. Previous research has shown that species-rich and dynamically balanced segetal communities can easily autoregulate a certain balance, in contrast to impoverished communities with distinctive and undesirable dominant species (Kropáč and Lecjaksová 2001).

As for individual crops, no major differences in the average number of species in one relevé between winter cereals and root crops were observed. The following averages were obtained: winter cereals, conventional, 9.23; root crops,

Table 2. Influence of environmental factors on species richness and β-diversity (ANOVA, simple regression)

	F-ratio	R^2	*P*-value
Species richness			
Type of farming	$F_{(1,200)}$ = 113.93	0.363	< 0.001
Altitude	$F_{(1,200)}$ = 30.51	0.132	< 0.001
Crop	$F_{(1,200)}$ = 0.40	0.002	ns
β-diversity			
Type of farming	$F_{(1,998)}$ = 21308	0.96	< 0.001
Crop (conv. farming)	$F_{(1,998)}$ = 76	0.07	< 0.001
Crop (org. farming)	$F_{(1,998)}$ = 472	0.32	< 0.001
Altitude (conv. farming)	$F_{(2,1497)}$ = 2404	0.76	< 0.001
Altitude (org. farming)	$F_{(2,1497)}$ = 262	0.26	< 0.001

ns – not significant; conv. – conventional, org. – organic conventional, 9.11; winter cereals, organic, 21.00 and root crops, organic, 21.40.

The average number of species in one relevé did not differ substantially from the previous results that were obtained by Kropáč (1986) in some intensively managed areas. That is, the decrease of species richness probably did not continue beyond the time of the study because the species that were sensitive to intensive farming disappeared; no new factors were introduced to further decrease the diversity. We also assumed that the overall decrease in fertilisation after 1992 may have played a role.

Thus, the organic elements of crop growing support the diversity of weed communities, which can have a positive impact on the overall biological diversity of a landscape. Bengtsson et al. (2005) indicated that 53 of 63 (84%) compared studies published before 2002 refer to the greater species richness in organic farming systems – with an average of 30% greater when compared with a conventional system. Callauch (1981) found two to three times more weed species in organically farmed fields. Heinken (1990) stated that the number of weed species was 10-fold higher where soils were rich in nutrients in organically farmed fields than at conventional sites.

When comparing the species richness of weeds, a significant increase in the number of species with increasing altitude in both management systems was observed (Figure 2). Nevertheless, it is generally accepted that higher species richness can be found in favourable, warmer, and nutrient-rich environments (Volf 1971). Rahbek (1995) deeply analysed this dependence and supports the view that species richness declines with elevation; however, this decline is not necessarily monotonous. In analysing our results, we assumed that stronger long-term selection pressure, due to intensive farming in better production areas in the lowland, led to the loss of many weed species, which are likely to also be found in the form of potential weediness in a soil-seed bank. Contrastingly, we found a higher species richness in the less productive areas where the intensification factors were not as highly employed. Our results confirm the findings of Lososová et al. (2004) and Fried et al. (2008), who also recorded higher species richness in agrophytocoenoses at higher altitudes.

β-diversity. Statistically significant effects of the type of farming, crop and altitude on β-diversity were observed (Table 2). Higher β-diversity was found in the conventional management system. These data are also confirmed by Roschewitz et al. (2005), who found significantly higher β-diversity in the conventional type of farming. In relation to the altitude factor, β-diversity declined with increasing altitude under organic farming. In the conventional system, the highest and lowest β-diversity results were recorded at altitudes between 250–350 m and > 350 m a.s.l., respectively (Figure 3). The results of this study endorse the findings of Fried et al. (2008), who also indicated a reduction in β-diversity at higher altitudes (> 300 m) and with extreme soil pH (acidic or alkaline) or on sandy soils. Lososová et al. (2004) also reported a clear decrease in β-diversity with increasing altitude. As for individual crops under conventional and organic farming, greater β-diversity was recorded for the root crops and winter cereals, respectively (Figure 3). Lososová and Cimalová (2009) found a higher β-diversity in root crops when compared to cereals. Conversely, Šilc (2008) recorded a higher β-diversity in cereals when compared to root crops but also confirmed a declining trend with increasing altitude with a significant decrease at the altitude of 600 m. The decline in β-diversity occurred from west to east. We and all of the above-cited authors confirm the decrease in β-diversity with increasing altitude. A possible explanation for this trend is that for α-diversity, an opposite trend was observed (i.e., α-diversity increased with increasing altitude with an observed higher species richness). Therefore, at higher altitudes, the occurrence probability that the same species existed in two weed communities was higher than that at lower altitudes. Another possible explanation is that when examining the impact of altitude, all weed communities were compared with each other (i.e., in all studied crop groups). Thus, in

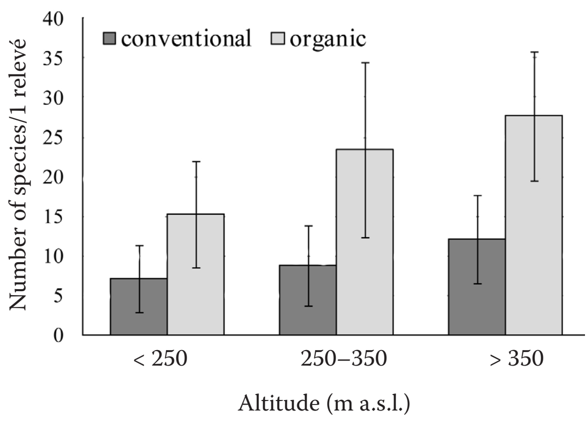
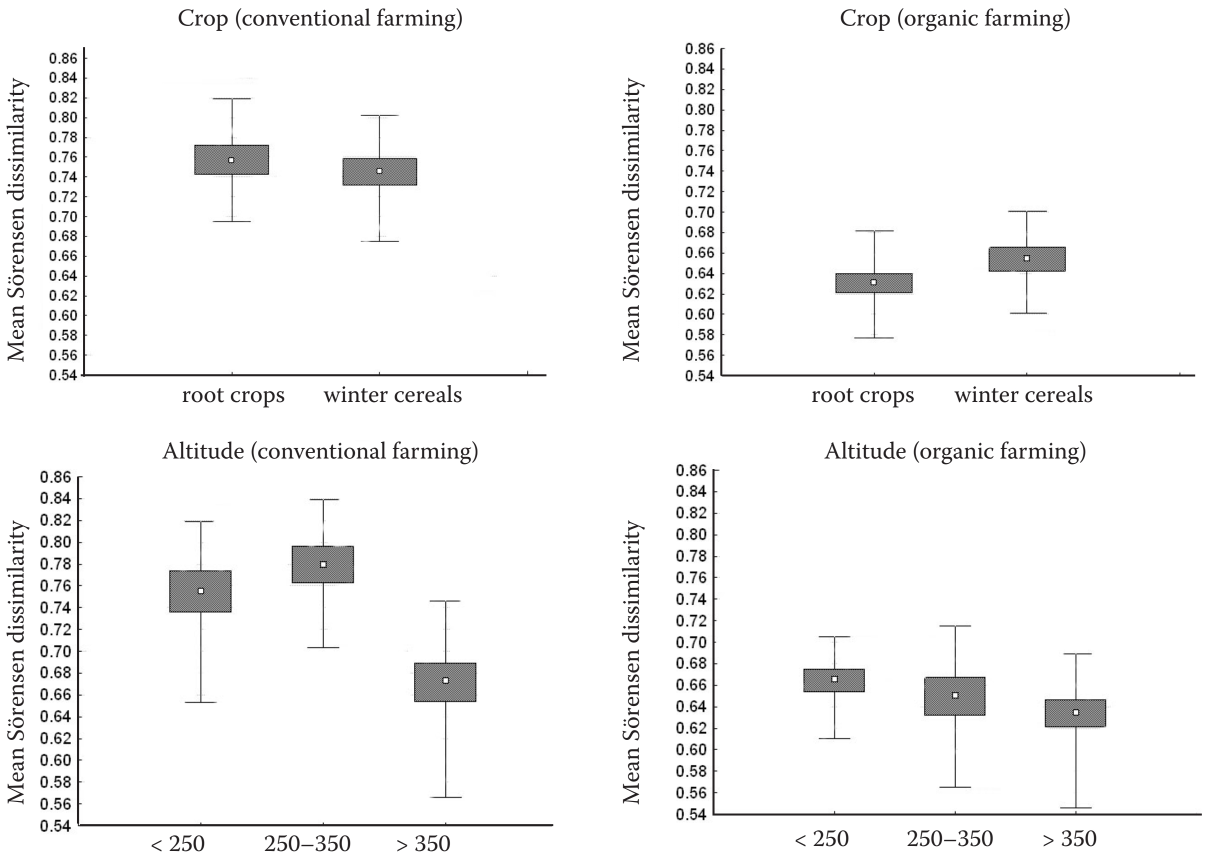


Figure 2. Number of recorded species in 1 relevé at different altitudes and for different types of farming



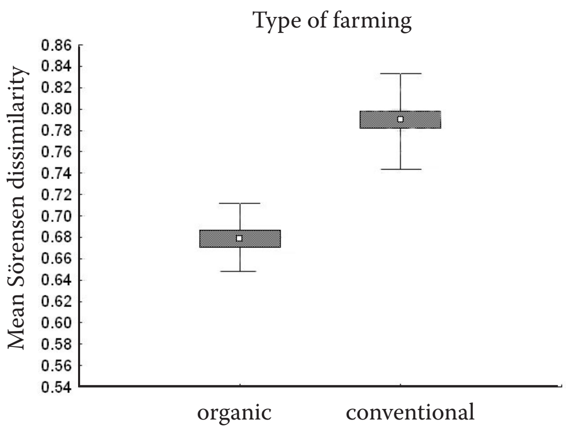


Figure 3. β-diversity in the different crops, along an altitude gradient and in the different types of farming (median, 25^{th} to 75^{th} percentile, minimum and maximum value)

areas with low altitude, when two fields that have different crops with a low number of species are compared, higher β-diversity is favoured.

In the presented analysis, it was found approximately twice as high species richness of weeds in organic agriculture. Also altitude was an important factor in biodiversity. Selection of observed localities was partly limited by the extent of areas with organically cultivated arable land. From the period of our research, however, there was a further significant increase of organically cultivated areas in the Czech Republic, so it would be appropriate to extent this monitoring also into other parts of our country.

REFERENCES

Azeez G. (2000): The Biodiversity Benefits of Organic Farming. Soil Association, Bristol.

Baessler C., Klotz S. (2006): Effects of changes in agricultural land-use on landscape structure and arable weed vegetation over the last 50 years. Agriculture, Ecosystems and Environment, *115*: 43–50.

Bengtsson J., Ahnström J., Weibull A.C. (2005): The effects of organic agriculture on biodiversity and abundance: A meta-analysis. Journal of Applied Ecology, *42*: 261–269.

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

Callauch R. (1981): Ackerunkraut-Gesellschaften auf biologisch und konventionell bewirtschafteten Äckern in der weiteren Umgebung von Göttingen. Tuexenia, *1*: 25–37.

Cimalová Š., Lososová Z. (2009): Arable weed vegetation of the northeastern part of the Czech Republic: Effects of environmental factors on species composition. Plant Ecology, *203*: 45–57.

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.

Hallgren E., Palmer M.W., Milberg P. (1999): Data diving with cross-validation: An investigation of broad-scale gradients in Swedish weed communities. Journal of Ecology, *87*: 1037–1051.

Heinken T. (1990): Die Ackerwildkraut-Vegetation auf biologisch und konventionell bewirtschafteten Ackerflächen bei Gut Adolphshof (Ldkrs. Hannover). Beiträge zur Naturkunde Niedersachsens, *43*: 38–45.

Hilbig W., Bachthaler G. (1992): Wirtschaftsbedingte Veränderungen der Segetalvegetation in Deutschland im Zeitraum von 1950–1990. Angewandte Botanik, *66*: 192–200.

Holub J., Procházka F. (2000): Red list of vascular plants of the Czech Republic – 2000. Preslia, *72*: 187–230.

Kohout V., Tyšer L., Holec J., Soukup J. (2003): The influence of changes in crop sowing area on the composition of weed communities on arable land in the Czech Republic. Herbologia, *4*: 13–19.

Kropáč Z. (1986): Evaluation of weed species in the Czech Socialist Republic with respect to their distribution and to the losses they cause. In: Proceedings X Czechoslovak Plant Protection Conference, Brno, 239–240. (In Czech)

Kropáč Z., Lecjaksová S. (2001): Segetal vegetation. In: Kolbek J. (2001): Vegetation of the Protected Landscape Area and Biosphere Reserve Křivoklátsko. 2. Plant Communities of the Rocks, Screes, Primitive Soils, Heathlands, Thermophilous Margins and Ruderal Sites. Academia, Praha, 121–163. (In Czech)

Kubát K., Hrouda L., Chrtek J.Jr., Kaplan Z., Kirschner J., Štěpánek J. (2002): The Key to Flora of the Czech Republic. Academia, Praha. (In Czech)

Lososová Z., Chytrý M., Cimalová S., 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.

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.

Magurran A.E. (2004): Measuring Biological Diversity. Blackwell Publishing, Oxford.

Manhoudt A.G.E., Udo de Haes H.A., De Snoo G.R. (2005): An indicator of plant species richness of semi-natural habitats and crops on arable farms. Agriculture, Ecosystems and Environment, *109*: 166–174.

Menalled F.D., Gross K.L., Hammond M. (2001): Weed aboveground and seedbank community responses to agricultural management systems. Ecological Applications, *11*: 1586–1601.

Němec J. (2001): Valuation and Assessment of Arable Land in the Czech Republic. Research Institute of Agricultural Economics, Praha. (In Czech)

Rahbek C. (1995): The elevational gradient of species richness: A uniform pattern? Ecography, *18*: 200–205.

Roschewitz I., Gabriel D., Tscharntke T., Thies C. (2005): The effects of landscape complexity on arable weed species diversity in organic and conventional farming. Journal of Applied Ecology, *42*: 873–882.

Salonen J., Hyvönen T. (2000): Response of weed floras in spring cereal fields to changes in crop production in Finland over four decades. In: XI^{eme} colloque international sur la biologie des mauvaises herbes, Dijon, 127–134.

Šilc U. (2008): Diversity of weed vegetation on arable land in Slovenia. Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz, Sonderheft, *21*: 351–356.

Tichý L. (2002): JUICE, software for vegetation classification. Journal of Vegetation Science, *13*: 451–453.

Tyšer L., Hamouz P., Nováková K., Nečasová M., Holec J. (2009): Changes in weed communities on selected areas with 30 years' interval. Scientia Agriculturae Bohemica, *40*: 18–25.

Vačkář D. (2005): Indicators of biodiversity changes: from the load to response. In: Vačkář D. (2005): Indicators of Biodiversity Changes. Academia, Praha, 275–294. (In Czech)

Van Elsen T. (2000): Species diversity as a task for organic agriculture in Europe. Agriculture, Ecosystems and Environment, 77: 101–109.

Veinert M. (2009): Agriculture 2008. Ministry of Agriculture of the Czech Republic, Praha. (In Czech)

Volf F. (1971): Weed communities in different types of agricultural production. Journal of University of Agriculture Prague, Faculty of Agronomy, Serie A, Crop Production, *54*: 181–199.

Received on November 20, 2012
Accepted on February 6, 2013

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