Biologia **65**/3: 465—478, 2010
Section Botany
DOI: 10.2478/s11756-010-0035-5

Changes in segetal vegetation in the Borská nížina Lowland (Slovakia) over 50 years

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Abstract: This article reports changes in the segetal vegetation in the Borská nížina Lowland (Western Slovakia) over 50 years. The study was based on phytosociological relevés obtained by Krippelová in the years 1949–1955, as well as our own recent data from the years 2002–2006. Using ordination and statistical methods, structural and floristic changes to four associations recorded in the area in both time periods were evaluated: *Veronicetum trilobae-triphyllidi*, *Consolido-Anthemidetum austriacae*, *Echinochloo-Setarietum pumilae* and *Setario viridis-Erigeronetum canadensis*. These plant communities are found in arable fields or young fallows. In some of these communities the proportion of invasive species, as well as archaeophytes and native species, has increased. Some agricultural practices (like fertilization and liming) support the spread of nitrophilous and calcareous species. Several ruderal species and herbicide-resistant species have expanded in the fields. In all studied associations the proportion of nutrient-demanding species has increased. Some rare and threatened species have declined or disappeared, but some threatened species that are missing from historical material are now present. However, the changes detected are not as substantial as expected based on data from other countries.

Key words: Ellenberg's indicator values; immigration status; invasive status; life forms; threat

Abbreviations: cont., continentality; Sh-W, Shannon-Wiener's index; Ac, *Atriplici-Chenopodietalia albi*; Cc, *Centaureetalia cyani*; cl, *Caucalidion lappulae*; Er, *Eragrostietalia*; SI, *Sisymbrienea*; SM, *Stellarietea mediae*; VA, *Violenea arvensis*; ve, *Veronico-Euphorbion*.

Introduction

Changes in agricultural practices have the biggest influence on structural changes in weed populations (Mahn 1984). During the 20th century fundamental changes in agricultural production took place, mainly in the 1950s when socialistic agriculture underwent much development. This led to the establishment of collective agriculture and the general intensification of production through mechanization, extensive use of mineral fertilizers and herbicides, changes in crop rotation, use of new plant cultivars, and improved seed cleaning (Opluštilová 1953; Kropáč 1977; Skalický 1981). Holzner & Immonen (1982) showed a similar trend throughout Europe after 1950. These changes also influenced the composition of plant communities in terms of the number of species and their abundance.

Changes in the segetal flora and vegetation at a regional level have been studied in the Czech Republic (Kropáč 1984; Koblihová 1989; Lososová 2003; Lososová & Simonová 2008); Germany (Hilbig & Jage 1984; Köck 1984; Kutzelnigg 1984; Günther & van Elsen 1993); Poland (Trzcińska-Tacik 1991); Slovenia (Šilc & Čarni 2005); Great Britain (Sutcliffe & Kay 2000) and Denmark (Andreasen et al. 1996).

In Slovakia (more precisely in the former Czechoslovakia) changes in segetal communities have been studied in less detail (Kropáč 1977; Skalický 1981; Eliáš 1987; Kropáč & Kopecký 1987), and comparison of weed vegetation in a specific area at different time points has been missing up to now.

Therefore we tried to compare the changes in segetal communities that have taken place over 50 years in one of the three biggest lowlands of Slovakia. The main aims were to evaluate structural changes in four selected associations in the Borská nížina Lowland, to compare their species composition, and to detect the decline or expansion of new species. Based on the abovementioned changes in agriculture, we expected floristic changes in segetal communities to have taken place. We also expected the amount and abundance of typical segetal species (i.e. annual archaeophytes) to decrease, especially rare species, and for neophytes to increase and perennial weeds to expand. As a result of application of nitrogen fertilizers ruderal species were also expected to have expanded in fields.

Study area

Borská nížina Lowland is situated in the western part of Slovakia, near the borders with Austria and Czech Republic (Fig. 1). Its natural border is formed by the Morava

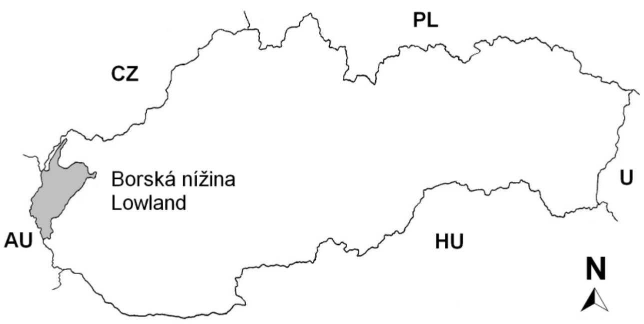

Fig. 1. Location of study area within the Slovak Republic.

River to the west and the Malé Karpaty Mountains to the east. With a size of approximately 1 000 km^2 (Krippelová & Krippel 1956) and altitude ranging from 138 to 290 m a.s.l., the territory lies in a warm climatic region (Lapin et al. 2002), with an average annual temperature of 9–10 °C (Šťastný et al. 2002) and average annual precipitation of 500–600 mm (Faško & Šťastný 2002). Phytogeographically, the area belongs to the province of Eupannonian xerotherm flora (Eupannonicum) of the Pannonian floral region (Pannonicum) (Futák 1980).

The soil substrate mostly consists of aeolian sands that are non-carbonate, siliceous and poor in nutrients. The dominant soil types are: podzols, regosols, hortic anthrosols, gleysols and histosols (Bedrna 2008).

Material and methods

Dataset

Comparison of changes in segetal communities was based on the analysis of two datasets (historic and recent) from the territory of the Borská nížina Lowland. The data were obtained from the unpublished relevés made by Krippelová during the years 1949–1955 (347 relevés) and from private databases of the first two authors (120 relevés obtained by Májeková and Zaliberová) and Jarolímek (one relevé) from the years 2002–2006. Recent relevés were not sampled in exactly the same localities as historic data, because of inexact identification of the localities of individual relevés in the historic dataset.

All relevés were obtained by following the standard procedures of the Zürich-Montpellier school (Braun-Blanquet 1964; Westhoff & van der Maarel 1978), mostly using a plot size of 100 m^2. Different scales of abundance and dominance have been used by different authors for different periods. To obtain data comparable with the numerical classification, all relevés were transformed into the nine-degree ordinal scale (Westhoff & van der Maarel 1978) and stored in a TURBOVEG database (Hennekens & Schaminée 2001). The data were exported into the JUICE 6.5 programme (Tichý 2002) for analysis. Taxa determined only to the genus level were excluded from the analyses. In the next step, all crop plants were eliminated from the datasets. They had, in contrast to other naturally occurring weed species, no information value. Because bryophytes were not recorded in all relevés, they were excluded from the datasets. Some taxa were included in more broadly-defined units: *Plantago major* (*P. uliginosa*), *Veronica hederifolia* (*V. sublobata*), *Chenopodium album* agg. (*Ch. album*), and *Polygonum aviculare* agg. (*P. aviculare*, *P. arenastrum*).

The nomenclature of the taxa follows the Checklist by Marhold (1998). The classification and nomenclature of syntaxa follows the work by Jarolímek et al. (1997).

Data analysis

Only relevés of the class *Stellarietea mediae* that originated from arable fields (or 1 to 2-year fallows) were used for the analysis. Relevés with deviating floristic composition were determined by DCA analysis in the CANOCO programme (ter Braak & Šmilauer 2002) and afterwards excluded from the datasets.

Numerical classification was performed using the programme SYN-TAX 2000 (Podani 2001). Recent and historic datasets were analysed separately (except the ordination analyses). The β-flexible clustering algorithm ($\beta = -0.25$) with Sorensen's similarity coefficient was used. The crispness of classification method for identifying the optimal number of clusters, proposed by Botta-Dukát et al. (2005), was applied. Different numbers of clusters (communities) were identified in the datasets and only those communities that were well defined in both of them were chosen.

The synoptic table was generated in the JUICE 6.5 programme (Tichý 2002). Each taxon was characterized by the frequency (in %) and fidelity (Φ, phi-coefficient $\times$ 100, upper index; Sokal & Rohlf 1995; Chytrý et al. 2002). The species with a fidelity threshold of above 24 ($\Phi > 0.24$) were considered as diagnostic and they are shown in bold in the table. This threshold was selected subjectively as it proved informative after a preliminary investigation of the synoptic table. Fidelity was calculated separately for historic and recent datasets. The phi-coefficient was standardized to the equal relevé size of all groups, the target group being the same size as the others (Chytrý et al. 2006; Tichý & Chytrý 2006). Those species with a probability of random occurrence in the vegetation type that was higher than 0.05 according to Fisher's exact test (Chytrý et al. 2002, 2006) were excluded from the list of diagnostic taxa.

Major gradients in species composition were analysed through ordination, using detrended correspondence analysis (DCA) from the CANOCO 4.5 package (ter Braak & Šmilauer 2002), which is considered suitable for analysis of heterogeneous data. For ecological interpretation of the ordination axes, the average Ellenberg's indicator values (Ellenberg et al. 1992) and Shannon-Wiener's index of diversity (Hill 1973) for relevés were calculated, using the JUICE 6.5 programme (Tichý 2002). These were plotted onto a DCA ordination diagram as supplementary environmental data.

To determine the differences between individual vegetation types in the past and present, we analysed the occurrence of chosen variables in individual relevés (life forms, Ellenberg's indicator values, Shannon-Wiener's index of diversity, invasiveness, immigration status, and number of threatened species).

Statistica 8.0 (http://www.statsoft.com) was used for correlation analyses and construction of Box and Whisker plots. The numbers of species belonging to particular variables were calculated for each relevé. Particular plant communities (historic and recent) were compared with respect to these variables. Since all calculated Ellenberg's indicator values had a normal distribution (Kolmogorov-Smirnov test), no transformation was needed. One-way ANOVA followed by the Tukey *post-hoc* test was used for multiple comparisons.

Life forms were defined according to Dostál & Červenka (1991, 1992). The taxa were divided into individual

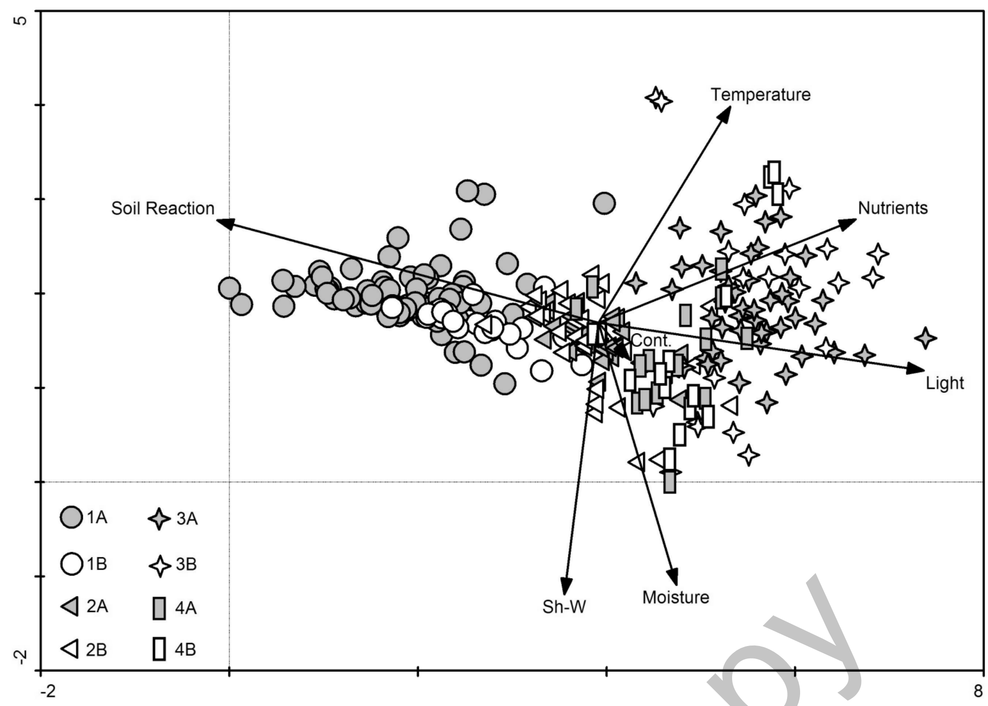

Fig. 2. Detrended correspondence analysis (DCA) ordination diagram of segetal communities in the Borská nížina Lowland based on average Ellenberg's indicator values. The length of gradients: 1st axis 7.385, 2nd axis 4.080; eigenvalues: 1st axis 0.791, 2nd axis 0.586. Only the first two axes are presented. (Legend: 1 – *Veronicetum trilobae-triphyllidi*, 2 – *Consolido-Anthemidetum austriacae*, 3 – *Echinochloo-Setarietum pumilae*, 4 – *Setario viridis-Erigeronetum canadensis*; A: historic dataset, B: recent dataset).

categories as follows: therophytes, hemicryptophytes, geophytes, chamaephytes and phanerophytes. The occurrence of the latter two life forms was insignificant; therefore we excluded them from the analyses. Categories of threat follow Feráková et al. (2001), and the invasive status (casual, naturalized, invasive) and immigration status (archaeophyte, neophyte, native) follow Pyšek et al. (2002).

Results and discussion

Using cluster analysis we identified several communities in the historic and recent datasets. For further analyses we selected only those that were common and well defined in both datasets. These were: *Veronicetum trilobae-triphyllidi*, *Consolido-Anthemidetum austriacae*, *Echinochloo-Setarietum pumilae* and *Setario viridis-Erigeronetum canadensis*. Comparison of the two time periods can be found in Table 1. The distribution of individual relevés in ordination space is shown in DCA diagrams (Figs 2, 3). The first two axes explain 28.6% of the total variability. The first axis correlates the most negatively with soil reaction and positively with light and nutrients. The second axis correlates the most negatively with moisture and diversity (Sh-W) and positively with temperature (Table 2). Along the first axis on the left of the diagram (Fig. 2) we can see the location of relevés from the association *Veronicetum trilobae-triphyllidi*, which in the past as well as today was limited to soils with higher soil pH, but at the same time is formed by species with modest light and nutrient requirements. The biggest input of nutrients is required by the association *Echinochloo-Setarietum pumilae*. Association *Setario viridis-Erigeronetum canadensis* is dispersed on the right side of the diagram and it is formed mostly by acidophilous species. Stands of association *Consolido-Anthemidetum austriacae* are placed in the middle of the diagram, having the least specific demands on environmental conditions of the studied communities.

Veronicetum trilobae-triphyllidi

This was a typical spring community in winter cereals and one-year fallows in the past as well as today. The average number of species per relevé has increased: from 10 in the historic dataset (min. 4, max. 23) to 18 in the recent dataset (min. 10, max. 29). The diversity of the association has also slightly increased, but the difference is not statistically significant (Fig. 4e). The diagnostic species *Veronica hederifolia* and *V. triphyllos* have a high frequency in both datasets (Table 1, columns 1A, 1B). Some diagnostic species from the past such as *Gagea pratensis*, *G. villosa* and *Veronica triloba*, have disappeared from the community, while some new taxa have appeared (e.g. *Papaver argemone*, *P. dubium* subsp. *austromoravicum*, *Veronica arvensis*).

In the past the community was formed by more basiphilous and thermophilous species than today. In contrast, today the demand for nutrients and moisture is slightly higher, but these changes are not statistically significant (Figs 5b,d,e,f).

The increase in the diversity of the association is due to the more frequent occurrence of archaeophytes, therophytes, native and invasive species that are significantly more common than in the past (Figs 4a,c, 6a,e).

Table 1. Comparison of segetal associations from years 1949–1955 and 2002–2006 in the Borská nížina Lowland. Diagnostic species are ordered according to decreasing fidelity values, other species are ordered according to decreasing frequency values. Fidelity was calculated separately for historic and recent datasets.
Column: 1 – *Veronicetum trilobae-triphyllidi*, 2 – *Consolido-Anthemidetum austriacae*, 3 – *Echinochloo-Setarietum pumilae*, 4 – *Setario viridis-Erigeronetum canadensis*; A: historic dataset, B: recent dataset.

Column	1A		1B		2A		2B		3A		3B		4A		4B	
Number of relevés	79		24		33		32		47		22		15		15	
Veronicetum trilobae-triphyllidi																
Veronica hederifolia VA	**89**	**92.4**	**88**	**76.2**	.	—	25	—	.	—	.	—	.	—	.	—
Erophila verna	**68**	**76.2**	**42**	**52.8**	3	—	6	—	.	—	.	—	.	—	.	—
Veronica triphyllos SM	**78**	**75.1**	**71**	**63.4**	15	—	25	—	.	—	.	—	.	—	.	—
Holosteum umbellatum	**61**	**68.2**	17	—	6	—	12	—	.	—	.	—	.	—	.	—
Gagea pratensis	**37**	**55.1**	.	—	.	—	.	—	.	—	.	—	.	—	.	—
Gagea villosa	**27**	**46.2**	.	—	.	—	.	—	.	—	.	—	.	—	.	—
Veronica triloba SM	**29**	**44.8**	.	—	3	—	.	—	.	—	.	—	.	—	.	—
Lithospermum arvense Cc	**25**	**35.3**	.	—	6	—	**12**	**31.1**	2	—	.	—	.	—	.	—
Lamium amplexicaule SM	**19**	**24.2**	**54**	**55.9**	12	—	16	—	.	—	.	—	.	—	.	—
Papaver dubium subsp. *austromoravicum* SM	.	—	**42**	**55.8**	.	—	3	—	.	—	.	—	.	—	.	—
Descurainia sophia SI	3	—	**58**	**49.0**	6	—	28	—	.	—	5	—	.	—	.	—
Stellaria media SM	37	23.1	**62**	**42.8**	24	—	**53**	**30.8**	21	—	.	—	.	—	.	—
Capsella bursa-pastoris SM	34	21.6	**67**	**40.0**	15	—	53	23.5	15	—	9	—	13	—	7	—
Papaver argemone Cc	.	—	**25**	**37.0**	6	—	6	—	.	—	.	—	7	—	.	—
Scleranthus annuus VA	4	—	**17**	**36.1**	9	—	.	—	9	—	.	—	**40**	**39.5**	.	—
Veronica polita SM	.	—	**17**	**36.1**	.	—	.	—	.	—	.	—	.	—	.	—
Viola arvensis VA	8	—	**96**	**33.8**	**45**	**31.4**	88	23.5	4	—	5	—	33	—	87	—
Lamium purpureum ve	1	—	**12**	**31.1**	.	—	.	—	.	—	.	—	.	—	.	—
Apera spica-venti Ac	.	—	**79**	**29.4**	**58**	**40.5**	**78**	**28.2**	2	—	5	—	**47**	**26.2**	53	—
Arabidopsis thaliana	4	—	**21**	**29.0**	.	—	9	—	.	—	.	—	.	—	.	—
Veronica arvensis VA	.	—	**21**	**29.0**	.	—	9	—	.	—	.	—	.	—	.	—
Consolido-Anthemidetum austriacae																
Vicia angustifolia	.	—	4	—	**58**	**60.2**	**28**	**30.4**	.	—	.	—	13	—	13	—
Vicia hirsuta VA	3	—	.	—	**73**	**57.1**	**25**	**44.7**	4	—	.	—	33	—	.	—
Cyanus segetum Cc	10	—	.	—	**70**	**53.1**	**44**	**60.7**	.	—	.	—	33	—	.	—
Fallopia convolvulus VA	3	—	54	—	**67**	**46.8**	**94**	**33.2**	36	8.2	32	—	13	—	87	—
Myosotis arvensis VA	1	—	21	—	**24**	**42.2**	**53**	**51.5**	.	—	.	—	.	—	.	—
Agrostemma githago Cc	6	—	.	—	**45**	**41.4**	**16**	**34.9**	.	—	.	—	20	—	.	—
Solanum tuberosum	.	—	.	—	**33**	**41.2**	.	—	11	—	.	—	.	—	.	—
Cota austriaca cl	13	—	25	—	**61**	**37.8**	**66**	**49.0**	9	—	.	—	40	—	20	—
Vicia villosa SM	4	—	17	—	**30**	**32.9**	19	—	.	—	.	—	13	—	.	—
Ranunculus arvensis VA	3	—	.	—	**24**	**31.1**	6	—	2	—	.	—	7	—	.	—
Medicago lupulina	.	—	4	—	**36**	**30.2**	**28**	**37.8**	4	—	5	—	27	—	.	—
Arenaria serpyllifolia	14	—	25	—	**48**	**25.0**	**34**	**24.2**	6	—	.	—	47	22.7	13	—
Consolida regalis VA	18	—	54	—	33	18.4	**88**	**55.3**	4	—	14	—	27	—	7	—
Galium aparine	.	—	4	—	3	—	**47**	**55.0**	.	—	5	—	.	—	.	—
Papaver rhoeas SM	4	—	33	—	27	7.1	**69**	**50.7**	4	—	14	—	**53**	**43.3**	.	—
Anagallis arvensis VA	.	—	4	—	39	22.5	**59**	**45.1**	19	—	5	—	33	—	33	—
Silene noctiflora cl	.	—	8	—	.	—	**44**	**42.8**	4	—	.	—	.	—	13	—
Galium spurium Cc	.	—	.	—	3	—	**12**	**31.1**	.	—	.	—	.	—	.	—
Aethusa cynapium Cc	.	—	.	—	.	—	**12**	**31.1**	.	—	.	—	.	—	.	—
Tripleurospermum perforatum SM	4	—	62	—	.	—	**78**	**29.5**	.	—	36	—	13	—	33	—
Vicia tetrasperma VA	3	—	4	—	15	14.4	**16**	**28.4**	2	—	.	—	13	—	.	—
Sonchus arvensis VA	.	—	4	—	6	—	**16**	**28.4**	6	—	.	—	.	—	.	—
Stachys annua SM	.	—	.	—	6	21.5	**9**	**26.8**	.	—	.	—	.	—	.	—
Geranium pusillum SM	3	—	4	—	3	—	**12**	**24.1**	.	—	.	—	.	—	.	—
Echinochloo-Setarietum pumilae																
Chenopodium album agg. SM	1	—	17	—	15	—	72	—	**96**	**80.1**	**95**	**34.3**	13	—	87	—
Echinochloa crus-galli SM	.	—	.	—	.	—	12	—	**53**	**67.8**	**68**	**60.8**	.	—	13	—
Setaria viridis Er	.	—	.	—	.	—	3	—	**62**	**59.1**	**23**	**25.1**	20	—	13	—
Galinsoga parviflora SM	.	—	4	—	3	—	3	—	**43**	**50.5**	5	—	7	—	.	—
Persicaria maculosa SM	.	—	.	—	6	—	6	—	**40**	**46.2**	.	—	7	—	.	—
Amaranthus retroflexus SM	.	—	.	—	.	—	6	—	**32**	**43.6**	**23**	**34.5**	7	—	.	—
Setaria pumila SM	.	—	4	—	.	—	16	—	**45**	**40.5**	14	—	27	—	**53**	**44.3**
Digitaria pectiniformis SM	.	—	.	—	.	—	.	—	**26**	**37.1**	.	—	7	—	.	—
Equisetum arvense	15	—	8	—	61	21.7	31	—	**72**	**35.4**	27	—	20	—	13	—
Persicaria lapathifolia SM	.	—	.	—	.	—	16	—	.	—	**41**	**44.4**	.	—	.	—
Xanthium albinum	.	—	.	—	.	—	.	—	.	—	**18**	**37.8**	.	—	.	—
Aster lanceolatus	.	—	.	—	.	—	3	—	.	—	**18**	**33.1**	.	—	.	—
Panicum miliaceum	1	—	.	—	.	—	.	—	.	—	**27**	**32.7**	.	—	13	—
Chenopodium polyspermum Ac	.	—	.	—	.	—	9	—	.	—	**23**	**31.2**	.	—	.	—
Amaranthus powellii SM	.	—	.	—	.	—	3	—	.	—	**14**	**27.2**	.	—	.	—

Table 1. (continued)

Column	1A	1B	2A	2B	3A	3B	4A	4B
Setario viridis-Erigeronetum canadensis								
Trifolium arvense	1 —	8 —	21 —	25 —	15 —	5 —	**93** 74.7	**40** 29.9
Logfia arvensis	. —	. —	. —	3 —	. —	. —	**53** 67.9	. —
Conyza canadensis SM	15 —	21 —	21 —	47 —	34 —	18 —	**80** 50.5	**67** 33.9
Herniaria hirsuta	. —	. —	3 —	. —	13 —	. —	**40** 43.4	. —
Daucus carota	1 —	. —	. —	6 —	2 —	5 —	**27** 41.9	. —
Gypsophila muralis SM	. —	. —	. —	6 —	4 —	. —	**27** 40.9	. —
Filaginella uliginosa Ac	. —	. —	. —	. —	. —	. —	**20** 39.7	. —
Spergularia rubra	. —	. —	. —	. —	. —	. —	**20** 39.7	. —
Crepis tectorum	1 —	. —	. —	. —	. —	. —	**20** 37.8	. —
Erodium cicutarium	13 —	4 —	3 —	9 —	9 —	18 —	**40** 37.7	20 —
Bromus secalinus VA	. —	. —	6 —	. —	2 —	. —	**27** 36.8	. —
Salsola kali	. —	. —	. —	. —	2 —	. —	**20** 36.5	7 —
Raphanus raphanistrum VA	3 —	4 —	30 —	19 —	47 12.3	23 —	**67** 36.1	**47** 32.3
Polycnemum arvense	. —	. —	. —	. —	2 —	. —	**13** 28.4	. —
Trifolium pratense	5 —	. —	6 —	. —	. —	. —	**20** 26.3	. —
Cynodon dactylon Er	. —	. —	. —	. —	4 —	. —	**13** 25.2	. —
Digitaria sanguinalis Er	. —	. —	. —	3 —	55 39.5	50 16.0	**47** 28.0	**93** 68.0
Spergula arvensis Ac	3 —	4 —	3 —	. —	2 —	. —	. —	**33** 47.5
Acetosella multifida agg.	4 —	. —	6 —	. —	6 —	. —	20 —	**20** 39.7
Anthemis ruthenica	. —	25 —	. —	9 —	. —	. —	. —	**33** 25.3
Caucalidion lappulae								
Galium tricornutum	. —	. —	3 —	. —	. —	. —	. —	. —
Adonis aestivalis	. —	. —	. —	3 —	. —	. —	. —	. —
Kickxia spuria	. —	. —	. —	6 —	. —	. —	. —	. —
Centaureetalia cyani								
Veronica persica	9 —	17 —	9 —	9 —	2 —	9 —	. —	. —
Tithymalus helioscopia	1 —	. —	. —	6 —	4 —	5 —	. —	. —
Lathyrus tuberosus	. —	. —	6 —	6 —	. —	. —	7 —	. —
Avena fatua	. —	. —	. —	6 —	. —	9 —	. —	. —
Tithymalus exiguus	. —	. —	. —	6 —	. —	5 —	. —	. —
Kickxia elatine	. —	. —	. —	3 —	. —	. —	. —	. —
Atriplici-Chenopodietalia albi								
Veronica agrestis	5 19.6	. —	. —	. —	. —	. —	. —	. —
Eragrostietalia								
Portulaca oleracea	1 —	. —	. —	. —	2 —	5 —	. —	. —
Eragrostis minor	. —	. —	. —	. —	6 22.1	5 —	. —	. —
Violenea arvensis								
Anthemis arvensis	3 —	. —	3 —	. —	. —	. —	. —	. —
Xanthoxalis stricta	. —	4 —	12 —	12 —	6 —	. —	13 —	7 —
Aphanes arvensis	. —	4 —	. —	. —	. —	. —	. —	. —
Sonchus asper	. —	. —	. —	. —	2 —	9 —	. —	. —
Sisymbrienea								
Lactuca serriola	. —	4 —	3 —	22 —	. —	5 —	. —	20 —
Sisymbrium altissimum	. —	4 —	. —	. —	. —	. —	. —	. —
Bromus tectorum	. —	. —	6 21.5	. —	. —	. —	. —	. —
Chenopodium strictum	. —	. —	3 —	. —	. —	5 —	. —	. —
Anthemis cotula	. —	. —	3 —	. —	. —	. —	. —	. —
Bromus sterilis	. —	. —	. —	3 —	. —	. —	. —	. —
Sisymbrium officinale	. —	. —	. —	. —	2 —	. —	7 —	. —
Tithymalus peplus	. —	. —	. —	. —	2 —	. —	. —	. —
Iva xanthiifolia	. —	. —	. —	. —	. —	5 —	. —	. —
Malva neglecta	. —	. —	. —	. —	. —	5 —	. —	. —
Stellarietea mediae								
Senecio vulgaris	3 —	. —	3 —	. —	2 —	. —	. —	. —
Thlaspi arvense	. —	21 23.7	3 —	6 —	. —	9 —	. —	. —
Myosurus minimus	. —	12 —	. —	6 —	. —	. —	. —	. —
Sinapis arvensis	. —	8 —	3 —	6 —	. —	5 —	. —	7 —
Camelina microcarpa	. —	4 —	12 13.6	3 —	. —	. —	13 —	. —
Tithymalus esula	. —	4 —	. —	. —	6 —	. —	7 —	. —
Sonchus oleraceus	. —	. —	. —	6 —	11 17.9	. —	7 —	. —
Atriplex patula	. —	. —	. —	6 —	. —	5 —	. —	. —
Mercurialis annua	. —	. —	. —	3 —	4 —	5 —	. —	. —
Chenopodium hybridum	. —	. —	. —	3 —	2 —	. —	. —	. —
Solanum nigrum	. —	. —	. —	. —	4 —	. —	. —	. —
Digitaria ischaemum	. —	. —	. —	. —	2 —	. —	. —	. —
Myosotis ramosissima	. —	. —	. —	. —	2 —	. —	. —	. —
Amaranthus albus	. —	. —	. —	. —	. —	5 —	. —	. —

Table 1. (continued)

Column	1A	1B	2A	2B	3A	3B	4A	4B
Others								
Elytrigia repens	30 11.6	54 —	12 —	66 —	19 —	59 —	27 —	60 —
Cirsium arvense	19 —	42 —	27 —	53 —	26 —	50 —	20 —	. —
Taraxacum sect. *Ruderalia*	6 22.0	. —	. —	6 —	. —	5 —	. —	. —
Achillea millefolium agg.	6 —	. —	. —	. —	2 —	. —	7 —	. —
Ranunculus repens	6 22.0	. —	. —	. —	. —	. —	. —	. —
Leopoldia comosa	5 —	. —	15 19.4	. —	. —	. —	7 —	. —
Secale cereale	4 —	4 —	18 14.7	12 —	6 —	. —	13 —	7 —
Brassica napus	4 —	4 —	. —	6 —	9 —	14 —	. —	. —
Plantago lanceolata	4 —	. —	. —	. —	. —	. —	13 —	. —
Galium mollugo	4 —	. —	. —	. —	. —	. —	. —	. —
Convolvulus arvensis	3 —	21 —	61 20.0	19 —	64 23.8	18 —	47 —	. —
Myosotis stricta	3 —	12 —	. —	16 —	. —	. —	. —	. —
Poa pratensis	3 —	. —	3 —	. —	2 —	. —	7 —	. —
Rorippa sylvestris	3 —	. —	. —	. —	4 —	5 —	. —	. —
Tithymalus cyparissias	3 —	. —	. —	. —	. —	. —	7 —	. —
Festuca pseudovina	3 —	. —	. —	. —	. —	. —	. —	. —
Gagea lutea	3 —	. —	. —	. —	. —	. —	. —	. —
Ornithogalum umbellatum	3 —	. —	. —	. —	. —	. —	. —	. —
Symphytum officinale	1 —	4 —	. —	3 —	. —	9 —	. —	. —
Poa annua	1 —	4 —	. —	. —	. —	. —	. —	. —
Saponaria officinalis	1 —	. —	3 —	. —	. —	. —	7 —	. —
Carex hirta	1 —	. —	3 —	. —	. —	. —	. —	. —
Plantago major	1 —	. —	. —	16 —	2 —	18 —	. —	. —
Silene latifolia subsp. *alba*	1 —	. —	. —	3 —	2 —	5 —	. —	7 —
Potentilla anserina	1 —	. —	. —	. —	2 —	5 —	. —	. —
Anchusa officinalis	1 —	. —	. —	. —	. —	. —	7 —	. —
Dactylis glomerata	1 —	. —	. —	. —	. —	. —	. —	. —
Falcaria vulgaris	1 —	. —	. —	. —	. —	. —	. —	. —
Fragaria vesca	1 —	. —	. —	. —	. —	. —	. —	. —
Lithospermum officinale	1 —	. —	. —	. —	. —	. —	. —	. —
Medicago sativa	1 —	. —	. —	. —	. —	. —	. —	. —
Onobrychis viciifolia	1 —	. —	. —	. —	. —	. —	. —	. —
Poa angustifolia	1 —	. —	. —	. —	. —	. —	. —	. —
Veronica dillenii	1 —	. —	. —	. —	. —	. —	. —	. —
Polygonum aviculare agg.	. —	50 —	30 15.6	69 23.1	21 —	36 —	27 —	40 —
Artemisia vulgaris	. —	17 —	. —	22 —	. —	32 —	. —	. —
Ambrosia artemisiifolia	. —	17 —	. —	3 —	. —	14 —	. —	7 —
Stachys palustris	. —	12 —	. —	3 —	. —	14 —	. —	. —
Mentha arvensis	. —	4 —	3 —	3 —	. —	. —	. —	. —
Erysimum cheiranthoides	. —	4 —	. —	12 —	4 —	9 —	. —	. —
Ranunculus sardous	. —	4 —	. —	6 —	. —	. —	. —	. —
Helianthus annuus	. —	4 —	. —	3 —	. —	9 —	. —	. —
Triticum aestivum	. —	4 —	. —	3 —	. —	. —	7 —	. —
Arctium lappa	. —	4 —	. —	. —	. —	9 —	. —	. —
Acer pseudoplatanus	. —	4 —	. —	. —	. —	. —	. —	. —
Anthriscus cerefolium	. —	4 —	. —	. —	. —	. —	. —	. —
Dichodon viscidum	. —	4 —	. —	. —	. —	. —	. —	. —
Veronica praecox	. —	4 —	. —	. —	. —	. —	. —	. —
Trifolium campestre	. —	. —	18 14.2	. —	4 —	. —	20 —	. —
Trifolium repens	. —	. —	6 —	6 —	. —	. —	7 —	. —
Vicia pannonica	. —	. —	6 —	. —	. —	. —	7 —	. —
Pisum sativum	. —	. —	6 21.5	. —	. —	. —	. —	. —
Asparagus officinalis	. —	. —	3 —	. —	2 —	. —	. —	. —
Vicia sativa	. —	. —	3 —	. —	2 —	. —	. —	. —
Chondrilla juncea	. —	. —	3 —	. —	. —	. —	7 —	7 —
Leontodon autumnalis	. —	. —	3 —	. —	. —	. —	. —	7 —
Onopordum acanthium	. —	. —	3 —	. —	. —	. —	. —	. —
Plantago media	. —	. —	3 —	. —	. —	. —	. —	. —
Rhinanthus alectorolophus	. —	. —	3 —	. —	. —	. —	. —	. —
Saxifraga tridactylites	. —	. —	3 —	. —	. —	. —	. —	. —
Vicia sepium	. —	. —	3 —	. —	. —	. —	. —	. —
Epilobium tetragonum	. —	. —	. —	9 —	. —	. —	. —	7 —
Persicaria amphibia	. —	. —	. —	6 —	2 —	5 —	. —	. —
Tanacetum vulgare	. —	. —	. —	6 —	. —	5 —	. —	. —
Lythrum salicaria	. —	. —	. —	3 —	. —	5 —	. —	. —
Juncus bufonius	. —	. —	. —	3 —	. —	. —	7 —	. —
Odontites vulgaris agg.	. —	. —	. —	3 —	. —	. —	7 —	. —
Arrhenatherum elatius	. —	. —	. —	3 —	. —	. —	. —	. —
Bromus commutatus	. —	. —	. —	3 —	. —	. —	. —	. —

Table 1. (continued)

Column	1A	1B	2A	2B	3A	3B	4A	4B
Cerastium glomeratum	.	.	.	3	.	.	.	.
Hypochaeris radicata	.	.	.	3	.	.	.	.
Microrrhinum minus	.	.	.	3	.	.	.	.
Pastinaca sativa	.	.	.	3	.	.	.	.
Rumex crispus	.	.	.	3	.	.	.	.
Viola tricolor	.	.	.	3	.	.	.	.
Phragmites australis	.	.	.	.	4	5	7	7
Bidens tripartita	.	.	.	.	4	.	.	.
Lycopersicon esculentum	.	.	.	.	4	.	.	.
Brassica oleracea	.	.	.	.	2	.	.	.
Cucumis sativus	.	.	.	.	2	.	.	.
Erigeron acris	.	.	.	.	2	.	.	.
Leucanthemum vulgare	.	.	.	.	2	.	.	.
Papaver somniferum	.	.	.	.	2	.	.	.
Potentilla recta	.	.	.	.	2	.	.	.
Reseda lutea	.	.	.	.	2	.	.	.
Solidago gigantea	.	.	.	.	.	9	.	.
Verbascum blattaria	.	.	.	.	.	9	.	.
Hypericum perforatum	.	.	.	.	.	5	7	.
Agrostis gigantea	.	.	.	.	.	5	.	7
Bidens frondosa	.	.	.	.	.	5	.	.
Bolboschoenus maritimus	.	.	.	.	.	5	.	.
Bromus inermis	.	.	.	.	.	5	.	.
Calamagrostis epigejos	.	.	.	.	.	5	.	.
Carduus acanthoides	.	.	.	.	.	5	.	.
Chenopodium ficifolium	.	.	.	.	.	5	.	.
Inula britannica	.	.	.	.	.	5	.	.
Lythrum virgatum	.	.	.	.	.	5	.	.
Phleum pratense	.	.	.	.	.	5	.	.
Scutellaria galericulata	.	.	.	.	.	5	.	.
Solanum dulcamara	.	.	.	.	.	5	.	.
Veronica anagalloides	.	.	.	.	.	5	.	.
Melilotus officinalis	.	.	.	.	.	.	7	7
Oenothera biennis agg.	.	.	.	.	.	.	7	7
Aira caryophyllea	.	.	.	.	.	.	7	.
Aira elegantissima	.	.	.	.	.	.	7	.
Berteroa incana	.	.	.	.	.	.	7	.
Crepis setosa	.	.	.	.	.	.	7	.
Eryngium campestre	.	.	.	.	.	.	7	.
Festuca ovina	.	.	.	.	.	.	7	.
Filago vulgaris	.	.	.	.	.	.	7	.
Linaria vulgaris	.	.	.	.	.	.	7	.
Lolium perenne	.	.	.	.	.	.	7	.
Nigella arvensis	.	.	.	.	.	.	7	.
Potentilla argentea	.	.	.	.	.	.	7	.
Securigera varia	.	.	.	.	.	.	7	.
Stellaria graminea	.	.	.	.	.	.	7	.
Tragopogon dubius	.	.	.	.	.	.	7	.
Veronica verna	.	.	.	.	.	.	7	.
Avena sativa	.	.	.	.	.	.	.	7
Hordeum vulgare	.	.	.	.	.	.	.	7
Logfia minima	.	.	.	.	.	.	.	7
Persicaria dubia	.	.	.	.	.	.	.	7
Spergula morisonii	.	.	.	.	.	.	.	7

Differences may be due to the fact that some of the historical relevés were not made at the optimal stage of development of the community. In addition, some taxa were determined only to the genus level and therefore were excluded from the analysis.

Šilc & Čarni (2005) observed changes in the association *Veronicetum trilobae-triphyllidi* over time, with an increase in demand for nutrients and a decrease in soil pH as a result of mineral fertilization.

The disappearance of geophytes of the *Gagea* genus is probably due to more careful preparation of soil and deeper tillage. In the Borská (or more precisely Záhorská) nížina Lowland, Opluštilová (1953) observed that most bulbs rooted at a depth of 3–15 cm. Deyl (1964) pointed out that deep tillage weakens plants. In the past many fields in the study area have been left without tillage in the autumn (cf. also Sutcliff & Kay 2000) and these provided good conditions for the development of such geophytes on a large scale (Opluštilová 1953). In recent times we have only found a few of these one-year fallows, as most fields are ploughed in the autumn.

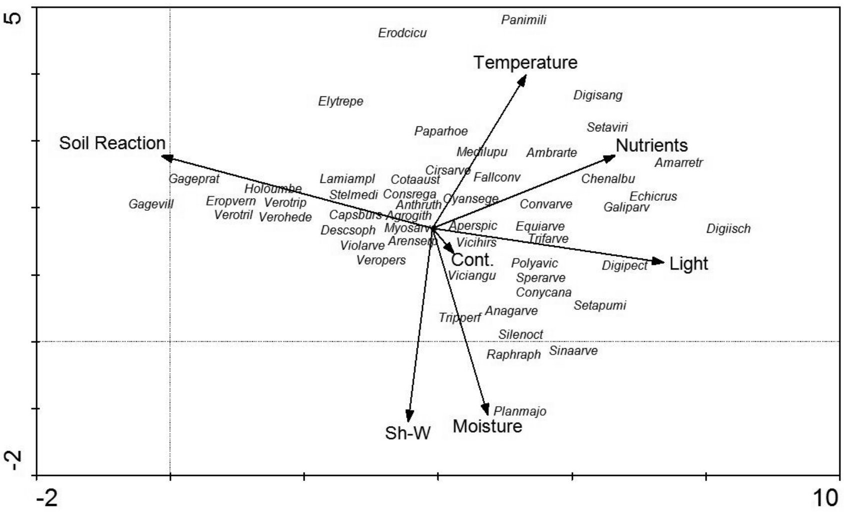

Fig. 3. Detrended correspondence analysis (DCA) ordination diagram of examined dataset. Ordination scores of the most important species (weight > 7%).
Species list: Agrogith – *Agrostemma githago*, Amarretr – *Amaranthus retroflexus*, Ambrarte – *Ambrosia artemisiifolia*, Anagarve – *Anagallis arvensis*, Anthruth – *Anthemis ruthenica*, Aperspic – *Apera spica-venti*, Arenserp – *Arenaria serpyllifolia*, Capsburs – *Capsella bursa-pastoris*, Chenalbu – *Chenopodium album* agg., Cirsarve – *Cirsium arvense*, Consrega – *Consolida regalis*, Convarve – *Convolvulus arvensis*, Conycana – *Conyza canadensis*, Cotaaust – *Cota austriaca*, Cyansege – *Cyanus segetum*, Descsoph – *Descurainia sophia*, Digiisch – *Digitaria ischaemum*, Digipect – *Digitaria pectiniformis*, Digisang – *Digitaria sanguinalis*, Echicrus – *Echinochloa crus-galli*, Elytrepe – *Elytrigia repens*, Equiarve – *Equisetum arvense*, Erodcicu – *Erodium cicutarium*, Eropvern – *Erophila verna*, Fallconv – *Fallopia convolvulus*, Gageprat – *Gagea pratensis*, Gagevill – *Gagea villosa*, Galiparv – *Galinsoga parviflora*, Holoumbe – *Holosteum umbelatum*, Lamiampl – *Lamium amplexicaule*, Medilupu – *Medicago lupulina*, Myosarve – *Myosotis arvensis*, Panimili – *Panicum miliaceum*, Paparhoe – *Papaver rhoeas*, Planmajo – *Plantago major*, Polyavic – *Polygonum aviculare* agg., Raphraph – *Raphanus raphanistrum*, Setapumi – *Setaria pumila*, Setaviri – *Setaria viridis*, Silenoct – *Silene noctiflora*, Sinaarve – *Sinapis arvensis*, Sperarve – *Spergula arvensis*, Stelmedi – *Stellaria media*, Trifarve – *Trifolium arvense*, Tripperf – *Tripleurospermum perforatum*, Verohede – *Veronica hederifolia*, Veropers – *Veronica persica*, Verotril – *Veronica triloba*, Verotrip – *Veronica triphyllos*, Viciangu – *Vicia angustifolia*, Vicihirs – *Vicia hirsuta*, Violarve – *Viola arvensis*.

Table 2. Inter set correlations of environmental variables with DCA ordination axes.

	Axis 1	Axis 2	Axis 3	Axis 4
Sh-W	−0.02	−0.25	−0.06	0.06
Light	0.43	−0.11	−0.03	−0.33
Temperature	0.16	0.18	0.03	−0.11
Continentality	0.04	−0.04	−0.17	0.01
Moisture	0.12	−0.26	0.14	0.03
Soil reaction	−0.51	0.17	0.06	0.27
Nutrients	0.33	0.05	0.14	0.17

Consolido-Anthemidetum austriacae

This community develops in the summer, mainly in cereals, and less frequently in fallows. The total number of species in the datasets has increased from 83 to 112 species. The average number of species per relevé has also increased, from 16 in the past (min. 6, max. 30) to 22 in the present (min. 16, max. 35). A rather large group of diagnostic species were found in both periods (Table 1, columns 2A, 2B), but many diagnostic species have appeared only recently. The largest increase in frequency can be seen in the species *Consolida regalis*, *Galium aparine*, *Papaver rhoeas*, *Silene noctiflora*, *Tripleurospermum perforatum* and *Viola arvensis*. In contrast, *Agrostemma githago*, *Cyanus segetum*, *Ranunculus arvensis*, *Vicia hirsuta* and *V. angustifolia* are now less frequent. The first three of these species belong to threatened taxa; their presence in stands has slightly decreased in general (Fig. 4d).

In the ordination diagram (Fig. 2) the stands from the past and present more or less overlap, but demand for nutrients has increased significantly (Fig. 5f). Invasive species have invaded the community, but it also has a higher number of therophytes, archaeophytes and native species (Figs 6a,e, 4a,c).

The calcareous archaeophytes *Consolida regalis* and *Silene noctiflora* (partly also *Papaver rhoeas*) have spread successfully in fields mainly due to liming (Hilbig & Jage 1984, Trzcińska-Tacik 1991). According to Hilbig & Jage (1984), the spread of *Galium aparine* and *Stellaria media* (both are native in Slovakia) is an indicator of the eutrophication of agrocoenoses.

The decline of speirochoric species (e.g., *Agrostemma githago*, *Bromus secalinus*, *Cyanus segetum*, *Ranunculus arvensis*) in segetal communities in cereal fields was also observed by Trzcińska-Tacik (1991).

Echinochloo-Setarietum pumilae

Stands of this association are the most demanding for nutrients among the studied phytocoenoses (Fig. 5f). In the past the community was found mainly in stubble, but also in root crops and vegetable fields with optimum development in August and September. Nowadays, the association is more heterogeneous. We recorded it in June to September, mainly in root crops, less in fallows, cereals and stubble. The diagnostic species in both datasets (Table 1, columns 3A, 3B) are different (with

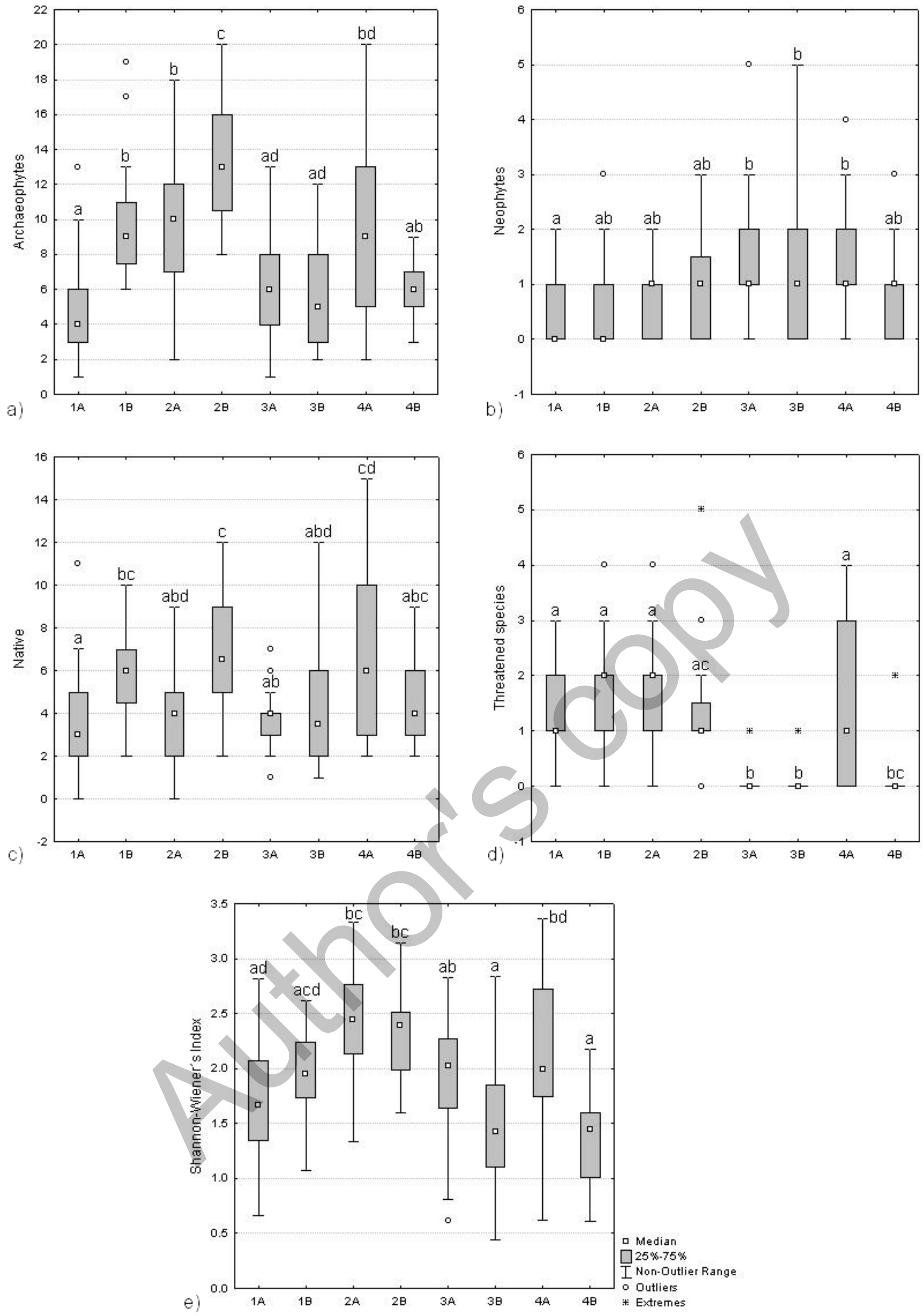

Fig. 4. Box and Whisker plots representing: a – number of archaeophytes, b – number of neophytes, c – number of native species, d – number of threatened species, e – Shannon-Wiener's index of diversity for clusters 1A–4B (explanation see Table 1). Labels a–d indicate homogenous groups according to *post-hoc* comparisons using ANOVA (Tukey test, $P < 0.001$).

the exception of *Chenopodium album* agg., *Echinochloa crus-galli*, *Setaria viridis* and *Amaranthus retroflexus*). Species that prefer more acidic soil, often without carbonates, have declined (*Digitaria pectiniformis*, *Galinsoga parviflora*, *Persicaria maculosa*, *Setaria pumila*). On the other hand, some new, alien species are now found in the association (*Amaranthus powellii*, *Aster lanceolatus*, *Panicum miliaceum*, *Xanthium albinum*).

The diversity of the association has slightly (but not significantly) decreased (Fig. 4e), although the average number of species per relevé has remained unchanged (12). Today the community is formed of species that are more continental, and require more soil moisture and higher soil reaction (Figs 5c,d,e). This increased demand for moisture is perhaps connected with migration of the community from stubble that dries out quickly, to growth in root crops where soil moisture is retained for a longer period.

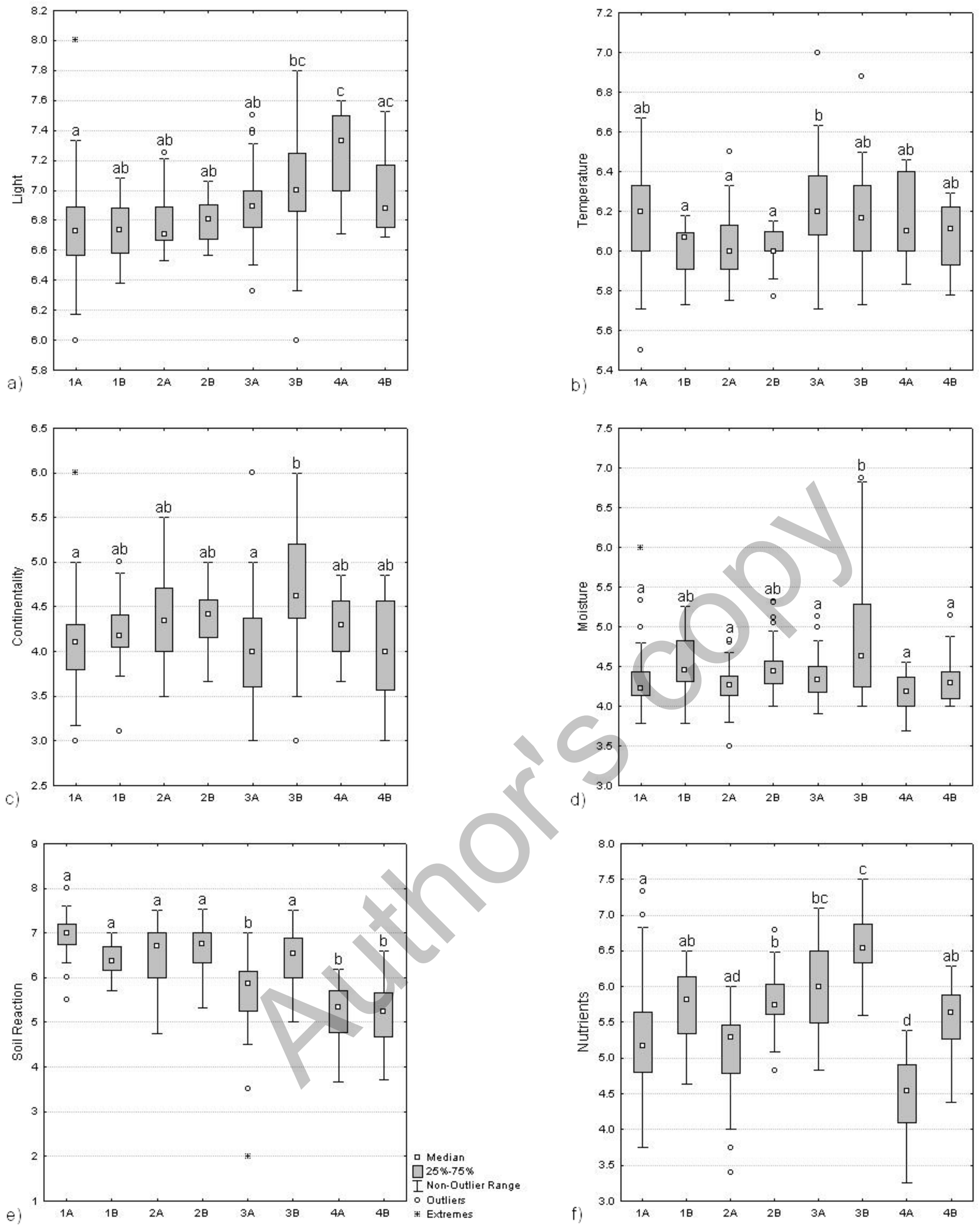

Fig. 5. Box and Whisker plots representing Ellenberg's indicator values for clusters 1A–4B (explanation see Table 1). Labels a–d indicate homogenous groups according to *post-hoc* comparisons using ANOVA (Tukey test, $P < 0.001$).

No threatened species were found in this community (Fig. 4d).

Setario viridis-Erigeronetum canadensis
This association prefers the most acidic soils of all the studied biotopes (Fig. 5e). It was found in the summer and autumn, in the past mainly in fallows and in cereals, and nowadays in stubble, cereals and less frequently in fallows. The diversity of the association has significantly decreased (Fig. 4e); the total number of species (from 90 to 46) and the average number of species per relevé has also decreased: from 18 in the historic dataset (min. 5, max. 36), to 13 in the recent dataset (min. 7, max. 17). The group of diagnostic taxa was much bigger in the past compared to the present (Table 1, columns 4A, 4B). Those found in both datasets were the xerophilous species *Conyza canadensis*, *Digitaria sanguinalis* and *Trifolium arvense*. Some

threatened species have disappeared from the community (*Agrostemma githago*, *Bromus secalinus*, *Cyanus segetum*, *Herniaria hirsuta*). Their overall occurrence is significantly lower today (Fig. 4d). Due to changes in agricultural management it came to impoverishment of the community.

This association has been described by Šomšák (1976) in the area of the Borská nížina Lowland as being characteristic of forest clearings and newly planted pine monocultures. As these are regularly cultivated (by hand or mechanically), the association is similar to the segetal vegetation found in the fields. Although the diagnostic species in the fields and forest clearings differ slightly, *Conyza canadensis* remains as the dominant and characteristic species.

Changes in species composition

In the 1950s 179 species were recorded in the studied communities. In the years 2002–2006 we recorded 164 species. A total of 100 species were found in both periods, with 79 only found in the historic dataset and 64 only in the recent dataset. The number of therophytes stayed more or less the same (113 in the past, 115 recently), but the number of hemicryptophytes (55/42) and geophytes (11/5) has decreased. Changes in the representation of life forms in particular associations can be seen in Figs 6a–c.

The occurrence of archaeophytes has changed slightly. Their total number decreased from 89 in the historic relevés to 80 in recent relevés. Despite this, their number significantly increased in the associations *Veronicetum trilobae-triphyllidi* and *Consolido-Anthemidetum austriacae*. In contrast it decreased in the association *Setario viridis-Erigeronetum canadensis* (Fig. 4a).

The floristic composition of the segetal vegetation has been enriched by several neophytes (*Amaranthus powelii*, *Ambrosia artemisiifolia*, *Aster lanceolatus*, *Xanthium albinum*) that were not recorded in these communities in the past (Table 1). The number of neophytes increased (from 13 to 19) but there was no statistically significant increase in the communities (Fig. 4b). An increase in neophytes on agricultural land has also been observed by Lososová et al. (2004) and Lososová & Simonová (2008). Arable land belongs to a biotope that is one of those most attacked by alien plant species (Chytrý et al. 2005).

The number of invasive species has also increased from 10 to 18. However, a statistically significant increase in invasive species was confirmed only in associations *Veronicetum trilobae-triphyllidi* and *Consolido-Anthemidetum austriacae* (Fig. 6e).

It is surprising that the total number of rare and threatened species has slightly increased from 13 to 16. A statistically significant difference was observed only in the association *Setario viridis-Erigeronetum canadensis*, where their numbers significantly decreased (Fig. 4d). Rare species like *Bromus secalinus*, *Herniaria hirsuta* and *Veronica triloba* totally disappeared from the fields, with a significant decrease in the frequency of *Agrostemma githago*, *Cyanus segetum* and *Ranunculus arvensis* (Table 1). On the other hand we found some new species (*Adonis aestivalis*, *Aphanes arvensis*, *Kickxia elatine*, *K. spuria*), the appearance of which is relatively rare. Therefore we suspect that these were overlooked by Krippelová, because they have already been found in the same area (cf. Futák 1982; Holub & Kmeťová 1992; Michalková 1997).

The decline of some specialized segetal species in Slovakia was recorded more than 20 years ago (Skalický 1981; Kropáč & Kopecký 1987). The decline or even disappearance of species that were common in the past and that today belong to rare and threatened, speirochoric species and species adapted to extreme habitat conditions has also been observed in other parts of Europe (Koblihová 1989; Trzcińska-Tacik 1991; Günther & van Elsen 1993; Lososová 2003; Lososová & Simonová 2008). Although these species are in decline, due to changes in agricultural management and due to convenient climatic conditions, some of them may reappear and spread in the fields due to the soil seed bank and the longevity of the seeds (Holzner & Immonen 1982; Sutcliff & Kay 2000).

In all studied associations the proportion of nutrient-demanding species has increased (Fig. 5f). This is mainly due to the higher dosages of mineral fertilizers applied compared to the past. These enrich the soil with nitrogen and other nutrients, which enables the spread of nitrophilous weeds in the fields. A similar trend has been observed in arable fields by several authors (Hilbig & Jage 1984; Köck 1984; Trzcińska-Tacik 1991; Lososová & Simonová 2008). Therefore the frequency of nitrophilous species such as *Chenopodium album* agg., *Stellaria media* and *Tripleurospermum perforatum* has increased strongly in the majority of the studied communities (Table 1).

In all associations the frequency of grasses *Apera spica-venti* and *Elytrigia repens* increased. Due to adaptations in the phenology of ripening and distribution of seeds in the former and effective vegetative reproduction (supported by tillage) in the latter, these species are predisposed for large-scale spreading in agrocoenoses. The use of herbicides represses dicotyledonous weeds, and as a result indirectly supports the development of undesirable grasses in planted cultures (Trzcińska-Tacik 1991). The spread of *Apera spica-venti* in fields was also observed by Hilbig & Jage (1984), and that of *Elytrigia repens* by Kropáč (1984) and Koblihová (1989).

We also observed the spread of other species that are probably resistant to herbicides (*Polygonum aviculare* agg., *Viola arvensis*) and species that are characteristic of ruderal biotopes (cf. Jarolímek et al. 2008), e.g. *Artemisia vulgaris*, *Descurainia sophia*, *Elytrigia repens*, *Lactuca serriola* and *Tripleurospermum perforatum*, which has an influence on the ruderalisation of the segetal vegetation. Most of the species that have shown a significant increase in frequency during last 50 years (*Chenopodium album* agg., *Elytrigia repens*, *Polygonum aviculare* agg., *Stellaria media*, *Tripleuros-*

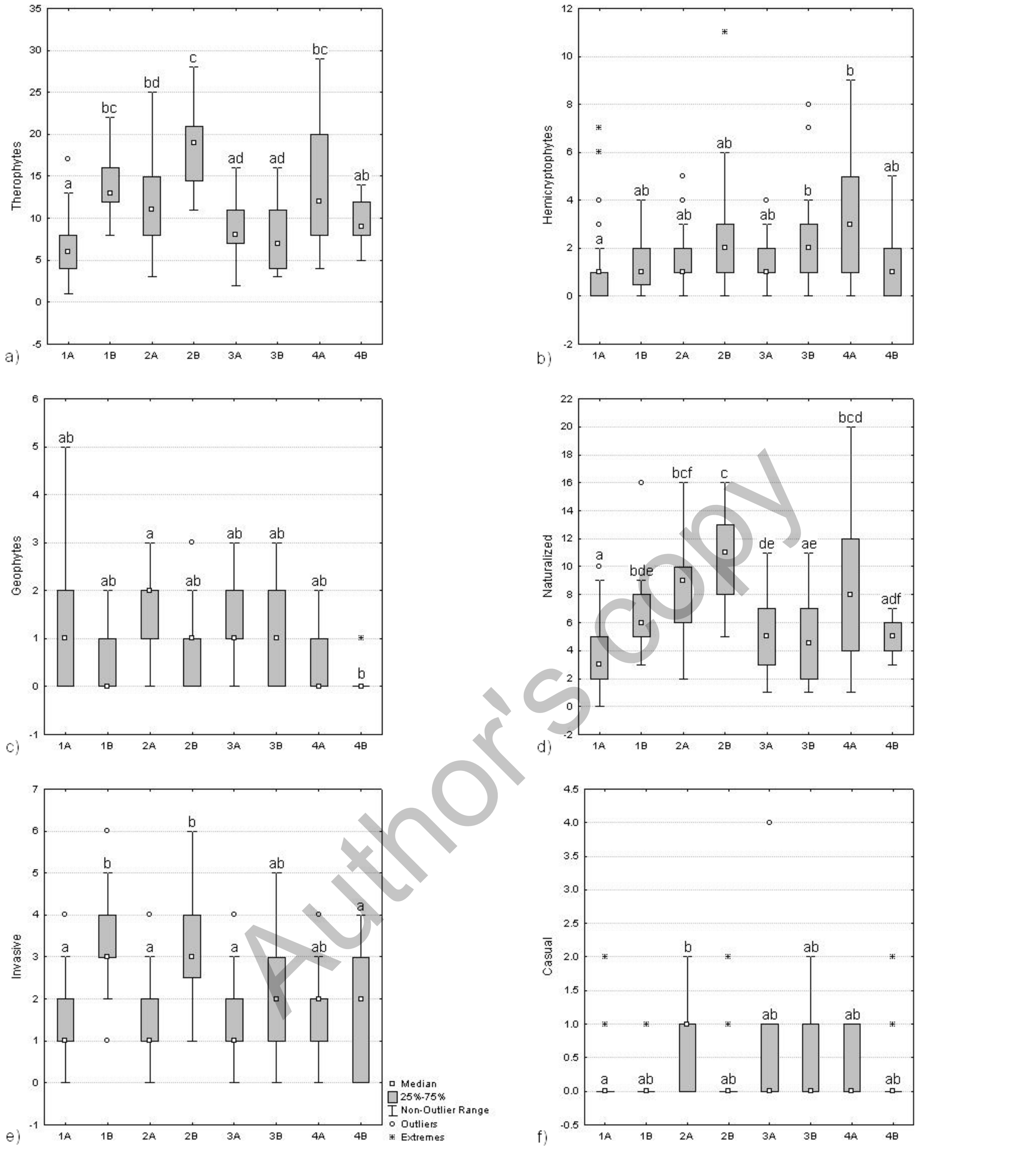

Fig. 6. Box and Whisker plots representing: a – number of therophytes, b – number of hemicryptophytes, c – number of geophytes, d – number of naturalized species, e – number of invasive species, f – number of casual species for clusters 1A–4B (explanation see Table 1). Labels a–f indicate homogenous groups according to *post-hoc* comparisons using ANOVA (Tukey test, $P < 0.001$).

permum perforatum and *Viola arvensis*) are among the ten most common weeds in fields of the Czech Republic (Lososová et al. 2008).

In conclusion we can state that comparison of historical and present phytosociological relevés showed that in some associations there was a significant increase in the number of invasive species. Surprisingly the number of archaeophytes and native species has also increased. These species have optimum development in other biotopes (mainly ruderal species) or their spread is indirectly supported by agricultural practices (liming, fertilization) or they are resistant to herbicides. On the other hand, some species that are currently rare or threatened have declined or disappeared.

The detected changes were not as substantial as expected or as observed in some other countries (cf. Andreasen et al. 1996). This may be because the Borská nížina Lowland is not one of the most important or productive agricultural areas of Slovakia, due to its soil conditions. Therefore many weeds can survive and spread in the fields.

Acknowledgements

We thank I. Jarolímek for providing his relevé and I. Šibíková for help with statistical data processing. The processing of data with Statistica software was possible thanks to a collaboration with Masaryk University (Brno, Czech Republic).

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Received February 26, 2008
Accepted May 25, 2009