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CLASSIFICATION OF WEED VEGETATION OF ARABLE LAND IN THE CZECH REPUBLIC AND SLOVAKIA

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Abstract: Numerical classification of 2653 geographically stratified relevés of weed vegetation from the Czech and Slovak Republics was performed with cluster analysis. Diagnostic species were determined for each of the seven main clusters using statistical measures of fidelity. The classification reflected clear distinctions between lowland (mostly calcicole) and highland (mostly calcifuge) sites, spring and summer phenological stages, and cereals and root crops. The results of the cluster analysis were compared with traditional phytosociological units. Two clusters corresponded to calcifuge weed vegetation of the *Scleranthion annui* alliance; one cluster represented the vegetation of root crops on moist soils of the *Oxalidion europaeae* alliance; one cluster contained thermophilous weed vegetation of the *Caucalidion lappulae* alliance; two clusters included weed vegetation of root crops and of stubble fields, which can be assigned to the *Caucalidion*, *Panico-Setarion*, *Veronico-Euphorbion* and *Eragrostion* alliances; one cluster included vernal weed vegetation in little disturbed habitats of the *Caucalidion lappulae* and *Scleranthion annui* alliances. Our analysis did not support the concept of the *Sherardion* and *Veronico-Taraxacion* alliances, which were included in earlier overviews of the vegetation units of the Czech Republic and Slovakia.

Keywords: Agriculture, Cluster analysis, Phytosociology, Plant community, *Stellarietea mediae*, Vegetation survey

Nomenclature: KUBÁT et al. (2002)

INTRODUCTION

Arable fields are among the most common habitats of Central Europe. Understanding of the floristic variation in weed vegetation, reflected in phytosociological surveys, underwent several changes during the 20th century. The first phytosociological studies recognized a single large class, *Rudereto-Secalinetea* (BRAUN-BLANQUET et al. 1936), which encompassed weed vegetation, nitrophilous river-bank vegetation and ruderal vegetation in human settlements. TÜXEN (1950) proposed a new classification of synanthropic vegetation with several narrower, floristically and ecologically more homogeneous classes. In this classification, annual synanthropic vegetation, occurring both on arable land and in human settlements, was included in a new class *Stellarietea mediae* and separated from perennial synanthropic vegetation. Tüxen's division into orders within this class followed a putative main dichotomy within annual synanthropic vegetation, i.e., the dichotomy between weed vegetation in winter cereals (*Centaureetalia cyani* order) and all other types of annual vegetation in both arable fields and human settlements (*Chenopodietalia albi*). However, ELLENBERG (1950) and some other authors pointed out that in many cases the difference between weed vegetation in winter and summer cereal fields is indistinct, mainly due to crop rotation. This was reflected in later studies, where the principal dichotomy in floristic composition of Central European weed vegetation was assumed between winter and summer cereals (usually labelled as class *Secalietea* or order *Secalietalia*) and root crops along with annual vegetation in human settlements (usually included in class *Chenopodietea* or order *Chenopodietalia*) (OBERDORFER 1957, 1993, MORAVEC et al. 1995, SOLOMAKHA 1996, MATUSZKIEWICZ 2001).

Later on, broad-scale analyses of the diversity in weed vegetation suggested that the difference between weed vegetation in cereal and root crops is more pronounced in warmer parts of Europe, and gradually decreases towards the cooler and more humid north and northwest (HOLZNER & IMMONEN 1982, GLEMNITZ et al. 2000). In Central Europe, there was a growing evidence that the main dichotomy in weed vegetation reflects soil and climatic factors rather than crop plants. A convincing demonstration of this, based on a large phytosociological data set from Germany, is provided by HÜPPE & HOFMEISTER (1990), who divided weed vegetation into two major groups, calcicole and calcifuge. This concept is followed in most of the recent phytosociological surveys of weed vegetation in Central European countries, including the Netherlands (HAVEMAN et al. 1998), Germany (POTT 1995, RENNWALD 2000, SCHUBERT et al. 2001), Austria (RIES 1992, MUCINA 1993), Liechtenstein (BERNHARDT 1994), Slovakia (JAROLÍMEK et al. 1997) and Hungary (BORHIDI 2003). The importance of factors other than crop plants in determining weed species composition is also recorded for the Mediterranean (NEZADAL 1989). DENGLER et al. (2003) and BERG et al. (2004) modified the concept of two groups, calcicole and calcifuge, by defining a third, intermediate group, which is characterized by the absence of both calcicole and calcifuge species.

In a recent study, LOSOSOVÁ et al. (2004) compiled a data set of 2653 geographically stratified relevés of weed vegetation of the Czech Republic and Slovakia and demonstrated using ordination techniques that the species composition of weeds on arable land is significantly affected by altitude, seasonal changes during the year and the crop plant. The effect of altitude was the most important and that of the crop plant the least important. This result corresponds to the conclusions of HÜPPE & HOFMEISTER (1990), because in the Czech Republic and less so in Slovakia, base-rich soils are more frequent at lower altitudes. Thus the main dichotomy in the Czech and Slovak weed vegetation depends on a combined gradient of climate and base status of the soils.

The last surveys of the weed vegetation of the Czech Republic and Slovakia (MORAVEC et al. 1995, JAROLÍMEK et al. 1997) differ in their basic concepts. While the Czech survey reflects the traditional system, with an emphasis on the dichotomy between cereal and root crops, the Slovak survey follows the newly accepted major dichotomy along a climatic/edaphic gradient. Both surveys contain some vegetation units, e.g. the alliances *Sherardion* and *Veronico politae-Taraxacion* (the latter only in the Czech survey), which are poorly differentiated from other types of weed vegetation and have not received wide acceptance.

Numerical analyses of large phytosociological data sets that span national boundaries are needed to reconcile the different classification schemes used in different countries (BRUELHEIDE & CHYTRÝ 2000) and test the appropriateness of traditional vegetation units. The aim of the present paper is to (1) identify major types of weed vegetation in the Czech Republic and Slovakia, using cluster analysis of a large phytosociological data set, (2) establish the relationship between the resulting types and traditional phytosociological units, and (3) put these results in the context of classification of the weed vegetation throughout Central Europe.

MATERIALS AND METHODS

The initial data set for the present analysis included 3481 relevés of weed vegetation of which 2596 were from the Czech Republic and 885 from Slovakia (Table 1). The relevés are stored in the national phytosociological databases of the Czech and Slovak Republics (CHYTRÝ & RAFAJOVÁ 2003 and VALACHOVIČ 1999, respectively) using the TURBOVEG program (HENNEKENS & SCHAMINÉE 2001). A stratified resampling from the initial data set was used to obtain relevés for data analysis. The purpose of the resampling was to reduce the effects of possible oversampling of some areas or particular vegetation types (KNOLLOVÁ et al. 2005). First, we deleted all relevés lacking a locality, date of record or crop plant. Second, we divided the territory of the two countries studied into grid squares of 1.25 longitudinal × 0.75 latitudinal minutes (ca. 1.5 × 1.4 km) and divided the relevés into spring (recorded before 1 June) and summer/autumn (recorded on 1 June or later). Third, we randomly selected only one relevé of each subset of relevés recorded for the same grid square, in the same crop and the same period (spring or summer/autumn). This stratification yielded 2653 relevés, recorded between 1954–2003 in plots ranging in size between 8–100 m^2. Prior to the analysis, we deleted from these relevés all records of crop plants, a few plants, that were only identified to genus, and bryophytes, which are usually not recorded and are of minor importance on arable land. This relevé data set is identical with that analyzed by LOSOSOVÁ et al. (2004) and can be obtained from the first author upon request.

We classified the entire data set using the cluster analysis in the PC-ORD 4 package (MCCUNE & MEFFORD 1999), relative Euclidean (chord) distance and beta-flexible clustering method with β = -0.15. We accepted seven of the relevé clusters indicated by the resulting dendrogram, after a preliminary inspection revealed that the acceptance of more clusters would result in some clusters with an unclear ecological meaning. Using the JUICE 6.3 program (TICHÝ 2002) and the phi coefficient of association as a measure of fidelity (SOKAL & ROHLF 1995, CHYTRÝ et al. 2002) a synoptic table was produced based on these clusters, and the diagnostic species for each cluster were determined. In these calculations, the frequency of each species in each cluster was compared with the frequency of the same species in the rest of the data set, which was treated as a single undivided group. In this way, divisions of the data set did not influence the fidelity of a species to a target cluster. As the

Table 1. The most important sources of the weed relevés used in this study.

Reference	Area	Number of relevés
KROPÁČ, unpubl.	entire study area, but mainly Bohemia	670
OTÝPKOVÁ, unpubl.	eastern Moravia	529
CIMALOVÁ, unpubl.	northern Moravia	347
LOSOSOVÁ, unpubl.	southern Moravia	262
MOCHNACKÝ (1987)	eastern Slovakia	173
OTÝPKOVÁ (2001)	Bílé Karpaty Mts. (eastern Moravia)	140
PASSARGE & JURKO (1975)	northern Slovakia	109
KRIPPELOVÁ (1981)	eastern Slovakia	71
VOLF (1974)	Bohemia	69
KUSÁK (1994)	eastern Moravia	54

unequal numbers of relevés included in individual clusters resulted in higher Φ values for larger clusters, each of the seven clusters was virtually equalized to 1/7 of the size of the entire data set, while holding the percentage occurrences of species within and outside the target cluster the same as in the original data set. The threshold Φ value for a species to be considered as diagnostic was set at 0.15. This value was selected subjectively, after preliminary inspection of some alternative groups of diagnostic species resulting from using lower or higher threshold values. The selected threshold value was low enough to produce a sufficient number of diagnostic species necessary for ecological interpretation of relevé clusters, and high enough to prevent too many generalist species or species diagnostic for more than one cluster becoming diagnostic species. This virtual equalization of the sizes of the clusters could result in increased Φ values for some rare species that occurred in relevés of some small clusters mainly by chance, even though their association with such clusters was not statistically significant because of their rarity. Therefore we additionally tested the statistical significance of the concentration of each species in each cluster by Fisher's exact test, using actual cluster sizes. The species whose occurrence in a cluster was not significantly different from random at $P < 0.001$ were not regarded as diagnostic species. The results of the classification were summarized in a synoptic table of percentage species frequencies (constancies) in which diagnostic species were ranked by decreasing fidelity, i.e., by decreasing Φ value (CHYTRÝ et al. 2002). Syntaxonomical interpretation of the clusters was based on a comparison of their diagnostic species with Central European phytosociological literature (Table 4).

RESULTS AND DISCUSSION

Clusters and their interpretation

The classification of Czech and Slovak weed vegetation into seven main clusters is presented in a synoptic table (Table 2), in which statistically determined diagnostic species are indicated and ranked by decreasing fidelity. This classification reflects the hierarchy of major factors, altitude and associated climatic factors, season and crop, as revealed by LOSOSOVÁ et al. (2004). At the same time, it supports the basic division of weed vegetation in the calcicole and calcifuge groups. Although the data cover the period from 1954 to 2003, changes in weed vegetation over past decades are not very pronounced, except for the fact that some clusters contain more relevés from either earlier or recent years. Clusters 1, 2 and 3 contain relevés from high altitudes, clusters 4, 5 and 7 from low altitudes and cluster 6 includes relevés of vernal weed vegetation. In addition, clusters 1, 2 and 4 include relevés mainly recorded in cereal fields, while those of clusters 3, 5 and 7 are mostly from root crops or stubble fields. Most clusters roughly correspond to alliances or broad associations of traditional phytosociology (Table 3) (HÜPPE & HOFMEISTER 1990, RIES 1992, MUCINA 1993, OBERDORFER 1993, MORAVEC et al. 1995, JAROLÍMEK et al. 1997). Cluster 1 of Table 2 contains relevés of cereal fields with a distinct group of calcifuge weeds (e.g. *Apera spica-venti*, *Matricaria recutita*, *Veronica arvensis*, *Vicia hirsuta* and *V. sativa*). This vegetation is found throughout the study area except for the warmer southeastern part of the Czech Republic and southern Slovakia. It is particularly frequent at middle and high altitudes. Syntaxonomically it corresponds to the *Aphano-Matricarietum* association of the *Scleranthion annui* alliance.

Cluster 2 is also characterized by calcifuge, but less thermophilous weeds, e.g. *Holcus mollis*, *Rumex acetosella*, *Scleranthus annuus* and *Spergula arvensis*. This vegetation type occurs only in the coldest and most humid areas used for agricultural production, at the upper altitudinal limit of arable fields. It includes relevés from any type of crop, as the difference between cereal and root-crop weed communities are small at high altitudes. This cluster fits the concept of the *Spergulo-Scleranthetum* association of the *Scleranthion annui* alliance.

Cluster 3 is the largest, containing relevés mainly recorded in root crop and stubble fields on moist and neutral soils throughout the study area, except the warmest areas in the southeast of the Czech Republic and southern Slovakia. This vegetation is dominated by, e.g. *Chenopodium polyspermum*, *Euphorbia helioscopia*, *Galinsoga quadriradiata* and *Persicaria lapathifolia*, together with some generalist weeds, e.g. *Amaranthus retroflexus*, *Chenopodium album*, *Echinochloa crus-galli* and *Galinsoga parviflora*. This cluster can be identified with the association *Panico-Chenopodietum polyspermi* of the *Oxalidion europaeae* alliance.

Cluster 4 is characterized by a group of thermophilous species, e.g. *Adonis aestivalis*, *Consolida regalis*, *Descurainia sophia*, *Lathyrus tuberosus* and *Silene noctiflora*. It includes the weed vegetation of cereal fields on base-rich soils, in the warmest low-altitude areas of the Czech Republic and Slovakia. It is traditionally assigned to the *Caucalidion lappulae* alliance.

Cluster 5 includes vegetation that develops in high summer, in stubble fields and root crops. Its geographical distribution is similar to that of cluster 4, but it has a later phenological optimum, as indicated by the late-summer annual weeds, e.g. *Euphorbia falcata*, *Setaria viridis* and *Stachys annua*. Some of the diagnostic species (*Digitaria sanguinalis*, *Portulaca oleracea* and *Setaria viridis*) are confined to dry sandy soils in the warmer parts of the study area. Some others (*Anagallis foemina*, *Euphorbia exigua*, *E. falcata* and *Stachys annua*) frequently occur in stubble fields on nutrient-rich soils in the lowlands. In phytosociological terms, this cluster includes weed vegetation belonging to the alliances of *Panico-Setarion* (*Echinochloo-Setarietum* association), *Caucalidion lappulae* (association *Euphorbio--Melandrietum*) and *Veronico-Euphorbion* (syn. *Fumario-Euphorbion*; association *Setario-Fumarietum* or *Setario-Veronicetum politae*).

Table 2. Synoptic table summarizing results of a cluster analysis of the weed vegetation of the Czech Republic and Slovakia. In the header, top-down branching of the classification dendrogram is indicated by zeros and ones. Species values are percentage frequencies. Species with a fidelity of $\Phi > 0.15$ are considered as diagnostic and ranked by decreasing value of Φ. They are indicated by asterisks and shown in bold. * = $\Phi > 0.15$; ** = $\Phi > 0.25$ (Φ was calculated for groups with equal numbers of relevés). Species with $\Phi < 0.15$ and frequency < 20% in all columns are not shown. s.d. – standard deviation.

Cluster number	1	2	3	4	5	6	7
Number of relevés	547	218	784	254	259	479	112
Cluster hierarchy	0	0	0	0	0	0	1
	0	0	0	0	0	1	
	0	0	1	1	1		
	0	1	0	1	1		
				0	1		
Altitude: mean	457	554	343	271	250	342	198
s.d.	152	158	133	106	104	138	113
Month of record/1st or 2nd half: median	6/2	7/1	7/1	5/2	7/2	4/2	8/1
Year of record: mean	1987	1979	1990	1982	1979	1990	1987
s.d.	15	14	14	14	15	13	10
Cereals (%)	91	73	58	93	71	83	42
Root crops (%)	9	27	42	7	29	17	58
Number of species per relevé: mean	29	27	26	23	24	20	16
s.d.	9	9	10	9	10	8	8
Ellenberg indicator values:							
Light: mean	6.7	6.7	6.8	6.7	6.9	6.7	7.1
s.d.	0.1	0.2	0.2	0.2	0.2	0.2	0.3
Temperature: mean	5.7	5.6	5.8	5.9	6.0	5.7	6.1
s.d.	0.1	0.1	0.2	0.2	0.2	0.2	0.3
Continentality: mean	3.8	3.7	3.9	4.3	4.3	3.9	4.4
s.d.	0.3	0.3	0.4	0.4	0.4	0.4	0.5
Moisture: mean	5.1	5.1	5.0	4.6	4.6	4.9	4.9
s.d.	0.3	0.3	0.3	0.4	0.3	0.3	0.4
pH: mean	6.2	5.3	6.8	7.1	6.7	6.7	6.5
s.d.	0.6	0.7	0.6	0.1	0.7	0.7	1.1
Nutrients: mean	6.2	5.8	6.5	6.0	6.0	6.3	6.8
s.d.	0.4	0.4	0.4	0.5	0.6	0.5	0.5
Cluster 1 (*Scleranthion annui*: *Aphano-Matricarietum*)							
Veronica arvensis	**58****	27	16	9	9	30	.
Apera spica-venti	**44****	18	9	12	14	8	4
Myosotis arvensis	**85****	57	40	30	20	49	7
Vicia hirsuta	**47****	34	15	7	22	9	5
Lapsana communis	**61****	44	30	9	8	29	4
Vicia sativa	**48****	40	19	13	15	12	3
Vicia tetrasperma	**37***	12	14	10	11	12	7
Matricaria recutita	**21***	3	5	11	6	1	3
Aphanes arvensis	**21***	11	2	5	3	8	.
Centaurea cyanus	**38***	22	10	10	29	13	4
Poa trivialis	**22***	10	5	2	1	12	2

Cluster number	1	2	3	4	5	6	7
Matricaria discoidea	**26***	15	13	6	2	4	4
Galium aparine	**69***	28	53	46	18	55	16
Odontites vernus	**9***	4	2	1	.	1	.
Juncus bufonius	**10***	9	2	1	.	.	1
Agrostis stolonifera	**23***	16	11	2	3	10	1
Sagina procumbens	**8***	8	1	.	.	1	.
Cluster 2 (*Scleranthion annui*: *Spergulo-Scleranthetum*)							
Spergula arvensis	23	**72****	12	.	3	5	4
Rumex acetosella	12	**55****	3	2	3	10	2
Holcus mollis	8	**40****	1	1	.	1	.
Scleranthus annuus	32	**70****	9	5	25	15	3
Raphanus raphanistrum	26	**71****	18	17	25	14	18
Achillea millefolium s.lat.	35	**66****	17	7	17	22	4
Agrostis capillaris	1	**12****	.	.	.	.	1
Persicaria maculosa	23	**46****	23	6	16	4	8
Hylotelephium maximum	3	**13****	1	.	.	2	.
Ranunculus repens	34	**5 ***	24	9	7	19	2
Stellaria graminea	8	**19***	2	.	4	2	1
Veronica chamaedrys	3	**11***	.	.	.	1	.
Mentha arvensis	30	**44***	23	3	9	8	4
Deschampsia cespitosa	1	**8***	.	.	.	.	.
Alchemilla vulgaris s.lat.	2	**9***	.	.	.	1	.
Hypericum maculatum	1	**8***	1	.	.	1	.
Cerastium holosteoides	22	**29***	7	4	3	13	1
Gnaphalium uliginosum	18	**25***	9	2	5	1	4
Leucanthemum vulgare s.lat.	3	**12***	2	.	2	2	.
Stachys palustris	25	**37***	25	4	6	3	4
Linaria vulgaris	5	**18***	4	7	10	2	.
Rumex acetosa	5	**12***	1	1	4	3	.
Prunella vulgaris	3	**9***	2	.	.	1	1
Sanguisorba officinalis	.	**4***	.	.	.	.	.
Cluster 3 (*Oxalidion europaeae*)							
Galinsoga quadriradiata	9	5	**26****	1	2	4	8
Euphorbia helioscopia	22	17	**48***	27	23	18	16
Persicaria lapathifolia	30	39	**47***	6	20	6	43
Chenopodium polyspermum	8	5	**24***	2	13	4	24
Sonchus asper	16	12	**36***	19	29	7	12
Veronica persica	56	16	**66***	39	44	53	15
Cluster 4 (*Caucalidion lappulae*)							
Consolida regalis	5	.	10	**70***	32	20	3
Adonis aestivalis	1	.	3	**34***	4	4	.
Descurainia sophia	2	.	6	**42***	12	18	4
Papaver rhoeas	22	1	19	**60***	27	30	5
Fumaria vaillantii	1	.	3	**18***	1	2	1
Caucalis platycarpos	.	.	1	**15***	7	.	.
Conringia orientalis	.	.	1	**12***	1	.	.
Silene noctiflora	7	.	26	**43***	28	9	8
Veronica triloba	.	.	.	**11***	.	4	.
Lathyrus tuberosus	5	.	15	**33***	23	5	10

Cluster number	1	2	3	4	5	6	7
Camelina microcarpa	1	.	1	**9***	4	1	.
Veronica polita	3	1	18	**34***	16	27	5
Neslia paniculata	12	5	13	**28***	8	9	4
Veronica praecox	.	.	.	**5***	.	1	.
Alyssum alyssoides	.	.	.	**3***	.	.	.
Cluster 5 (*Caucalidion lappulae + Panico-Setarion + Veronico-Euphorbion*)							
Setaria viridis	1	3	6	3	**34****	1	16
Stachys annua	1	.	5	4	**26****	1	9
Conyza canadensis	1	2	4	5	**25****	7	7
Misopates orontium	1	.	.	.	**10****	.	.
Convolvulus arvensis	35	35	51	52	**76****	18	47
Trifolium arvense	5	3	1	.	**14***	.	1
Euphorbia falcata	.	.	3	4	**13***	.	1
Euphorbia exigua	3	1	16	23	**29***	1	3
Anagallis foemina	.	.	4	6	**14***	.	2
Medicago lupulina	13	2	19	15	**34***	3	4
Trifolium campestre	4	2	2	1	**13***	1	.
Digitaria sanguinalis	.	.	1	.	**7***	.	4
Kickxia spuria	.	.	5	2	**11***	.	1
Securigera varia	1	.	.	2	**6***	.	.
Portulaca oleracea	.	.	.	.	**5***	.	4
Ajuga chamaepitys	.	.	.	4	**7***	.	2
Reseda lutea	.	.	2	2	**7***	.	1
Salvia verticillata	.	.	1	1	**5***	.	.
Falcaria vulgaris	.	.	3	4	**9***	1	.
Anagallis arvensis	46	34	47	35	**58***	5	21
Kickxia elatine	2	1	2	1	**8***	.	2
Vicia grandiflora	.	.	.	.	**3***	.	.
Filago arvensis	.	.	.	.	**4***	.	.
Plantago media	.	5	1	4	**8***	2	.
Digitaria ischaemum	.	.	1	.	**5***	.	2
Anthemis ruthenica	.	.	.	.	**3***	.	.
Cluster 6 (vernal communities)							
Veronica hederifolia (incl. *V. sublobata*)	10	13	6	37	3	**71****	4
Veronica triphyllos	2	3	.	6	3	**17****	.
Erophila verna	3	2	1	2	1	**15****	.
Lamium purpureum	43	12	42	20	9	**66****	12
Arabidopsis thaliana	16	13	6	6	4	**25***	.
Holosteum umbellatum	.	.	.	4	.	**6***	.
Stellaria media	78	72	71	50	44	**88***	34
Thlaspi perfoliatum	1	.	.	5	1	**8***	.
Myosotis stricta	4	4	1	2	1	**10***	.
Capsella bursa-pastoris	63	59	59	60	40	**78***	32
Cluster 7 (*Veronico-Euphorbion + Eragrostion*)							
Hibiscus trionum	.	.	.	.	1	.	**14****
Datura stramonium	.	.	1	.	.	.	**11****
Amaranthus powellii	.	.	4	1	5	.	**18****
Bidens tripartita	1	3	1	.	1	.	**11***
Eragrostis minor	.	.	.	.	2	.	**6***

Cluster number	1	2	3	4	5	6	7
Solanum nigrum	.	.	7	.	7	.	**15***
Hyoscyamus niger	.	.	1	1	.	.	**7***
Eragrostis cilianensis	.	.	.	.	.	.	**4***
Cynodon dactylon	.	.	.	.	2	.	**4***
Malva sylvestris	.	.	.	.	.	.	**4***
Malva neglecta	.	.	4	2	5	1	**11***
Clusters 1 + 2 (*Scleranthion annui*)							
Galeopsis tetrahit	**59****	**83****	23	9	6	18	4
Anthemis arvensis	**34***	**40***	8	9	20	17	3
Viola arvensis	**85***	**85***	52	76	54	70	20
Persicaria hydropiper	**18***	**31****	4	.	1	3	3
Clusters 3 + 7							
Chenopodium album	47	56	**81***	53	69	26	**86***
Echinochloa crus-galli	3	3	**33***	4	29	1	**85***
Galinsoga parviflora	3	6	**24***	2	22	2	**29***
Amaranthus retroflexus	.	.	**21***	3	20	1	**66***
Clusters 3 + 4							
Sinapis arvensis	15	6	**42***	**50***	27	13	14
Clusters 4 + 6							
Lamium amplexicaule	14	6	19	**41***	14	**46***	15
Clusters 5 + 7							
Setaria pumila	2	1	7	.	**31****	.	**43****
Gypsophila muralis	2	.	1	.	**10***	.	**14***
Other constant species							
Tripleurospermum inodorum	68	41	58	50	41	58	74
Fallopia convolvulus	75	71	64	60	57	34	23
Cirsium arvense	67	55	76	60	59	47	41
Polygonum aviculare	59	49	56	58	55	28	30
Elytrigia repens	59	54	52	45	49	38	29
Thlaspi arvense	49	34	53	58	21	53	22
Poa annua	43	30	27	12	7	37	9
Taraxacum sect. *Ruderalia*	42	49	54	38	34	59	24
Plantago major	33	37	42	15	27	13	32
Sonchus arvensis	29	21	32	19	30	17	16
Equisetum arvense	27	31	26	9	16	8	23
Rumex crispus	24	24	22	13	9	16	12
Tussilago farfara	12	20	12	6	4	5	1
Campanula rapunculoides	18	20	13	17	11	8	2
Atriplex patula	16	6	26	23	20	7	11
Sonchus oleraceus	10	6	26	7	27	9	23
Avena fatua	16	6	24	30	22	7	10
Geranium pusillum	15	11	20	24	14	20	9
Aethusa cynapium	15	4	16	24	19	6	5
Fumaria officinalis	11	7	19	20	3	9	4
Daucus carota	15	10	14	6	26	8	6

Cluster 6 contains relevés with vernal ephemeral therophytes, e.g. *Arabidopsis thaliana*, *Erophila verna*, *Holosteum umbellatum*, *Veronica hederifolia* (incl. *V. sublobata*) and *V. triphyllos*. This vegetation type represents the spring phenological aspect of weed communities in little disturbed habitats, such as winter cereal fields, vineyards and abandoned fields. The phytosociological concept of separating weed communities from the same site into vernal and summer associations (KROPÁČ et al. 1971, HOLZNER 1973) reflects the fact that annual weed communities are highly dynamic and form distinct phenological aspects. In the traditional phytosociological hierarchy, vernal weed vegetation is assigned to the associations *Erophilo-Arabidopsietum* of high altitude or low pH soils and *Veronicetum hederifolio-triphylli* of low altitude or high pH soils, which are usually classified among different alliances, *Scleranthion annui* and *Caucalidion lappulae*, respectively. However, our analysis suggests that similarity between vernal communities from different habitats can be higher than that between vernal and summer communities in the same habitat.

Cluster 7 is characterized by a group of thermophilous diagnostic species (e.g. *Datura stramonium*, *Eragrostis cilianensis*, *E. minor* and *Hibiscus trionum*). This vegetation develops mostly in root crops in the warmest parts of the southeastern region of the Czech Republic and southern Slovakia. Its phenological optimum is in late summer and autumn. The floristic composition of this vegetation is similar to the thermophilous annual vegetation of trampled habitats (*Eragrostio-Polygonion arenastri* sensu ČARNI & MUCINA 1998, *Eragrostion* sensu auct.) and the poorly known thermophilous weed vegetation of the Pannonian basin and southeastern Europe (alliances *Amarantho-Chenopodion*, *Tribulo-Eragrostion*; see BORHIDI 2003). The phytosociological status of this vegetation needs further study.

Alliances not recognized by the cluster analysis

Numerical classification did not support the concept of a separate alliance *Sherardion*, which is accepted in Czech and Slovak standard vegetation classifications (MORAVEC et al. 1995, JAROLÍMEK et al. 1997), and that of alliance *Veronico-Taraxacion*, accepted in Czech classification (MORAVEC et al. 1995), but not in those of other countries of Central Europe (Table 4). The *Sherardion* alliance was established as a weed vegetation type intermediate between the calcicole *Caucalidion* alliance and the calcifuge *Scleranthion* alliance (KROPÁČ & HEJNÝ 1975, KROPÁČ 1978). In the original description (KROPÁČ 1978), the *Sherardion* alliance was characterized by a group of diagnostic species that included *Galeopsis ladanum*, *Geranium dissectum*, *Kickxia elatine*, *Misopates orontium*, *Sherardia arvensis* and *Valerianella dentata*. In our analysis, the relevés labelled as *Sherardion* by their original authors did not form a coherent group but were divided among six columns of the synoptic table (Table 2), with the highest concentration in clusters 1, 3 and 5. The above mentioned species, considered as diagnostic by KROPÁČ (1978), show different affinities (Table 2). A considerable overlap in the diagnostic species of *Sherardion* and those of *Caucalidion* and *Scleranthion* was also found in a statistical analysis of diagnostic species based on a large data set covering all types of Czech vegetation (CHYTRÝ & TICHÝ 2003). *Sherardion* also could not be recognized in a study that used the Coktail method for formalized reproduction of weed vegetation syntaxa in southern Moravia (LOSOSOVÁ 2004).

Table 3. Syntaxonomical and ecological interpetation of the clusters. Cluster numbers correspond to the columns in Table 2.

Cluster number	Syntaxonomy	Altitude	Climate	Soil status	Phenological optimum	Crop
1	*Scleranthion annui* (*Aphano-Matricarietum*)	colline	moderately cool/ moderately wet	neutral to acid	June	cereals
2	*Scleranthion annui* (*Spergulo-Scleranthetum*)	submontane	cool/wet	acid	July	cereals/ root crops
3	*Oxalidion europaeae*	colline/ submontane	moderately cool/ moderately wet	neutral to acid	July	cereals/ root crops
4	*Caucalidion lappulae* (excl. *Veronicetum hederifolio-triphylli*)	lowland/colline	warm/dry	base-rich	May	cereals
5	*Caucalidion lappulae*, *Panico-* *-Setarion*, *Veronico-Euphorbion*	lowland	warm/dry	base-rich	July	cereals/ root crops
6	*Caucalidion lappulae* (*Veronicetum hederifolio-triphylli*), *Scleranthion annui* (*Erophilo-Arabidopsietum*)	colline	warm/dry to moderately cool/ moderately wet	base-rich to acid	April	cereals/ root crops
7	*Veronico-Euphorbion*, *Eragrostion*	lowland	warm/dry	base-rich	August	cereals/ root crops

Similarly, our analysis did not support the concept of the *Veronico-Taraxacion* alliance (MORAVEC et al. 1995). It was defined as weed vegetation of permanent fodder crops growing on loamy and clayey soils (KROPÁČ et al. 1971). Only nine relevés assigned to this alliance by KROPÁČ (unpubl. relevés) were present in the data set analyzed here. These relevés were either classified as vernal weed communities (cluster 6) or as the *Caucalidion* alliance (cluster 4) (Table 3). According to KROPÁČ (in MORAVEC et al. 1995), the *Veronico-Taraxacion* alliance is characterized by the diagnostic species *Plantago lanceolata*, *P. media*, *Silene alba*, *S. dichotoma*, *Taraxacum* sect. *Ruderalia*, *Thlaspi perfoliatum* and *Valerianella locusta*. However, all of these species have a broad ecological range and occur also in meadows and different kinds of synanthropic vegetation. Thus these species can hardly be considered as diagnostic of this alliance. Recent statistical analysis of data from the Czech National Phytosociological Database (CHYTRÝ & TICHÝ 2003) detected that the relevés assigned to *Veronico-Taraxacion* only had two rather weak diagnostic species, *Sinapis arvensis* and *Veronica polita*, both shared with the *Caucalidion* alliance.

Our results seem to be consistent with the concept of two major alliances associated with cereal crops, *Caucalidion lappulae* and *Scleranthion annui*, and four alliances with root crops, *Veronico-Euphorbion*, *Oxalidion europaeae*, *Panico-Setarion* and *Eragrostion*. However, there may be other well supported alliances of Central European weed vegetation, which were not recognized by our analysis due to their rarity in, or absence from, our data set. First, it is the *Arnoseridion minimae* alliance, which includes weed vegetation of cereal fields on base-poor, well-drained sandy soils. This alliance (or suballiance in some concepts; Table 4) is recognized in the northwestern, subatlantic part of Central Europe and its only association *Sclerantho-Arnoseridetum minimae* is characterized by *Aphanes australis*, *Arnoseris minima* and *Teesdalia nudicaulis* (OBERDORFER 1993, POTT 1995, HAVEMAN et

Table 4. Overview and comparison of weed vegetation alliances used in standard handbooks on Central European plant communities. Plus and minus signs mean that the alliance is or is not, respectively, included in a particular monograph. Synonymous names denoting alliances of roughly identical delimitation are indicated by "syn.". Inclusion of an alliance in a more broadly conceived alliance is indicated by "included in". Vegetation transitional between weed and ruderal communities (*Eragrostion* s. lat.) is not included in this overview.

Alliance	Czech Republic (Moravec et al. 1995)	Slovakia (Jarolímek et al. 1997)	Austria (Mucina 1993)	southern Germany (Oberdorfer 1993)	Germany (Pott 1995)	Germany (Rennwald 2000)	Germany (Schubert et al. 2001)	Germany Mecklenburg--Vorpommern (Berg et al. 2004)	the Netherlands (Haveman et al. 1998)	Poland (Matuszkiewicz 2001)	Hungary (Borhidi 2003)
Caucalidion	+	+	+	+	+	+	+	+	+	+	+
Sherardion	+	+	–	–	–	–	–	–	–	–	–
Scleranthion annui	+ (syn. *Aphanion*)	+	+	+ (as suballiance *Aphanenion* within *Aperion*)	+ (as suballiance *Aphanenion* within *Aperion*)	+ (included in *Aphanion*)	+ (included in *Aperion*)	+ (divided into alliances *Scleranthion annui* and *Aphanion arvensis*)	+ (included in *Aperion*)	+ (included in *Aperion*)	+
Arnoseridion	+ (syn. *Scleranthion*)	–	+	+ (as suballiance *Arnoseridenion* within *Aperion*)	+ (as suballiance *Arnoseridenion* within *Aperion*)	+ (included in *Aphanion*)	+ (included in *Aperion*)	+ (included in *Scleranthion annui*)	+ (included in *Aperion*)	+ (included in *Aperion*)	–
Trifolio-Medicaginion	–	–	–	–	–	–	–	–	–	–	+
Veronico-Taraxacion	+	–	–	–	–	–	–	–	–	–	–
Veronico-Euphorbion	+ (syn. *Fumario--Euphorbion*)	+	+	+ (syn. *Fumario--Euphorbion*)	+ (syn. *Fumario--Euphorbion*)	+	+	+	+ (included in *Fumario--Euphorbion*)	+ (included in *Polygono--Chenopodion*)	+
Oxalidion	+ (syn. *Spergulo--Oxalidion*)	+ (syn. *Spergulo--Oxalidion*)	+ (syn. *Spergulo--Oxalidion*)	+ (included in *Polygono--Chenopodion*)	+ (syn. *Polygono--Chenopodion*)	+ (syn. *Spergulo--Oxalidion*)	+ (syn. *Spergulo--Oxalidion*)	+	+ (included in *Fumario--Euphorbion*)	+ (included in *Polygono--Chenopodion*)	–
Panico-Setarion	+	+	+	+ (included in *Polygono--Chenopodion*)	+ (syn. *Digitario--Setarion*)	+	+	–	+ (syn. *Digitario--Setarion*)	+	+ (included in *Caucalidion*)
Lolio remoti-Linion	–	–	–	+	+ (order *Lolio remoti-Linetalia*)	+	–	–	–	+	+

al. 1998, SCHUBERT et al. 2001). These species are at their southeastern limit of distribution in the Czech Republic and Austria (MEUSEL et al. 1965–1992). In the Czech Republic, this vegetation has only been recorded for a single site in southern Bohemia (PRACH 1999), where all three above mentioned species occur as weeds in a cereal field, on base-poor sandy soil.

In Germany, Poland and Hungary, a separate alliance *Lolio remoti-Linion* of flax-field weed vegetation, with linicole specialists such as *Camelina alyssum*, *Cuscuta epilinum*, *Lolium remotum* and *Silene linicola* is distinguished (Table 4) (OBERDORFER 1993, POTT 1995, RENNWALD 2000, MATUSZKIEWICZ 2001, BORHIDI 2003). This vegetation type may have also occurred in the Czech Republic and Slovakia in the past, as can be inferred from the sporadic records of its diagnostic species, e.g. *Camelina alyssum*, *Cuscuta epilinum* and *Lolium remotum*, prior to 1950 (SVOBODOVÁ 1974, SMEJKAL 1981). Linicole weeds, however, are now extremely rare or extinct in both countries (HOLUB & PROCHÁZKA 2000, FERÁKOVÁ et al. 2001). The current occurrence of *Lolio-Linion* vegetation is thus highly improbable. The removal of weed from flax seed is the reason for the disappearance of flax weed vegetation, not only in the Czech Republic and Slovakia, but also in the whole of Central Europe (RENNWALD 2000, MATUSZKIEWICZ 2001).

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