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Weed vegetation of small grain crops in Serbia: environmental and human impacts

Sava VRBNICANIN[1], Zora Dajic STEVANOVIC[1], Katarina Jovanovic RADOVANOV[1], Ahmet ULUDAĞ[2,*]

[1]Faculty of Agriculture University of Belgrade, Nemanjina 6, 11080 Belgrade-Zemun, SERBIA

[2]İzmir Agricultural Quarantine Directorate, Liman Cad. 25, Alsancak, İzmir - TURKEY

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Abstract: Weed flora of winter and spring small grain crops (wheat, barley, oats, and rye) was surveyed in lowland and mountainous areas of the central part of Serbia, which are dissimilar in environmental conditions, primarily climate and soil characteristics, and crop management practices. The weed community of the mountainous area was more diverse that of the lowlands. The weed community of the mountainous area was characterized by a significantly higher proportion of dicotyledonous species, mainly hemicryptophytes, probably due to insufficient tillage and the consequent impact of surrounding grassland vegetation. Different environmental conditions and crop managements of the 2 sites caused the occurrence of 2 separate weed communities, the ass. *Consolido-Polygonetum avicularae* in the lowland area, and ass. *Galeopsi-Brassicetum campestrae* in the mountain area of the surveyed region in central Serbia.

Key words: Correspondence analysis, weed communities, weed survey in cereal stands

Sırbistan'da serin iklim tahıllarında yabancı ot vejetasyonu: çevre ve insan etkileri

Özet: Orta Sırbistan'ın, başta iklim ve toprak özellikleri olmak üzere farklı çevre şartlarına ve farklı tarım uygulamalarına sahip iki bölgesinde (dağlık bölge ve alçak ova bölgesi) kışlık ve yazlık serin iklim tahıllarında (buğday, arpa, yulaf ve çavdar) yabancı ot sürveyleri gerçekleştirilmiştir. Dağlık bölgede yabancı ot topluluğu ova bölgesine göre daha fazla çeşitlilik göstermiştir. Dağlık alandaki yabancı ot toplulukları, yetersiz toprak işleme ve etraftaki çayır mera alanlarından dolayı, başta hemikrofitler olmak üzere iki çenekli bitkilerden oluşmuştur. Çevre şartlarındaki ve tarım uygulamalarındaki farklılıklar orta Sırbistan'da iki farklı yabancı ot topluluğunun oluşmasına sebep olmuştur: Alçak ovalarda *Consolido-Polygonetum avicularae* birliği ve dağlık alanlarda *Galeopsi-Brassicetum campestrae* birliği.

Anahtar sözcükler: Korrespondens analizi, yabancı ot birlikleri, tahıllarda yabancı ot sürveyi

Introduction

Weed communities co-evolve with cropping systems, allowing the populations to adapt to highly, regularly disturbed environments (Martínez-Ghersa et al., 2000). Floristic composition and the structure of weed communities of arable land are considered to be an ecological response to environmental impacts, mainly soil properties and regional climate (Saavedra et al., 1990, Moser et al., 2002, Streit et al., 2003; Bratli et al., 2006), as well as a result of agricultural practices

* E-mail: ahuludag@yahoo.com

such as weed control practices applied (Wrucke and Arnold, 1985; Anderson and Milberg, 1998; Uludag et al., 1999; Shrestha et al., 2002, Albrecht, 2003, Gerowitt, 2003), the type and the cycle of crop rotation (Barberi et al., 1997; Uludag et al., 1999; Shrestha et al., 2002), and timing and method of tillage practices (Buhler and Daniel, 1988; Kapusta and Krauz, 1993; Ball and Miller, 1990; van Elsen, 1994; Gerowitt, 2003). It is well established that application of herbicides causes serious shifts in weed flora and vegetation (Ajder, 1992; Derksen et al., 1995; Streit et al., 2003). Thus, understanding the composition and structure of weed communities is an important component for developing strategies of weed control. It is difficult to estimate the relevance of each individual factor because numerous factors are involved in the formation and development of weed flora and vegetation. Such studies require either designing a model able to evaluate the effect of a single factor (Anderson and Milberg, 1998) or performing long-term field experiments. Surveying fields and collecting information about agricultural practices and natural factors such as climate and soil are another method that provides information about floral composition and shifts and helps in the development of strategies.

Despite generally favorable conditions for agricultural production in Serbia, and the fact that 55% of the total territory of the country (102,173 km^2) is considered agricultural land, the agricultural sector has faced many constraints. Weeds and inadequate weed control are considered one of the foremost detrimental factors affecting crop production. There is a strong need for permanent investigation of weed vegetation to keep weed abundance below the reasonable thresholds, providing farmers with higher crop yields. In spite of the fact that yield losses caused by the presence of weeds vary depending on crop and environmental conditions, it has been estimated that yield losses span a range between 10% and even above 25% in developed and developing countries, respectively (Tamado and Milberg, 2000). Farming is practiced in central part of Serbia in lowland with an altitude 195-530 m and mountainous part with elevations 890 to 1270 m. Small grains such as wheat, barley, oats, and rye are produced in both areas; but preceding crops and cropping season show differences as well as edaphic and climatic factors. The aims of the study were to determine current weed flora in small grain crops of the lowland and mountain rural area in the central part of Serbia, to compare floral differences between the 2 areas, to find out floral shifts regarding to earlier floral studies and to explain reasons of floral differences and changes.

Materials and methods

Study area

The study area is situated from 43°20′ to 43°45′ west longitude and from 20°25′ to 21°0.0′ south latitude. The region extends approximately 200 km in the north-south and 100 km in the east-west directions. Surveys were carried out in a lowland area and a mountainous area with 195 through 530 m and 890 through 1270 m of altitude, respectively. The soil type varied among sites in both study areas (Tables 1 and 2). Classification of soils follows Skoric et al.

Table 1. General characteristics of investigated sites in the lowland area.

Crop	Site*	Altitude	Type of soil
oat	1	350	Colluvial soil a
wheat, barley	2, 3	340, 345	Fluvisol
wheat, oat	4-6	325-340	Colluvial soil b
oat, barley, wheat	7-9	300-345	Colluvial cambic soil
barley, wheat	10-12	235-250	Fluvisol
wheat, barley	13	220	Pseudogley b
wheat	14	208	Pseudogley a
wheat	15,16	195, 200	Humofluvisol b
wheat, oat	17-19	195, 210	Humofluvisol a

* Numbers present in this column show a site described in the Materials and Methods

Table 2. General characteristics of investigated sites in the mountainous area.

Crop	Site*	Altitude	Type of soil
wheat, oat, rye	20-23, 38, 39	890-960	Kalkocambisol (on limestone)
wheat, oat, rye	24-30	1000-1150	Luvisol a
wheat, oat, rye	31-37	1150-1270	Luvisol b

* Numbers present in this column show a site described in the Materials and Methods

(1985). Basic chemical properties of the soil (Table 3) were determined using samples taken from the soil profile of each site and performing standard methods such as a potentiometer method in H_2O for pH, the Tjurin method modified by Simakov for the content of carbon and humus, Kjeldahl's semi-micro method modified by Bremner for the total nitrogen content, Al-method by Egner-Riehm for the content of available phosphorus and potassium, colorimeter for P_2O_5, and a flame photometer for K_2O.

Climate also varies between the 2 areas. Climate data for last 20 years obtained from local Meteorological Centers of the Republic of Serbia shows that the lowland area is warmer and dryer than the mountainous area (Table 4). While the hottest and coldest months were the same in both areas, the month receiving the highest precipitation is June in the lowlands and February in the mountainous area. February has the lowest sum of precipitation in the lowland area.

Survey of weed flora and vegetation

Surveys of weed communities in small grain crops (wheat, barley, oats, and rye) were conducted in the lowland and mountainous rural landscapes of the central part of Serbia over 3 years, starting from 2000. Qualitative and quantitative evaluation of the presence of weeds was performed twice during the growing season, in May and July in lowlands and in June and August in the mountainous area.

In the lowland area, the weed community was studied in wheat (through 105 plots within 11 sites) and barley (34 plots within 3 sites) sown as winter crops, and oats (58 plots within 5 sites) sown as a spring crop. Maize was the preceding crop in all fields. In the mountainous area, the weed community was

Table 3. Chemical properties of soil of investigated sites.

Type of soil	pH/H_2O	C (%)	Humus (%)	Total N (%)	C:N	P_2O_5 (mg 100 g^{-1})	K_2O (mg 100 g^{-1})
Humofluvisol a	7.1	1.89	3.25	0.18	10.32	23	40
Humofluvisol b	5.9	1.99	3.44	0.24	8.29	19.4	26.8
Pseudogley a	4.5	1.13	1.95	0.12	9.14	4.4	8.9
Pseudogley b	5.9	1.52	2.62	0.17	8.88	42.4	37.3
Fluvisol	5.1	1.4	2.42	0.16	8.87	2.3	7.4
Colluvial cambic soil	5.8	1.53	2.64	0.17	9.02	2.3	17.9
Colluvial soil a	6.4	2.5	4.29	0.23	10.83	12.3	40
Fluvisol	6.6	1.21	2.09	0.13	9.41	8.2	21.6
Colluvial soil b	6.1	1.34	2.3	0.15	8.91	18.7	30
Kalkocambisol (on limestone)	5.7	2.63	4.54	0.3	8.75	5.8	25.5
Luvisol a	4.1	2.63	4.58	0.28	9.54	18.6	15
Luvisol b	4.6	1.15	1.98	0.14	8.21	13.6	35

Table 4. Meteorological data of experimental areas.

Area	Temperature (°C)			Precipitation (mm)	
	Average	Minimum Average	Maximum Average	Yearly Sum	Highest in a Month
Lowland	11.6	0.1 (January)	20.8 (July)	781	102.1 (June)
Mountainous	6.2	-2.9 (January)	14.2 (July)	1346	89 (February)

surveyed in wheat (96 plots within 11 sites), oats (65 plots within 6 sites), and rye (23 plots within 3 sites), sown as spring crops. The preceding crops were maize, potatoes, or small grains. The total number of plots studied (corresponding to relevés) was 381, including 197 and 184 in the lowland and mountain areas, respectively. The size of each plot was approximately 50 m^2. Farmers provided information concerning crop management and performance (i.e. tillage system and fertilization). No-herbicide-applied fields were surveyed in the survey year(s).

All species seen in a plot were recorded. Samples of weed species were collected and vouchers are kept in the Herbaria of the Department of Botany of the Faculty of Agriculture, University of Belgrade. Nomenclature follows Flora Europea (http://rbg-web2.rbge.org.uk/FE/fe.html) and Flora of Serbia (Vol. I to Vol. IX, 1970-1977). Abundance and coverage of plants were assessed in the plot using a scale according to Westhoff and van der Maarel (1973). Cover value was calculated according to a scale (Table 5).

Constancy of species was calculated according to the Braun-Blanquet principles, and was expressed from I to V, where I means that the species was present in 1% to 12% of relevés, II in 20% to 40%, III in 40% to 60%, IV in 60% to 80%, and V in 80% to 100% of surveyed relevés.

Data analysis

Performances of weed communities obtained in the lowland and mountainous areas of Serbia were analyzed in term of species composition (floristic structure) and in terms of morphotypes and physiotypes. Each species was classified by its life form (annual, biennial, and perennial, where the third category included geophytes, hemicryptophytes, chamaephytes, and phanaerophytes), morphotype (monocotyledonous and dicotyledonous), floristic element, and the affiliation of the weed species to a particular phyto-sociological group. The phyto-sociological position of the weed flora and vegetation was determined according to the principles of Braun-Blanquet (1964) and Tüxen (1950), and was

Table 5. The scale for calculating cover values.

Abundance of plants according to Braun-Blanquet	Abundance of plants according to Westhoff and van der Maarel	Coverage (%)	Cover value
+	2	< 1	0.5
1	3	1-10	5.0
2	5	10-25	17.5
3	7	25-50	37.5
4	8	50-75	62.5
5	9	75-100	87.5

synchronized with a previous synthetic survey on weed vegetation of arable land of Serbia (Kojic et al., 1998). All analyzed characteristics (morphotypes, life form, floristic element, phyto-sociological affiliation) were calculated as

$$(\%)\ \text{Character}_i = 100 \times n_i / N,$$

where n_i is number of individuals (calculated using the scale of abundance by Westhoff and van der Maarel) of a particular character, and N is the total number of individuals in the community. Comparisons of means were carried out by unpaired Student's *t*-test and homogeneity of variances (*F*-test), where the 2 tested areas (lowland and mountainous areas) were used as categorical variables.

Sørensen coefficient of community (CC) (Magurran, 1988) was used as a distance measure for surveyed areas and was calculated as

$$CC = 2W / A + B$$

where *W* is the number of common species presented in the 2 areas, and *A* and *B* are the total number of species in each area.

Data were processed using the FLORA software package (Karadzic et al., 1998). Correspondence analysis (CA) was used for ordination of species. This ordination technique is based upon eigenvalues analysis of symmetric matrices (Morison, 1973; Legendre and Legendre, 1998). The phytocoenological sheet consisting of "n" species and "m" relevés represents a dimensional matrix of the "n" multiply by "m", thus expressing a geometrical equivalent. Elements of this matrix specify the position of "m" points in "n"-dimensional Euclidean space. The distribution of points that simulate fields in such a space is caused by the floristic composition of species. If the 2 sites are floristically more similar to each other, their distance in Euclidean space will be shorter. Coefficient of Euclidean distance was calculated as

$$ED\ i,j = \sqrt{\sum (X\ h,i - X\ h,j)^2},\ h = 1,2,3, \ldots n,$$

where X h,i and X h,j represent abundance of the h-species in i- and j- relevé.

Ordination methods make the dimensionality reduction of Euclidean space possible whereby the relation between some sites (points in space) remains more or less unchanged.

Results

In the lowland area, 141 weed species were determined. The number of dicotyledonous species was 120 and of monocot species was 21. There were 35 annual, 35 biannual, and 71 perennial species, including 51 hemicryptophytes, 17 geophytes, 2 chamaephytes, and 1 phanaerophyte. The characteristic group of the community consisted of 16 species (Table 6). These species showed constancy over III and abundance over 2. According to the previous phyto-sociological analysis (Kojic et al., 1998), the weed community of winter small grain crops in the lowland area (Ass. 1) was determined as ass. *Consolido-Polygonetum avicularae*, Kojic, 1973, belonging to the alliance *Caucalion lappulae* Tx. 1950, order *Centauretalia cyani* Tx., Lohm. et Prsg. 1950, and class *Stellarietea mediae* (Br.-Bl.1932) Tx., Lohm. et Prsg. 1950. *Chenopodium album*, *Polygonum lapathifolium*, and *Viola arvensis* were the most abundant species, while *C. album*, *Cirsium arvense*, *Galium aparine*, and *Agropyrum repens* were the most frequent species (with the constancy of V).

In the spring small grain crops of the mountainous area, 134 dicotyledonous and 20 monocotyledons plant species out of 154 species were recorded. Regarding their life cycles, 42 annual, 32 biennial, and 80 perennial species were determined. Among the perennial species there were 61 hemicryptophytes, 15 geophytes, 3 chamaephytes, and 1 phanaerophyte. The characteristic group of the community consisted of 31 species (Table 7). Weed association of spring small grain crops of the mountainous area was described as ass. *Galeopsi-Brassicetum campestrae* Ajder, 1997, belonging to the alliance *Galeopsion speciosae-pubescentis* Kojic, 1992, of the order *Centauretalia cyani* Tx., Lohm. et Prsg. 1950, and the class *Stellarietea mediae* (Br.-Bl.1932) Tx., Lohm. et Prsg. 1950. The most abundant were *Brassica campestirs*, *Galeopsis tetrahit*, and *Centaurea cyanus*. The most frequent species (constancy of V) were *G. tetrahit*, *B. campestris*, *Lapsana communis*, *Stellaria media*, *Viola arvensis*, and *Polygonum aviculare*.

The number of species expressing higher constancies (over III) was more in the mountainous area than the lowland area (Table 8). Total coverage value was about 10% higher in the mountainous area.

Table 6. Characteristic group of species of the weed community in the lowland area.

Species	Sites																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Chenopodium album L.	3	5	8	5	5	5	7	3	5	2		3	3	3	3	2	3	3	3
Rumex crispus L.	2	2	2	2	3	5		2	3	3	2	2		3	2	2			2
Polygonum aviculare L.	2	2		2	2	3	3		3	3	2		2	2	2	3	5	3	
Agropyrum repens (L.)P.B.	5	2	2	3	2	3	2	2	3	5	5	5	3		3	3	5	3	2
Galium aparine L.	3	2	2	2	3		3	3	3	3	2	3		2	3	7	7	3	2
Cirsium arvense (L.) Scop.	3	3	5	2	2	2		3	2	3		5	3	5	5	3	3	3	7
Convolvulus arvensis L.	2	3		3	2			2	3	5	3	5	3	3	2	5		3	5
Polygonum lapathifolium L.	8	7	7	7	3	3	2	3	5	5	3	5	2						
Viola arvensis Murr.	8	8	5	8	2		5	3	3		3		2	3		3	2	3	
Bilderdykia convolvulus L.	2	3	3	3	3	3	7	3	3	2		2		5	7	3			
Taraxacum officinale Web.	3	2			3			2	3	2				3	2			2	
Potentilla reptans L.	2			2	2			2	2	2		2			2			2	
Sonchus arvensis L.		2	2		3	2	2			2		3	2	2	3	2		3	
Daucus carota L.		2			2		2	2	7	2		2		2	2	2	2	3	3
Consolida regalis S.F.Gray		2	2	3			2	2			3	3	2	2	2	2	2	5	2
Capsella bursa pastoris (L.) M.	2		2			2				2		2	3	3		3	2		

Table 7. Characteristic group of species of the weed community in the mountainous area.

Species	Sites																			
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Galeopsis tetrahit L.	7	3	5	7	5	7	3	7	5	7	5	7	8	3	7	5	5	5	3	2
Brassica campestris L.	2	7	7	5	7	3	3	3	8	7	7	7	7	2	7	3	3	7	7	.
Lapsana communis L.	2	2	5	3	3	2	3	2	3	3	3	5	3	3	5	2	3	2	2	3
Stellaria media (L.) Vill.	2	3	2	5	2	.	2	5	2	2	5	2	2	3	2	2	2	2	2	3
Viola arvensis Murr.	3	3	5	3	3	3	3	3	2	2	2	3	3	2	5	5	.	5	3	3
Polygonum aviculare L.	2	.	2	2	3	2	.	3	2	2	3	5	2	2	2	2	.	2	2	3
Spergula arvensis L.	5	3	3	5	7	3	5	3	3	3	3	5	5	3	5	.	.	.	.	.
Anthemis arvensis L.	.	3	2	2	.	2	2	2	2	2	2	3	2	2	2	.	.	.	.	.
Centaurea cyanus L.	2	.	5	3	5	.	8	5	3	3	3	8	3	2	5	.	3	.	.	.
Agrostemma githago L.	3	.	2	5	5	2	2	2	3	5	2	3	.	2	2	.	2	.	2	.
Stellaria graminea L.	2	2	3	2	3	3	3	.	5	.	2	2	3	2	.	2	3	2	.	.
Trifolium repens L.	.	2	2	.	2	2	2	2	2	2	2	2	2	3	2	2	2	.	.	2
Trifolium pratense L.	.	2	2	2	2	.	2	2	2	1	.	.	2	2	2	2	2	.	2	.
Achillea millefolium L.	.	2	2	2	2	2	2	.	2	.	2	2	.	2	2	2	2	3	2	.
Capsella bursa pastoris (L.)M.	2	.	2	2	2	.	2	.	2	2	2	2	2	2	.	.	.	.	2	2
Poa trivialis L.	2	.	2	2	2	.	.	.	2	.	2	2	3	2	2	2	.	2	3	.
Chenopodium album L.	2	2	.	.	.	2	2	3	2	3	3	2	3	3	2	.	2	2	2	3
Bilderdykia convolvulus L.	2	2	3	2	.	2	.	2	3	.	2	3	2	3	3	.	3	.	3	3
Sonchus arvensis L.	.	.	2	3	.	.	2	2	2	2	3	2	3	3	2	2	.	.	3	5
Agropyrum repens (L.)P.B.	.	.	.	.	.	2	3	2	3	.	3	5	3	2	2	3	3	.	5	5
Scleranthus annuus L.	2	.	5	8	5	2	3	2	3	.	8	.	3	3	5	.	.	.	.	.
Rumex acetosella L.	2	.	3	3	5	2	2	.	3	.	2	2	.	2	2	.	3	.	.	.
Rumex crispus L.	.	.	2	.	3	.	2	2	.	2	2	2	2	2	2	2	2	.	.	.
Taraxacum officinale Web.	.	.	2	2	2	.	2	.	2	.	2	.	.	2	2	2	2	2	.	2
Vicia sativa L.	2	.	2	2	.	.	2	.	.	2	2	2	.	2	2	.	.	2	3	2
Carduus nutans L.	2	.	.	2	1	.	.	1	.	.	2	2	.	2	2	2	.	.	2	.
Vicia hirsuta (L.) S.F.Gray.	2	.	2	3	3	.	3	.	.	.	2	2	2	2	.	.	.	.	2	2
Myosotis arvensis (L.) Hill.	.	2	2	2	3	.	.	.	2	2	2	.	.	.	2	3	3	.	.	.
Cirsium arvense (L.) Scop.	.	.	.	2	.	.	2	.	2	.	2	2	2	.	.	.	3	2	2	3
Galium aparine L.	.	.	.	.	.	.	.	2	2	2	.	.	.	2	2	2	2	2	2	3
Daucus carota L.	.	.	.	.	2	.	2	.	.	.	.	2	2	.	2	2	2	2	7	5

Table 8. Comparative analysis of constancy and total cover value in the 2 weed communities.

Weed communities	The number of species expressing particular constancy					Total cover value of the weed community
	I	II	III	IV	V	
Lowland	91	31	6	9	4	13,324.3
Mountainous	103	18	13	14	6	14,788.0

Analysis of the morphotypes of weeds indicates a common dominance of dicotyledonous species. However, the ratio of dicotyledoneous species in mountainous area was significantly higher than that in the lowland area ($P < 0.001$). The percentage of dicotyledons plants was 90.17 in the mountainous area and 86.03 in the lowland area. The ratio of monocotyledons was not significantly different between the mountainous area (9.82% of plants) and lowlands area (13.96%). Significant differences were determined ($P < 0.001$) relating to the participation of particular life forms of weeds in the mountainous area and lowland area, such as biannual, geophytes, and hemicryptophytes (Table 9).

Most of the weeds in both areas studied belong to the Euro-Asian floristic element, followed by Cosmopolitan, Middle-Euro-Asian, and Adventive (Table 10). Significant differences regarding phyto-sociological affiliation of weeds in the lowland and mountainous areas (Table 11) were determined for weeds belonging to the classes such as *Stellarietea mediae, Festuco-Brometea, Agropyretea repentis, Bidentetea tripartitii, Querco-Fagetea*, and *Thlaspietea rotundifolii*.

The Sørensen coefficient of community was calculated as 67.8%, indicating differences in the floristic structure of the studied communities, and the significance of discriminatory species, i.e. weeds determined only for the lowland area or only for the mountainous area (Table 12). In the lowland area, weeds that exhibited the highest abundance and cover value are the following: *Amaranthus retroflexus, Chenopodium polyspermum, Glechoma hederacea, Lactuca viminea, Malva silvestris,* and *Polygonum hydropiper*. In the mountainous area, the species were *G. tetrahit, Agrostemma githago, Bifora radians, Salvia verticillata, Scleranthus annuus*, and *Euphorbia falcata*.

Correspondence analysis (Figure 1) performed on the basis of weed species of the highest abundance and coverage clearly showed the floristic differences in vegetation of the 2 areas studied. The sites of the lowland area, assigned from 1 to 19, were grouped on the left site of the first CA axis, while the sites of the mountain study area (20-38) occupied the opposite site the ordination. Sites of the mountain area assigned as 38 and especially 39 have been more dislocated from the other sites of this area, due to the presence of the high frequent common species of the

Table 9. Life forms of species in the 2 weed communities.

Life forms and morphotypes	Weed communities and percentage of life forms		
	Lowland (%)	Mountainous (%)	P level
Annual	29.60	25.20	n.s.
Biannual	22.74	28.60	< 0.001
Geophyte	16.05	6.95	< 0.001
Hemicryptophyte	30.50	38.06	< 0.001
Chamaephyte	0.55	0.79	n.s.
Phanaerophyte	0.55	0.39	n.s.

Table 10. Comparative analysis of floristic elements in the 2 weed communities.

Floristic elements	Weed communities and percentage of floristic elements		
	Lowland (%)	Mountainous (%)	P level
Euro-Asian	52.8	48.8	< 0.05
Cosmopolitan	16.5	13.2	< 0.05
Middle European	14.0	14.9	n.s.
Adventive	2.6	8.1	< 0.001
Circumpolar	8.3	5.6	< 0.05
Sub-Mediterranean	1.5	5.1	< 0.001
Pontic-Central-Asian	4.3	4.1	n.s.

Table 11. Comparative analysis of phyto-sociological affiliation of weed species in the 2 weed communities.

Phyto-sociological affiliation (Class)	Weed communities and percentage of phyto-sociological affiliation		
	Lowland (%)	Mountainous (%)	P level
Stellarieatea mediae Tx., Lohm et Prsg. 1950	51.0	41.4	< 0.05
Molinio-Arrhenatheretea Tx. 1937	21.9	21.4	n.s.
Artemisietea vulgaris Lohm, Prsg. et Tx. 1950	7.6	7.5	n.s.
Festuco-Brometea Br- Bl. et Tx. 1943	6.2	9.1	< 0.001
Agropyretea repentis Oberd., Müll. et Görs 1967	3.9	2.1	< 0.05
Plantaginetea majoris Tx. et Prsg. 1950	2.9	3.3	n.s.
Bidentetea tripartiti Tx., Lohm et Prsg. 1950	4.1	0 b	< 0.05
Chenopodietea albae Br.-Bl. 1951	1.4	1.2	n.s.
Querco-Fagetea Br.-Bl. et Vlieg. 1937	0.9	0	< 0.05
Thlaspietea rotundifolii Br.-Bl. 1947	0	5.5	< 0.001
others	0	8.5	< 0.001

2 studied areas, including *C. album, Cirsium arvense, Daucus carota, Viola arvensis, Polygonum aviculare, Sonchus arvensis, Agropyrum repens*, and *Galium aparine*. These species are known to be adaptive to a wide spectrum of environmental factors and thus could occur in different habitats.

Discussion and conclusions

Characteristic species, i.e. the most frequent and dense species, between the 2 areas were different (Tables 5 and 6). In addition, roughly 1/3 of weeds in each community were discriminatory species, which were only determined either in the lowland or mountainous area (Table 12). Spatial variation in the species diversity in arable plant communities can be caused by differences in natural site conditions (Seavers and Wright, 1999; Milberg et al., 2000) and previous management practices (Albrecht, 2003). One important reason for the differences of weed species found in different crops cultivated under central European climate conditions is the seasonal variation in temperature. This is caused by cold spells in autumn and early spring favoring weeds with a strong

Table 12. Discriminatory species of the 2 weed communities.

Weed species present only in small grain crops of the lowland area		
Weed species	Const.	Cover
Aira capilaris	I	2.63
Amaranthus retroflexus	I	92.1
Aristolochia clematitis	I	26.31
Bidens tripartitus	I	7.89
Calepina irregularis	I	2.63
Camelina microcarpa	I	2.63
Ch. polyspermum	II	36.84
Conium maculatum	I	5.26
Digitaria sanguinalis	I	2.63
Eryngium campestre	I	2.63
Filipendula hexapetala	I	2.63
Galeopsis ladanum	I	5.26
Glechoma hederacea	I	31.58
Gratiola officinalis	I	5.26
Gypsophylla muralis	I	2.63
Heracleum sphondylium	I	2.63
Hypericum perforatum	I	2.63
Lactuca saligna	I	7.89
Lactuca viminea	I	2.63
Lolium multiflorum	II	34.21
Lolium perenne	II	13.42
Lychnis flos cuculi	I	5.26
Malva sylvestris	I	7.89
Matricaria chamomilla	I	52.63
Echinochloa crus-galli	I	2.63
Pastinaca sativa	I	2.63
Polygonum hydropiper	I	2.63
Polygonum persicaria	II	63.16
Rumex obtusifolius	I	2.63
Scrophularia nodosa	II	18.42
Setaria glauca	I	7.89
Setaria viridis	I	26.31
Silene viridiflora	I	2.63
Solanum nigrum	I	28.95
Stachys palustris	I	2.63
Stellaria nemorum	I	2.63
Teucrium chamaedrys	I	2.63
Thlaspi perfoliatum	I	26.31
Urtica dioica	I	2.63
Verbena officinalis	I	7.89
Veronica chamaedrys	I	5.26

Weed species present only in small grain crops of the mountainous area		
Weed species	Const.	Cover
Adonis flammea	II	12.5
Agrostemma githago	IV	360
Ajuga reptans	I	2.5
Alopecurus pratensis	I	2.5
Alyssum alyssoides	I	2.5
Anthoxantum odoratum	I	7.5
Arenaria serpyllifolia	I	5
Bifora radians	I	115
Bromus sterilis	I	2.5
Brunella vugaris	II	17.5
Carduus nutans	III	20
Centaurea scabiosa	I	7.5
Chaerophyllum temulum	I	2.5
Chenopodium hybridum	I	2.5
Coronilla varia	I	2.5
Crepis biennis	II	18
Crepis setosa	I	10
Cynosurus cristatus	I	5
Echium vulgare	I	7.5
Euphorbia cyparissias	I	0.5
Euphorbia falcata	I	87.5
Euphorbia platyphyllos	I	2.5
Festuca rubra	I	2.5
Fumaria officinalis	I	27.5
Galeopsis speciosa	I	25
Galeopsis tetrahit	V	2340
Galium verum	I	5
Hieracium pilosella	I	2.5
Hordeum murinum	I	27
Hypochoeris radicata	I	7.5
Lathyrus latifolius	I	2.5
Legousia speculum-veneris	I	2.5
Leontodon automnalis	I	2.5
Lotus corniculatus	I	10
Neslia paniculata	I	2.5
Nonnea pulla	I	2.5
Onobrychis viciaefolia	I	27.5
Ononis spinosa	I	2.5
Phleum pratense	I	27.5
Plantago major	II	17.5
Pteridium aquilinum	I	7.5
Raphanus raphanistrum	I	7.5
Reseda phyteuma	I	2.5
Salvia nemorosa	I	2.5
Salvia verticillata	II	42.5
Scleranthus annuus	III	995
Spergula arvensis	IV	912.5
Stachys annua	I	2.5
Stachys recta	I	5
Thlaspi arvense	I	2.5
Trifolium incarnatum	I	2.5
Trifolium pratense	IV	32.5
Veronica arvensis	I	2.5
Veronica officinalis	I	52.5

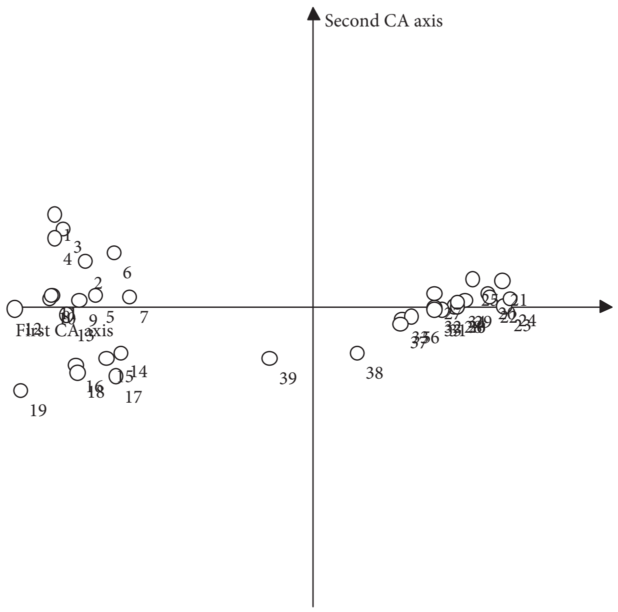

Figure 1. Ordination of sites based upon correspondence analysis (CA).

adaptation to germination at low temperatures (Otte, 1996). Among them, the following could be stressed: the *Galeopsis ladanum, Heracleum sphondylium*, and *Stellaria nemorum*. It was also shown that a high percentages of autumn sown crops favored problematic weeds, e.g. grass weeds (Pallutt, 1999), which was confirmed by the occurrence of *Digitaria sanguinalis, Setaria glauca, Setaria viridis, Aira capillaris*, and *Echinochloa crus-galli* within the community of the winter small grain crops in the lowland area. The time of tilling and sowing is very important, causing the occurrence of different plant communities in winter and spring crops (van Elsen, 1994), which was shown by occurrence of the ass. *Consolido-Polygonetum avicularae* in winter small grain crops (lowland area) and ass. *Galeopsi-Brassicetum campestrae* in spring small grain crops (mountainous area).

The almost doubled number of species making the characteristic group of the weed community of the mountainous area compared with the weed community of the lowlands (Tables 5 and 6) might be first a consequence of reduced tillage (including lack of crop rotation) performed on fields in the mountain rural landscape, and to some extent a result of different environmental conditions. Higher coverage value of weeds and the number of weeds with high constancy in mountainous area (Table 8) could be attributed to traditional practices. The traditional agricultural practices usually performed by old households in the mountain area include production of small grains in the monoculture, without previous seed processing and herbicide application. Furthermore, after harvesting the plots usually are not managed for a year or two, allowing an expansion of perennial weeds. In such "rest" periods the untilled fields are exposed to invasion by surrounding grassland flora. This can explain the presence of some typical grassland species identified only for the weed community in the mountainous area, including *Anthoxanthum odoratum, Cynosurus cristatus, Festuca rubra, Galium verum, Hieracium pilosella, Leontodon autumnalis, Hypochoeris radicata, Onobrychis viciaefolia*, and *Pteridium aquilinum*. Similar trends were obtained in previous weed vegetation studies of the neighboring region (Ajder, 1997; Vrbnicanin et al., 1998). Insufficient crop management in the mountain area has also led to the appearance of some rare weed species, such as *Agrostemma githago*, *Legousia speculum-veneris, Reseda phyteuma*, and *Neslia paniculata*. A similar result was obtained for some endangered 'red list' species (*Silene noctiflora*, *Centaurea cyanus,* and *Chrysanthemum segetum*) occasionally found in the biodynamic fields, but not determined in the conventional fields (Bratli et al., 2006). On the other hand, it was noted that the effects of diverse crop rotation performed on fields of the lowland area caused a decrease in infestations with weeds, which was also shown by Claupein and Baeumer, (1992), Dubois et al. (1998), and Pallutt (1999). In addition, higher total number of weeds and related higher number of species of the characteristic group determined in the weed association of the mountain area might be an effect of lower crop density of spring small grain crops, as was shown for crops studied by intensification methods (Weiner et al., 2001).

Significant differences were determined in relation to the participation of particular life forms of weeds in the mountainous and lowland areas, such as biannuals, geophytes, and hemicryptophytes (Table

9). These differences might be an effect of different management practices, i.e. human impact, especially tillage system and cropping technology, allowing for example the widening of grassland hemicryptophytes within insufficiently managed fields of the mountainous area. In undisturbed soils the importance of the hemicryptophyte species increased (Zanin et al., 1997), which was shown within the list of discriminatory species of the mountainous area, including *Trifolium repens, Trifolium pratense, Achillea millefolium, Poa trivialis, Rumex acetosella, Rumex crispus*, *Taraxacum officinale*, *Crepis biennis, Crepis setosa, Nonnea pulla, Brunella vulgaris*, and *Phleum pratense*. The species linked to disturbance were annuals and in particular *Amaranthus retroflexus*, *Chenopodium album*, and *Echinochloa crus-galli* (Zanin et al., 1997), which was also determined for the community of the more intensively managed fields in the lowland area. The amount of perennial species (hemicryptophytes, geophytes) was higher at the field margins, which is in agreement with the results reported by van Elsen (2004).

Most of weeds of the 2 studied areas belong to the Euro-Asian floristic element, followed by Cosmopolitan, Middle-Euro-Asian, and Adventive (Table 10). Differences in geographic origin of weeds of the 2 areas might be more related to differences in general environmental conditions, rather than ones linked to human impacts.

Significant differences regarding phyto-sociological affiliation of weeds in the 2 areas (Table 11) were determined for weeds belonging to classes such as *Stellarietea mediae, Festuco-Brometea, Agropyretea repentis, Bidentetea tripartitii, Querco-Fagetea*, and *Thlaspietea rotundifolii*. A higher participation of weed species of the class *Festuco-Brometea* in the weed community of the mountain area is related to an influence of surrounding grasslands, while the occurrence of weeds of the class *Thlaspietea rotundifolii* might be an effect of high mountain herbaceous vegetation that developed on dry rocky places, typical for some studied sites at the highest elevation. For the weed community of the lowland area there were some higher proportions of weeds of classes *Stellarieatea mediae, Agropyretea repentis*, and *Bidentetea tripartitii*, which could be a consequence of more intensive field management, knowing that species of the classes *Stellarieatea mediae* and *Agropyretea repentis* occur as typical segetal and field margin species, respectively. Certain participation of weeds of the class *Bidentetea tripartiti* is supposed to be linked to lowland sites developed in the vicinity of local river valleys, i.e. wet places.

Sites in the 2 areas were grouped together with distinctive feature of the 2 areas (Figure). However, sites of the mountainous area assigned as 38 and 39 have been more dislocated from the other sites of mountainous area due to the presence of the high frequent common species of the 2 studied areas, including *Chenopodium album, Cirsium arvense, Daucus carota, Viola arvensis, Polygonum aviculare, Sonchus arvensis, Agropyrum repens*, and *Galium aparine*. These species are known to be adaptive to a wide spectrum of environmental factors and thus could occur in different habitats.

It is reported that species composition of single patches in the agricultural landscape is related to local environmental factors and land use (Austrheim et al., 1999; Norderhaug et al., 2000; Moser et al., 2002; Vandvik and Birks, 2002; Luoto et al., 2003). Regarding the environmental impacts on floristic and vegetation differences of the 2 studied areas, alterations in climate and soil characteristics should be considered. For example, in the weed community of the mountain area at sites developed on acidic soils such as Luvisol pseudogleic (sites 24-30) and especially Luvisol podzolic (sites 31-37) the high presence of semi-acidophilic and acidophilic species was determined, such as *Galeopsis tetrahit*, *Anthemis arvensis, Stellaria graminea,* and *Spergula arvensis, Scleranthus annuus,* and *Rumex acetosella*, respectively.

The existence of different patterns of variation in species richness and species composition on different scales (Wagner et al., 2000; Vandvik and Birks, 2002; Waldhardt et al., 2004) was confirmed in this study, suggesting that environmental conditions but also crop management practices differed among scales. In the region studied in central Serbia, the phytosociological position of weed vegetation was found to be different for lowland - ass. *Consolido-Polygonetum avicularae* and mountain area - ass. *Galeopsi-Brassicetum campestrae,* where the latter community was included in a separate alliance, *Galeopsion speciosae-pubescentis*, indicating that recurrent patterns of variation in species diversity are clearly related to both environmental or historical complex-gradients (Økland, 1990) and crop management (Swanton et al., 1993; Pallutt, 1999).

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