

WEED COMPOSITION IN CONVENTIONALLY AND ORGANICALLY GROWN MEDICAL AND AROMATIC PLANTS

Branka Ljevnaić-Mašić¹, Milka Brdar-Jokanović², Dejana Džigurski¹,
Ljiljana Nikolić¹, Maja Meseldžija¹

¹ Department of Field and Vegetable Crops, Faculty of Agriculture, University of Novi Sad, Trg Dositeja Obradovića 8, 21 000 Novi Sad, Serbia

² Alternative Crops and Organic Production Department, Institute of Field and Vegetable Crops, National Institute of the Republic of Serbia, Maksima Gorkog 30, 21 000 Novi Sad, Serbia

ABSTRACT

This study aimed to compare weed flora in conventionally and organically grown medicinal and aromatic plants (MAPs): basil, pot marigold, dill, and peppermint; in terms of weed composition and weed abundance. A total of 28 weed species (25 and 15 species in conventional and organic crops, respectively) were identified. The presence and abundance of certain weed species were affected by MAP species and farming system. Higher weed diversity and weediness, and lower floristic similarity were found in conventionally grown crops. Also, the analysed MAPs differed in weediness by individual weed species. Correspondence analysis pointed to conventional and organic MAPs with the most frequent and most abundant weed species. *Setaria pumila* and *Portulaca oleracea* were the most frequent species in conventional; and *Amaranthus retroflexus*, *Datura stramonium*, and *Sorghum halepense* in organic crops. In both conventional and organic farming systems, therophytes were the most dominant life forms indicating a strong anthropogenic influence. The results should contribute to establishing weed control measures that are adequate for the two farming systems.

Key words: aromatic plants, conventional farming, diversity indices, medical plants, organic farming, weeds

INTRODUCTION

Medicinal and aromatic plants (MAPs) encompass a large number of species with various agronomic properties. They are often used in human diets as spices, as well as in disease prevention and therapy. MAPs contain secondary metabolites with specific and valuable medicinal properties [WHO 2003, Honermeier et al. 2013]. Being a constituent of wild flora in any area, MAPs have traditionally been collected from the natural environment. However, the collected material often does not meet the requirements of the industry and market, which results in an increased interest in MAPs cultivation [Schippmann et al. 2002, WHO 2003, Carrubba and

Catalano 2009]. However, the majority of the MAPs have not been subjected to breeding, as is the case for other agricultural plants. Those crops are often not competitive enough to suppress weeds which are among major constraints in MAP growing [Schippmann et al. 2002, Carrubba and Catalano 2009].

As in the case of other agricultural plants, weeds compete with MAPs for resources [Ryan et al. 2009, Benaragama et al. 2016] thereby significantly affecting their metabolic processes, causing problems during mechanized harvest, and possibly contaminating the harvested material [Carrubba 2017]. Therefore, weeds can significantly decrease the quality and yield of

MAPs [Carrubba and Catalano 2009, Carrubba and Militello 2013, Hendawy et al. 2019]. Chemical weed control is limited in MAPs, even in conventional farming; therefore, the production has increasingly been based on the principles of organic farming, which prohibits the use of chemicals according to EU regulations [EEC 1991, EEC 1992]. Even though there are clear guidelines for organic crops management, it is often difficult to maintain weed populations below the tolerance threshold. Therefore weed control in organic farming is based on direct and/or indirect alternative non-chemical measures: agronomic, biological, and physical [Barberi 2002, Carrubba and Militello 2013].

Weed composition depends on several factors: crop species, weed control measures, environmental conditions, soil fertility, climate, etc. [Roschewitz et al. 2005, Barroso et al. 2015, Pinke et al. 2016, Travlos et al. 2018, Hendawy et al. 2019]. Understanding how the farming system affects weed composition is a necessary step for transfer from reactive to predictive weed control management [Barroso et al. 2015]. Also, climate changes may cause changes in the composition of weeds, e.g. certain species may become invasive [Scott et al. 2014]. Because of the dynamic nature of crop weediness, constant monitoring gains in importance. Identification of dominant weeds in MAPs and understanding their biology and ecology is a necessary step forward to the establishment of the appropriate management strategies [Hendawy et al. 2019].

This study aimed to compare weed flora in conventionally and organically grown MAPs (basil, pot marigold, dill, and peppermint), in terms of weed composition (species richness, floristic diversity, evenness, dominance) and weed abundance (weediness, frequency). The results should contribute to establishing appropriate weed control measures.

MATERIAL AND METHODS

Floristic study of weeds in medicinal and aromatic plants (MAPs): basil (*Ocimum basilicum*), pot marigold (*Calendula officinalis*), dill (*Anethum graveolens*), and peppermint (*Mentha × piperita*), grown in conventional and organic farming was carried out in three growing seasons (2014, 2015, 2016), at the experimental fields of the Institute of Field and Veg-

etable Crops, National Institute of the Republic of Serbia, Alternative Crops and Organic Production Department, in Bački Petrovac (Vojvodina province, Serbia; 45.36° N, 19.62° E; elevation 86 m; continental climate). The study was set up in two experimental fields, conventional and organic. Each plant species was grown in both production systems. The main plots were of the same size for all crops and consisted of 12 rows, 25 m long, with the between-row spacing of 70 cm. The main plots were replicated three times for each variant. The organic field of 7 ha was established in 2009, following a two-year conversion period that took place in compliance with all the principles of organic agriculture. The practice included organic fertilization regime, integrated non-chemical weed and pest management, crop rotation, intercropping, floral corridors; all adapted to the specific cultivated plant species. The organic field was under crop rotation regime which included legumes, small grains, and various MAPs in consecutive years. The preceding crop was winter barley in all three seasons. In the conventional plot, the MAPs were rotated randomly every year. The organic field was fertilized with 15 t ha⁻¹ farmyard manure applied in November 2011, and the conventional plot was fertilized every autumn with 400 kg ha⁻¹ NPK 15 : 15 : 15. The fields were ploughed and harrowed at the end of every season. Weather data and the results of the soil analyses are given in Figure 1 and Table 1, respectively. The weeds were not controlled during the study.

Species names are given according to Nikolić [2015]. The status of weed invasiveness for Europe and Serbia, as well as the invasive species of global importance, were given according to DAISIE [2018], Lazarević et al. [2012], and GISD [2019], respectively. Taxonomic affiliation of species to families, life forms, and time of flowering are given according to Takhtajan [2009], Ujvárosi [1973], and Landolt et al. [2010], respectively.

The weediness (the number of individuals per square metre – m²) was determined using the quantitative method of squares, by completely random sampling, by counting the present individual plants of every species per 1 m² in three repetitions, after which the average number was calculated (Formula 1). The total weediness of each crop was calculated according to Formula 2. To gain insight into floristic similarities/

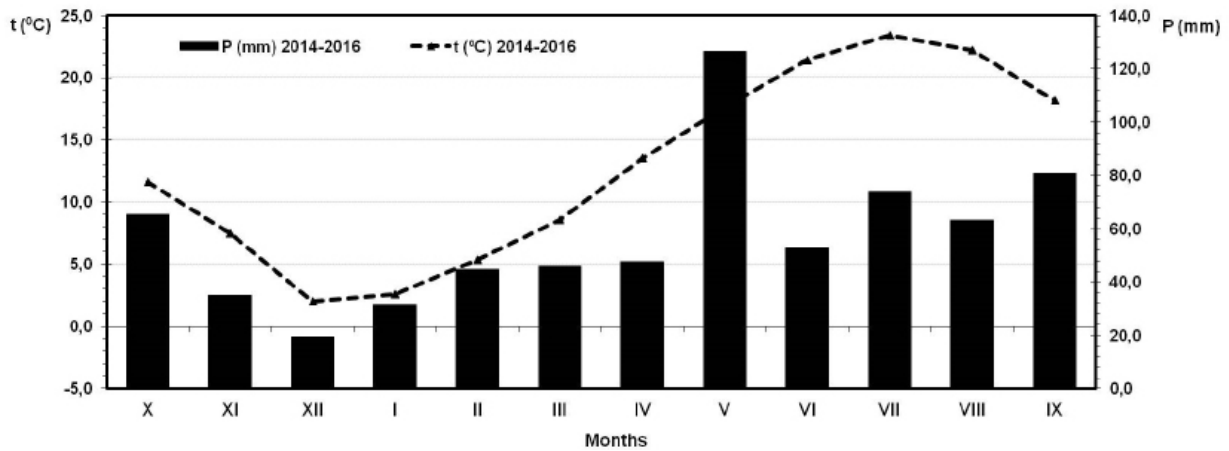


Fig. 1. Average monthly temperatures (dashed line) and precipitation (columns) for the studied period (2014–2016)

Table 1. Basic chemical properties of soil samples from the organic and conventional experimental fields

Plot	pH-KCl	AL-P ₂ O ₅ (mg/100 g)	AL-K ₂ O (mg/100 g)	N (%)	CaCO ₃	Humus (%)
Organic	7.84	28.33	25.92	0.108	12.90	2.15
Conventional	7.72	34.47	29.94	0.126	3.13	2.51

differences in weed composition, weed abundance and dominance in MAPs, the following were calculated: species richness (S), weediness, frequency, Shannon-Weaver index of diversity (H'), Shannon-Weaver index of evenness (E), Simpson's index of dominance (D), Jaccard's similarity index (S_j) and Steinhaus's coefficient index (S_A), based on the Formulae 3–9 [Shannon and Weaver 1949, Magurran 2004, Nkoa et al. 2015].

$$\bar{x}_i = \frac{n_i/m^2}{3} \quad (1)$$

$$\text{Weediness} = \frac{\sum N}{m^2} \quad (2)$$

$$\text{Frequency} = \frac{\sum z_i}{Z} \times 100 (\%) \quad (3)$$

$$H' = -\sum_{i=1}^{S_i} p_i \ln p_i \quad (4)$$

$$p_i = \frac{n_i}{N} \quad (5)$$

$$E = \frac{H'}{\ln S} \quad (6)$$

$$D = \sum \frac{n_i(n_i - 1)}{N(N - 1)} \quad (7)$$

$$S_j = \frac{c}{a + b + c} \times 100 (\%) \quad (8)$$

$$S_A = \frac{2W}{(A + B)} \quad (9)$$

where are:

\bar{x}_i – the average number of individual plants of species i in plot measured in 3 repetitions;

n_i – number of the i^{th} species;

N – the total number of individuals of all species in the plot;

Z_i – number of sampling plots with species i present;

Z – total number of sampling plots surveyed;

p_i – a proportional abundance of i^{th} species;

\ln – natural logarithm;

S – species richness (total number of species);

a – total number of species in the first population;

b – total number of species in the second population;

c – number of common species;

A – total number of individuals in population A;

B – total number of individuals in population B;

W – sum of the lower of the two abundances of each species in the population.

Differences in weediness between conventionally and organically grown MAPs and their interactions were determined using ANOVA and t-test. Correspondence analysis was used to determine the relationship between the presence and abundance of weed species in the studied MAPs. All calculations were performed using Statistica 13.2 software [Dell™ Statistica™ 13.2 University License].

RESULTS

Weed composition. Floristic study of weeds in basil, pot marigold, dill, and peppermint cultivated in conventional and organic production systems, found a total of 28 species, 25 species of which in conventional and 15 species in organic farming (Tab. 2). All weeds belong to 15 families. All of them are invasive species in Europe, while *Ambrosia artemisiifolia*, *Cirsium arvense*, *Senecio vulgaris*, and *Sorghum halepense* are invasive species of global importance. Five species are invasive in Serbia: very invasive *Ambrosia artemisiifolia*, sporadically invasive *Sorghum halepense*, and species *Amaranthus retroflexus*, *Datura stramonium*, and *Veronica persica* which are, currently classified as potentially invasive in Serbia.

Conventional basil (16 species) and conventional peppermint (15 species) were with the highest species richness, while conventional and organic pot marigold and organic basil were with the lowest number of weed species (7 species each). The therophytes were the most dominant life forms in all studied crops (70–90%). Weediness was significantly higher in conventional

than in organic crops. Conventional crops were mostly weeded by *Setaria pumila* and *Portulaca oleracea*, and organic crops by *Amaranthus retroflexus*. The most frequent weed species in both MAP farming systems were *Amaranthus retroflexus*, *Chenopodium album*, and *Senecio vulgaris* with a frequency of 100%.

The floristic diversity of weeds was higher in conventional MAPs ($H' = 2.46$), with higher evenness ($E = 0.76$) and lower dominance of the most frequent weed species ($D = 0.12$) than in organic crops (Tab. 2). The weeds in the organic crops were floristically more similar than in the conventional crops (Fig. 2). When comparing the weeds composition relative to the farming systems the highest floristic similarity was found for conventional basil and pot marigold ($S_j = 43.75\%$), and organic basil and peppermint ($S_j = 70.00\%$), Figure 2a. When comparing the composition of weeds relative to MAPs, pot marigold crops were most similar ($S_j = 75.00\%$), while dill crops were least similar ($S_j = 19.05\%$). On the other hand, Steinhaus's coefficient index (S_A), which takes into account both the total number of individual plants and abundance of species, showed that organic dill and peppermint ($S_A = 0.6277$) were most similar regarding weed composition and abundance (Fig. 2b).

Weed flowering time is significant for a timely application of adequate weed control measures. The majority of identified weeds start flowering in June (11 weeds) and July (7 weeds), mostly ending flowering in September (16 weeds) and October (10 weeds), Figure 3. The earliest flowering with the longest flowering period (February to October) has *Veronica persica*, while *Polygonum aviculare* has the shortest flowering period (May to July). *Ambrosia artemisiifolia* starts flowering the last (in August) and ends in October.

Statistical analyses. ANOVA and t-test determined significant differences in the weediness among all the analyzed variables: weed species, MAPs, and farming systems. The interactions were also significant (Tab. 3, Fig. 4, Fig. 5). Weediness, i.e. the frequency and abundance of certain weed species in MAPs, was affected by crop species and farming system, which was confirmed by correspondence analysis (Tab. 2, Fig. 6). The correspondence analysis separated conventional and organic MAPs with the most frequent and most abundant weed species. Conventional dill differed

Table 2. Weed composition in conventional and organic MAPs

No.	Plant species	Family	LC	LF	Weediness (average No. of ind./m ²) conventional vs. organic MAPs crops								Total No. of ind./m ²		Weed abundance			
					basil		pot marigold		dill		peppermint				average No. of ind./m ²		frequency (%)	
					CP	OP	CP	OP	CP	OP	CP	OP	CP	OP	CP	OP	CP	OP
1.	<i>Amaranthus retroflexus</i> L.*	Amarathaceae	A	T ₄	4.33	12.00	1.33	9.33	2.67	25.33	26.67	42.67	35.00	89.33	8.75	22.33	100	100
2.	<i>Ambrosia artemisiifolia</i> L. ●***	Asteraceae	A	T ₄	0.33	–	–	–	–	–	–	–	0.33	–	0.08	–	25	–
3.	<i>Anagallis arvensis</i> L.	Primulaceae	A	T ₄	0.33	–	–	–	–	–	1.33	–	1.66	–	0.42	–	50	–
4.	<i>Anagallis coerulea</i> Schreb.	Primulaceae	A	T ₄	–	–	–	–	–	–	1.33	–	1.33	–	0.33	–	25	–
5.	<i>Capsella bursa-pastoris</i> (L.) Medik	Brassicaceae	B	T ₁	–	–	–	–	–	–	1.33	–	1.33	–	0.33	–	25	–
6.	<i>Chamomilla recutita</i> (L.) Rauschert	Asteraceae	A	T ₂	–	–	–	–	2.67	–	4.00	–	6.67	–	1.67	–	50	–
7.	<i>Chenopodium album</i> L.	Chenopodiaceae	A	T ₄	0.33	1.33	1.33	1.33	5.33	13.33	4.00	2.67	10.99	18.66	2.75	4.67	100	100
8.	<i>Chenopodium hybridum</i> L.	Chenopodiaceae	A	T ₄	–	–	–	–	–	–	9.33	2.67	9.33	2.67	2.33	0.67	25	25
9.	<i>Cirsium arvense</i> (L.) Scop. ●	Asteraceae	P	G ₃	5.33	–	–	–	–	–	–	–	5.33	–	1.33	–	25	–
10.	<i>Convolvulus arvensis</i> L.	Convolvulaceae	P	G ₃	0.33	–	4.00	1.33	8.00	4.00	1.33	–	13.66	5.33	3.42	1.33	100	50
11.	<i>Datura stramonium</i> L.*	Solanaceae	A	T ₄	3.33	2.67	2.67	4.00	–	24.00	–	14.67	6.00	45.64	1.50	11.41	50	100
12.	<i>Erigeron annuus</i> (L.) Desf.	Asteraceae	A	T ₄	–	–	–	–	–	2.67	–	1.33	–	4.00	–	1.00	–	50
13.	<i>Fallopia convolvulus</i> (L.) Á. Löve	Polygonaceae	A	T ₄	0.67	2.67	–	–	1.33	1.33	–	5.33	2.00	9.33	0.50	2.33	50	75
14.	<i>Fumaria officinalis</i> L.	Fumariaceae	A	T ₃	–	–	–	–	1.33	–	–	–	1.33	–	0.33	–	25	–
15.	<i>Heliotropium europaeum</i> L.	Boraginaceae	A	T ₄	–	–	–	–	–	–	1.33	–	1.33	–	0.33	–	25	–
16.	<i>Hibiscus trionum</i> L.	Malvaceae	A	T ₄	0.33	–	–	–	1.33	–	1.33	–	2.99	–	0.75	–	75	–
17.	<i>Lamium amplexicaule</i> L.	Lamiaceae	A	T ₁	–	–	–	–	2.67	–	–	–	2.67	–	0.67	–	25	–
18.	<i>Polygonum aviculare</i> L.	Polygonaceae	A	T ₄	–	–	–	–	1.33	–	–	–	1.33	–	0.33	–	25	–
19.	<i>Polygonum hydropiper</i> L.	Polygonaceae	A	T ₄	–	1.33	–	–	–	1.33	–	1.33	–	3.99	–	0.99	–	75
20.	<i>Portulaca oleracea</i> L.	Portulacaceae	A	T ₄	11.00	–	2.67	4.00	–	–	40.00	–	53.67	4.00	13.42	1.00	75	25
21.	<i>Senecio vulgaris</i> L. ●	Asteraceae	A	T ₁	1.33	2.67	1.33	1.33	1.33	1.33	1.33	5.33	5.32	10.66	1.33	2.67	100	100
22.	<i>Setaria pumila</i> (Poir.) Roem. et Schult.	Poaceae	A	T ₄	37.33	–	9.33	–	1.33	1.33	18.67	–	66.66	1.33	16.67	0.33	100	25
23.	<i>Stachys annua</i> (L.) L.	Lamiaceae	A	T ₄	1.33	–	–	–	–	4.00	–	–	1.33	4.00	0.33	1.00	25	25
24.	<i>Solanum nigrum</i> L.	Solanaceae	A	T ₄	–	–	–	–	2.67	1.33	32.00	–	34.67	1.33	8.67	0.33	50	25
25.	<i>Sonchus arvensis</i> L.	Asteraceae	P	G ₃	6.67	–	–	–	–	1.33	–	1.33	6.67	2.66	1.67	0.67	25	50
26.	<i>Sorghum halepense</i> (L.) Pers. ●**	Poaceae	P	G ₁	–	13.33	–	4.00	–	8.00	–	16.00	–	41.33	–	10.33	–	100
27.	<i>Veronica hederifolia</i> L.	Scrophulariaceae	A	T ₁	4.00	–	–	–	–	–	1.33	–	5.33	–	1.33	–	50	–
28.	<i>Veronica persica</i> Poir.*	Scrophulariaceae	A	T ₁	4.00	–	–	–	6.67	–	–	–	10.67	–	2.67	–	50	–
Species richness (S)				28	16	7	7	7	13	13	15	10	25	15				
Number of annual plants				23	13	6	6	5	12	10	13	8	21	12				
Number of biennial plants				1	–	–	–	–	–	–	1	–	1	–				
Number of perennial plants				4	3	1	1	2	1	3	1	2	3	3				
Weediness (total number of ind./m ²)				–	80.97	36.00	22.66	25.32	38.66	89.31	145.31	93.33	287.57	244.26				
Diversity index <i>H'</i>				–	1.88	1.56	1.67	1.71	2.34	1.97	1.98	1.66	2.46	1.95				
Evenness <i>E</i>				–	0.68	0.80	0.86	0.88	0.91	0.77	0.73	0.72	0.76	0.72				
Dominance index <i>D</i>				–	0.24	0.25	0.20	0.19	0.09	0.18	0.18	0.26	0.12	0.21				

● – invasive species of global importance; * – potentially invasive in Serbia; ** – sporadically invasive species in Serbia; *** – very invasive species in Serbia; A – annual plants; B – biennial plants; P – perennial plants; Hab. – habitus; LC – life cycle; LF – life form; T₁ – annual plants; germinate in autumn, fruiting in early spring; T₂ – annual plants; germinate in autumn and early spring, fruiting in early summer; T₃ – annual plants; germinate in spring, bring seeds in early summer; T₄ – annual plants; germinate in spring, bring seeds in late summer; G₁ – perennial plants with thin underground shoots (rhizomes); G₃ – perennial plants with root shoots (i.e. with adventitious buds on the root); CP – conventionally production; OP – organic production; *H'* – Shannon-Weaver's diversity index; *E* – evenness; *D* – Simpson's dominance index

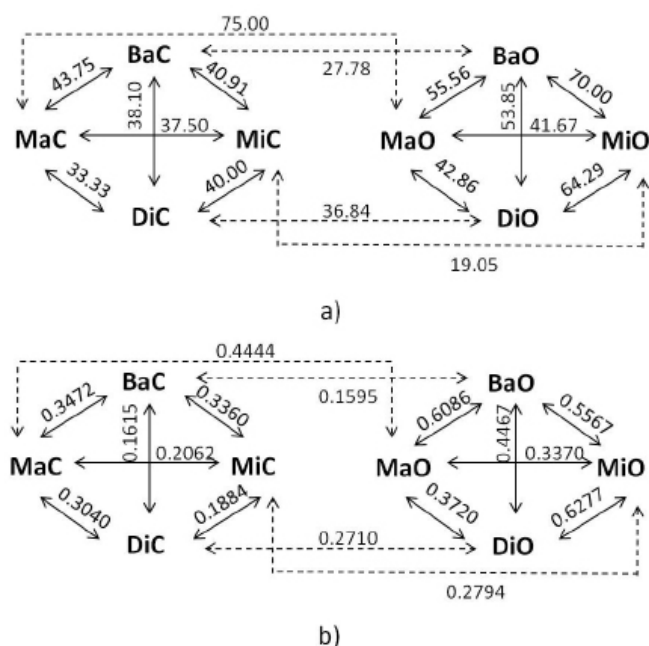


Fig. 2. Comparisons of the floristic similarity indices among conventional and organic MAPs: a) Jaccard similarity index (%), b) Steinhaus coefficient index (BaC – conventional basil, BaO – organic basil, MaC – conventional pot marigold, MaO – organic pot marigold, DiC – conventional dill, DiO – organic dill, MiC – conventional peppermint, MiO – organic peppermint)

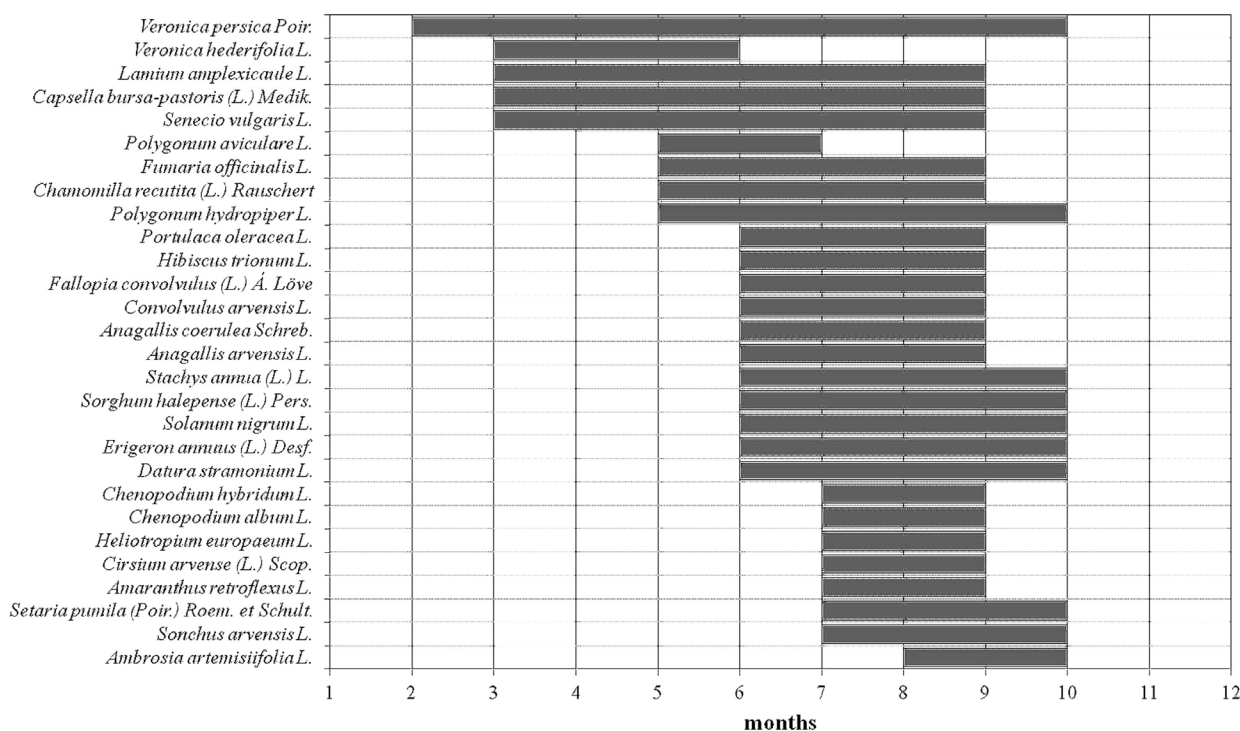


Fig. 3. Flowering time of the weeds identified in MAPs

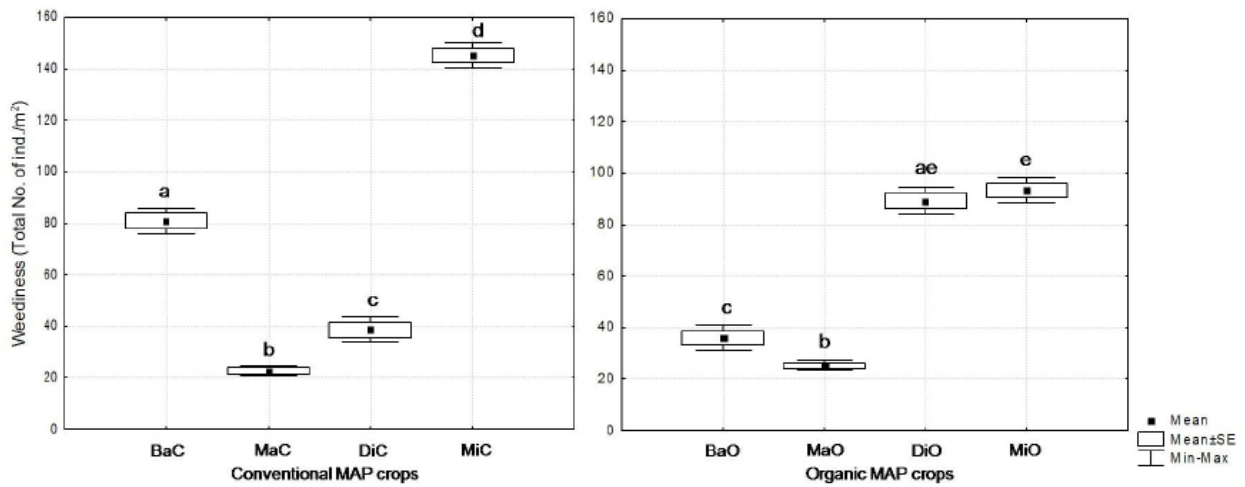


Fig. 4. Differences in weediness among MAPs (BaC – conventional basil, BaO – organic basil, MaC – conventional pot marigold, MaO – organic pot marigold, DiC – conventional dill, DiO – organic dill, MiC – conventional peppermint, MiO – organic peppermint) grown in conventional and organic farming systems (boxes followed by the same letter do not differ significantly according to *t*-test)

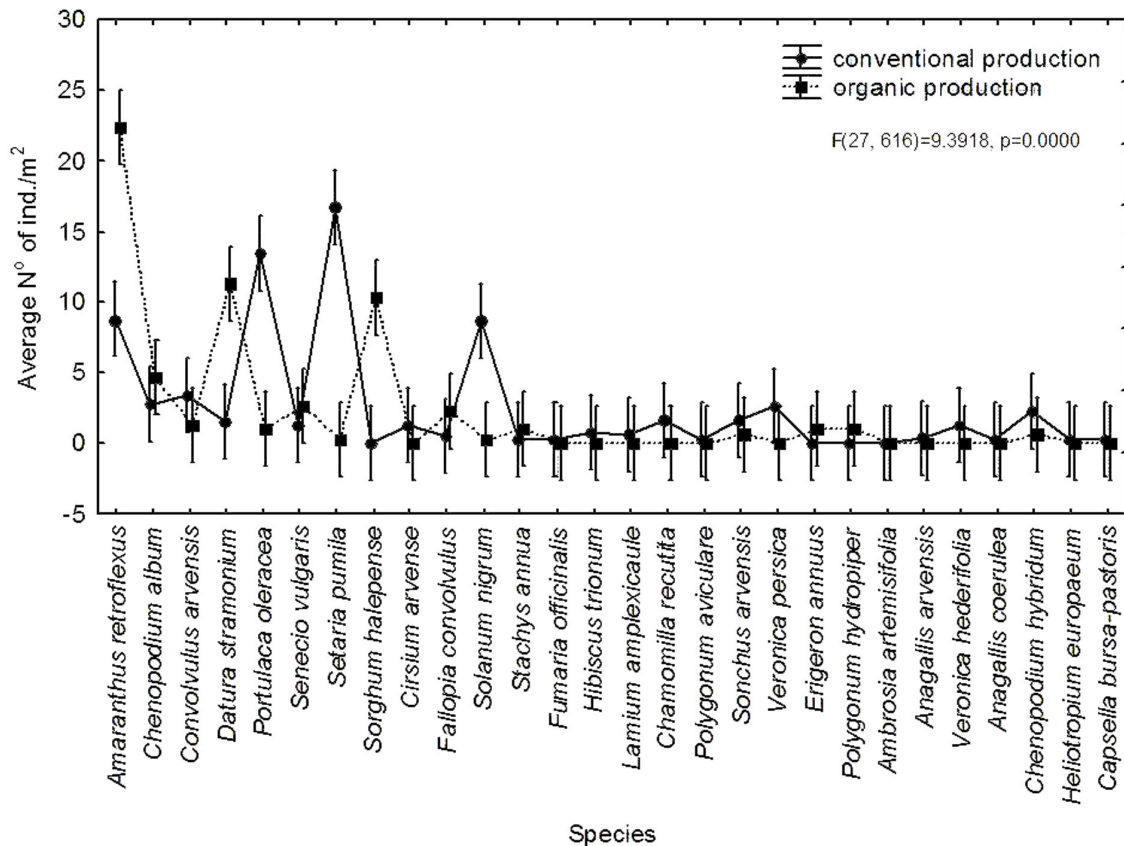


Fig. 5. Differences between the average numbers of weed species in two MAPs production systems (ANOVA)

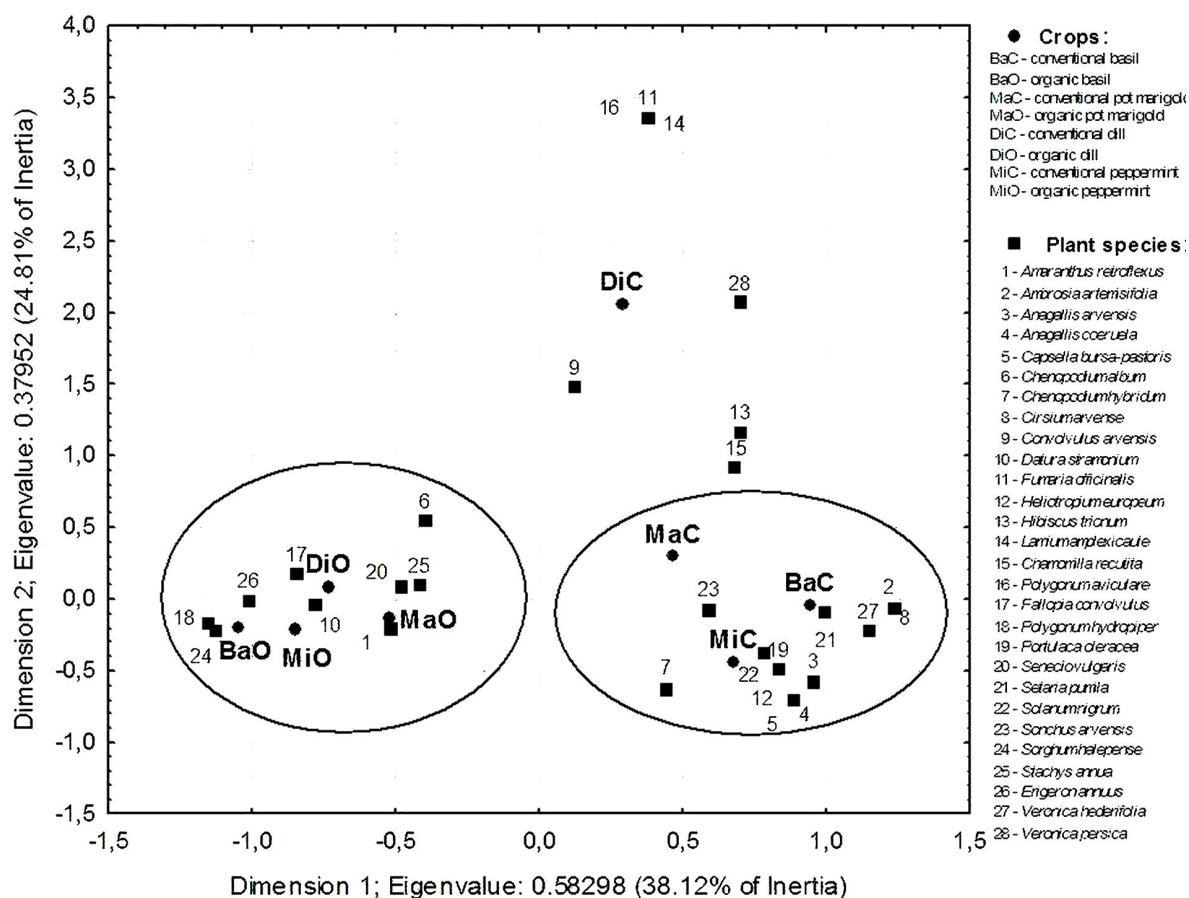


Fig. 6. Correspondence analysis of the relationships between weed abundance and farming system of the MAPs (BaC – conventional basil, BaO – organic basil, MaC – conventional pot marigold, MaO – organic pot marigold, DiC – conventional dill, DiO – organic dill, MiC – conventional peppermint, MiO – organic peppermint, 1 – *Amaranthus retroflexus*, 2 – *Ambrosia artemisiifolia*, 3 – *Anagallis arvensis*, 4 – *Anagallis coerulea*, 5 – *Capsella bursa-pastoris*, 6 – *Chenopodium album*, 7 – *Chenopodium hybridum*, 8 – *Cirsium arvense*, 9 – *Convolvulus arvensis*, 10 – *Datura stramonium*, 11 – *Fumaria officinalis*, 12 – *Heliotropium europaeum*, 13 – *Hibiscus trionum*, 14 – *Lamium amplexicaule*, 15 – *Chamomilla recutita*, 16 – *Polygonum aviculare*, 17 – *Fallopia convolvulus*, 18 – *Polygonum hydropiper*, 19 – *Portulaca oleracea*, 20 – *Senecio vulgaris*, 21 – *Setaria pumila*, 22 – *Solanum nigrum*, 23 – *Sonchus arvensis*, 24 – *Sorghum halepense*, 25 – *Stachys annua*, 26 – *Erigeron annuus*, 27 – *Veronica hederifolia*, 28 – *Veronica persica*)

from other MAPs, probably due to its highest floristic diversity ($H' = 2.34$) and the highest evenness of weed flora ($E = 0.91$), without the domination of the most abundant weed species (Tab. 2, Fig. 6).

DISCUSSION

Presence and abundance of certain weed species in the studied MAPs, under studied agro-ecological

conditions, were affected by crop species and farming systems, which was similar to the results of other authors [Roschewitz et al. 2005, Ryan et al. 2009, Barroso et al. 2015, Pinke et al. 2016, Baker et al. 2018, Travlos et al. 2018, Hendawy et al. 2019]. Intensive cultivation practices limit flora diversity within a farming system [Nkoa et al. 2015], therefore studies comparing conventional and organic systems often report higher weed abundance and richness in the organic

systems [Ryan et al. 2009, Benaragama et al. 2016, Travlos et al. 2018]. However, in this study, higher species richness and weediness were found in conventional MAPs. This is probably related to slightly higher soil fertility, achieved by the intensive application of mineral fertilizers, in the conventional plot on the one hand; and crop rotation in the organic farming system on the other hand.

Higher floristic diversity most often causes higher evenness, however lower dominance of the most abundant species, and vice versa [He and Legendre 2002, Magurran 2004, Jost 2010]. This was confirmed in this study. All evenness values were relatively high and did not differ much, which resulted in low dominance values of the most abundant species in both farming systems. Floristic similarities found in MAPs were the result of specific and similar conditions of their cultivation. However, certain authors report species richness to be negatively correlated with evenness [Stirling and Wilsey 2001, Magurran 2004, Zhang et al. 2012]. Therefore, according to He and Legendre [2002], research into the mechanisms that affect evenness can facilitate understanding the species diversity.

In conventional farming systems, certain weeds are ecologically well-adapted and able to survive agronomic selective pressures, and therefore their control is more difficult. According to Nkoa et al. [2015], lower floristic diversity within an agroecosystem can lead to its greater vulnerability. The situation allows new species to inhabit, and this was confirmed in our study. Invasive species *Sorghum halepense*, as well as *Amaranthus retroflexus*, and *Datura stramonium*, potentially invasive weed species in Serbia, were among the most abundant weeds in organic MAPs which had lower floristic diversity. Possible reasons for the greater presence of invasive weeds in organic MAPs may be apparently still unbalanced agroecological conditions found in these recently established organic plots, and crop rotation [Brdar-Jokanović et al. 2018]. Although preceding crop partially suppressed weed growth in organic plots, invasive species in organic MAPs developed first and spread fast due to their extreme adaptability. Additionally, the organic field remained less fertile than the conventional plot, despite the long-term beneficial effects of farmyard manure on soil properties. Requirements of weeds for nutrients

are species dependant [Travlos et al. 2018]. For example, the competitive ability of *Amaranthus retroflexus* increases with higher levels of nitrogen [Blackshaw and Brandt 2008], which is consistent with our study where *Amaranthus retroflexus* was one of the most frequent and most abundant weeds in both farming systems. Hence, low nitrogen fertilization could decrease the density of *Amaranthus retroflexus* and enhance the effectiveness of weed control [Travlos et al. 2018].

The majority of MAPs are less competitive to weeds, which causes substantial weediness with annual species – therophytes [José-María et al. 2011]. In this study, the therophytes were the most common life forms in all studied crops. The dominance of therophytes points to intensive anthropogenic effects, i.e. intensive cultivation practices in both farming systems, which has led to their good adaptability. The adaptability is reflected by longer flowering period, a tendency for seed dispersal, and low harvest index [Carrubba and Militello 2013, Abouzienna and Haggag Wafaa 2016]. Other authors found that annual species are associated with a range of tillage systems, while perennial species are associated with reduced- and zero-tillage systems [Sans et al. 2011, Thomas et al. 2017, Travlos et al. 2018].

There is no single method that could be used to provide highly efficient weed control under the organic farming system. Due to the specific cultivation of MAPs, the following control measures are recommended: pre-sowing irrigation, sowing methods, hilling, hand weeding, drip irrigation method, natural herbicides, hot water, soil mulch, etc. [Carrubba and Militello 2013, Hendawy et al. 2019]. Further, there is a need for alternative weed management depending upon the weed composition, farming system, and management practices such as fertilization and tillage [Baker et al. 2018, Travlos et al. 2018]. Since the recorded weeds flower, until the development of more efficient methods that are in compliance with the principles of organic farming, mechanical weeding should be performed at least three times during the growing season [Brdar-Jokanović et al. 2018].

CONCLUSION

This is the first comparative analysis of weed composition and abundance between conventional and or-

ganic farming systems of MAPs (basil, pot marigold, dill, and peppermint) in agro-ecological conditions of Serbian province Vojvodina. It represents a step towards establishing adequate weed control measures. Weed composition and abundance were affected by MAP species and farming system. The crops under conventional production systems were characterized by higher weed diversity and weediness, and lower floristic similarity, comparing to organic crops. Weediness by individual plant species differed among the studied MAPs. The most frequent species in conventional crops were *Setaria pumila* and *Portulaca oleracea*. *Amaranthus retroflexus*, *Datura stramonium*, and *Sorghum halepense* were the most frequent species in organic crops. Therophytes were the most dominant weed life forms.

The results of this study could be helpful for the assessment of appropriate weed control measures. Further studies are required to understand the weed effects on MAP yields and quality; as well as to confirm the hypothesis on the suppressing effects of certain MAPs. Furthermore, it is necessary to raise awareness on the importance of conserving weeds biodiversity as an integral part of balanced agroecosystems.

SOURCE OF FUNDING

This research was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, grant numbers: 451-03-68/2022-14/200032 and 451-03-68/2022-14/200117.

REFERENCES

- Abouziena, H.F., Haggag Wafaa, M. (2016). Weed control in clean agriculture: a review. *Planta Daninha*, 34(2), 377–392. <https://doi.org/10.1590/S0100-83582016340200019>
- Baker, C., Madakadze, I.C., Swanepoel, C.M., Mavunganidze, Z. (2018). Weed species composition and density under conservation agriculture with varying fertiliser rate. *S. Afr. J. Plant Soil*, 35(5), 329–336. <https://doi.org/10.1080/02571862.2018.1431814>
- Barberi, P. (2002). Weed management in organic agriculture: are we addressing the right issues? *Weed Res.*, 42(3), 177–193. <https://doi.org/10.1046/j.1365-3180.2002.00277.x>
- Barroso, J., Miller, Z.J., Lehnhoff, E.A., Hatfield, P.G., Menalled, F.D. (2015). Impacts of cropping system and management practices on the assembly of weed communities. *Weed Res.*, 55(4), 426–435. <https://doi.org/10.1111/wre.12155>
- Benaragama, D., Shirliffe, S.J., Johnson, E.N., Duddu, H.S.N., Syrovy, L.D. (2016). Does yield loss due to weed competition differ between organic and conventional cropping systems? *Weed Res.*, 56(4), 274–283. <https://doi.org/10.1111/wre.12213>
- Blackshaw, R.E., Brandt, R.N. (2008). Nitrogen fertilizer rate effects on weed competitiveness is species dependent. *Weed Sci.*, 56(5), 743–747. <https://doi.org/10.1614/WS-08-065.1>
- Brdar-Jokanović, M., Ljevnaić-Mašić, B., Džigurski, D., Koren, A., Merkulov-Popadić, L., Nikolić, L., Adamović, D. (2018). Weed flora in organic common mallow (*Malva sylvestris* L.). *Contemp. Agric.*, 67(2), 143–148. <https://doi.org/10.2478/contagri-2018-0020>
- Carrubba, A. (2017). Weed and weeding effects on medicinal herbs. In: Ghorbanpour, M., Varma, A. (eds). *Medicinal plants and environmental challenges*. Springer, Cham, 295–327. https://doi.org/10.1007/978-3-319-68717-9_17
- Carrubba, A., Catalano, C. (2009). Essential oil crops for sustainable agriculture – a review. In: Lichtfouse, E. (ed.). *Climate change, intercropping, pest control and beneficial microorganisms*. *Sustainable Agriculture Reviews*, vol. 2, Springer, Dordrecht, 137–188.
- Carrubba, A., Militello, M. (2013). Nonchemical weeding of medicinal and aromatic plants. *Agron. Sustain. Dev.*, 33(3), 551–561. <https://doi.org/10.1007/s13593-012-0122-9>
- DAISIE (2018). Delivering Alien Invasive Species Inventories for Europe. Available: <https://www.europe-aliens.org/> [date of access: 20.01.2018].
- EEC (1991). Council regulation (ECC) No. 2092/91 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. Available: <https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1991R2092:20060506:EN:PDF> [date of access: 22.07.2019].
- EEC (1992). Council regulation (ECC) No. 2078/92 on agricultural production methods compatible with the requirements of the protection of the environment and the maintenance of the countryside. Report from the Commission to the Council and the European Parliament. Available: <http://aei.pitt.edu/6215/1/6215.pdf> [date of access: 20.07.2019].
- GISD (2019). Global Invasive Species Database. Available: <http://www.iucngisd.org/gisd/> [date of access: 28.09.2019].
- He, F., Legendre, P. (2002). Species diversity patterns derived from species-area models. *Ecol.*, 83(5), 1185–1198.

- [https://doi.org/10.1890/0012-9658\(2002\)083\[1185:SD-PDFS\]2.0.CO;2](https://doi.org/10.1890/0012-9658(2002)083[1185:SD-PDFS]2.0.CO;2)
- Hendawy, S.F., Abouziena, H.F., Abd El-Razik, T.M., Amer, H.M., Hussein, M.S. (2019). Winter weeds and its control in the medicinal plants in Egypt: a survey study. *Egypt. Pharm. J.*, 18(1), 16–26. https://doi.org/10.4103/epj.epj_13_18
- Honermeier, B., Ali, S., Leschhorn, B., Mahmood, A., Ijaz, M., Russo, M., Shafiee-Hajiabad, M., Ullah, H., Zeller, S. (2013). Cultivation of medicinal and spice plants in Germany – a review. *Int. J. Agric. Biol.*, 15(6), 1379–1388.
- José-María, L., Blanco-Moreno, J.M., Armengot, L., Sans, F.X. (2011). How does agricultural intensification modulate changes in plant community composition? *Agric. Ecosyst. Environ.*, 145(1), 77–84. <https://doi.org/10.1016/j.agee.2010.12.020>
- Jost, L. (2010). The relation between evenness and diversity. *Diversity*, 2(2), 207–232. <https://doi.org/10.3390/d2020207>
- Landolt, E., Bäumler, B., Erhardt, A., Hegg, O., Klötzli, F.A., Lämmler, W., Nobis, M., Rudmann-Maurer, K., Schweingruber, F.H., Theurillat J.P., Urmi E., Vust, M., Wohlgemuth, T. (2010). *Flora indicativa – ecological indicator values and biological attributes of the flora of Switzerland and the Alps*. 2nd ed. Haupt, Bern, pp. 376.
- Lazarević, P., Stojanović, V., Jelić, I., Perić, R., Krsteski, B., Ajtić, R., Sekulić, N., Branković, S., Sekulić, G., Bjedov, V. (2012). Preliminarni spisak invazivnih vrsta u Republici Srbiji sa opštim merama kontrole i suzbijanja kao potpora budućim zakonskim aktima. *Zaštita Prirode*. Zavod za zaštitu prirode Srbije. [Preliminary list of invasive species in the Republic of Serbia with general control and suppression measures to support future legislation. *Protection of Nature*. Institute for Nature Conservation of Serbia]. 62(1), 5–31 [in Serbian].
- Magurran, A.E. (2004). *Measuring biological diversity*. Blackwell Publishing.
- Nikolić T. (2015). *Flora Croatica Database*. Faculty of Science, University of Zagreb. Available: <http://hirc.botanic.hr/fcd> [date of access: 16.02.2020].
- Nkoa, R., Owen, M.D.K., Swanton, C.J. (2015). Weed abundance, distribution, diversity, and community analyses. *Weed Sci.*, Issue SP1, 64–90. <https://doi.org/10.1614/WS-D-13-00075.1>
- Pinke, G., Blazsek, K., Magyar, L., Nagy, K., Karácsony, P., Czúcz, B., Botta-Dukát, Z. (2016). Weed species composition of conventional soybean crops in Hungary is determined by environmental, cultural, weed management and site variables. *Weed Res.*, 56(6), 470–481. <https://doi.org/10.1111/wre.12225>
- Ryan, M.R., Smith, R.G., Mortensen, D.A., Teasdale, J.R., Curran, W.S., Seidel, R., Shumway, D.L. (2009). Weed-crop competition relationships differ between organic and conventional cropping systems. *Weed Res.*, 49(6), 572–580. <https://doi.org/10.1111/j.1365-3180.2009.00736.x>
- Roschewitz, I., Gabriel, D., Tschardtke, T., Thies, C. (2005). The effects of landscape complexity on arable weed species diversity in organic and conventional farming. *J. Appl. Ecol.*, 42(5), 873–882. <https://doi.org/10.1111/j.1365-2664.2005.01072.x>
- Sans, F.X., Berner, A., Armengot, L., Mäder, P. (2011). Tillage effects on weed communities in an organic winter wheat–sunflower–spelt cropping sequence. *Weed Res.*, 51(4), 413–421. <https://doi.org/10.1111/j.1365-3180.2011.00859.x>
- Scott, J.K., Webber, B.L., Murphy, H., Ota, N., Kriticos, D.J., Loechel, B. (2014). Weeds and climate change: supporting weed management adaptation, *AdaptNRM*. Available: https://adaptnrm.csiro.au/wp-content/uploads/2014/08/Adapt-NRM_M2_WeedsTechGuide_5.1_LR.pdf [date of access: 12.07.2019].
- Schippmann, U., Leaman, D.J., Cunningham, A.B. (2002). Impact of cultivation and gathering of medicinal plants on biodiversity: global trends and issues. In: *FAO. Biodiversity and the ecosystem approach in agriculture, forestry and fisheries*. Satellite event on the occasion of the Ninth Regular Session of the Commission on Genetic Resources for Food and Agriculture. 12–13 October 2002, Inter-Departmental Working Group on Biological Diversity for Food and Agriculture. Rome, 1–21. Available: <http://www.fao.org/3/aa010e/AA010E00.pdf> [date of access: 6.07.2022].
- Shannon, C.E., Weaver, W. (1949). The mathematical theory of communication. *Open J. Forest.*, 4(5), 1–117.
- Stirling, G., Wilsey, B. (2001). Empirical relationships between species richness, evenness, and proportional diversity. *Am. Nat.*, 158(3), 286–299. <https://doi.org/10.1086/321317>
- Takhtajan, A. (2009). *Flowering Plants*. 2nd ed. Springer.
- Thomas, A.G., Derksen, D.A., Blackshaw, R.E., Van Acker, R.C., Légère, A., Watson, P.R., Turnbull, G.C. (2017). A multistudy approach to understanding weed population shifts in medium- to long-term tillage systems. *Weed Sci.* 52(5), 874–880. <https://doi.org/10.1614/WS-04-010R1>
- Travlos, I.S., Cheimona, N., Roussis, I., Bilalis, D.J. (2018). Weed-species abundance and diversity indices in relation to tillage systems and fertilization. *Front. Environ. Sci.*, 6, 11. <https://doi.org/10.3389/fenvs.2018.00011>

- Ujvárosi, M. (1973). *Gyomnövények*. Mezőgazdasági Kiadó [Weeds. Agricultural Publishing], Budapest [in Hungarian].
- WHO (2003). Guidelines on good agricultural and collection practices (GACP) for medicinal and aromatic plants. World Health Organization Publications, Geneva. Available: <http://apps.who.int/medicinedocs/pdf/s4928e/s4928e.pdf> [date of access: 30.10.2019].
- Zhang, H., John, R., Peng, Z., Yuan, J., Chu, C., Du, G., Zhou, S. (2012). The relationship between species richness and evenness in plant communities along a successional gradient: a study from sub-Alpine meadows of the Eastern Qinghai-Tibetan Plateau, China. *PLoS One*, 7(11): e49024. <https://doi.org/10.1371/journal.pone.0049024>