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WEEDS OF LATTUCE (*LACTUCA SATIVA* L. SUBSP. *SECALINA*) IN ORGANIC AGRICULTURE

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Abstract

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The paper reviews the weed flora that develops during the organic production of lettuce, with the objective of establishing differences in weed infestation among different variants of lettuce production (non-woven agro textile mulch , straw mulch, cultivation, no cultivation - control; all previous variants were tested with and without fertilization). Weed range was estimated during the vegetation period of lettuce 2009-2010. General weed infestation rate was the highest in the control variant with organic fertilizers application (28.9 individuals/m^2), and the lowest in the variant without fertilization with cultivation (7.1 individuals/m^2). Lettuce plants were best developed in the variant with cover cloth and fertilization, while the weakest plants were registered in the variants with straw mulch. The total of 23 weed species was found in the examined variants, of which 5 were segetal weeds, 17 weed-ruderal and only one ruderal plant. Four weed species, which were also, most numerous, were present in all production variants: *Bilderdykia convolvulus* (L.) Dum., *Datura stramonium* L., *Hibiscus trionum* L., *Polygonum lapathifolium* L., *Sinapis arvensis* L., *Solanum nigrum* L. and *Sorghum halepense* (L.) Pers.

Most of the registered species start flowering in June, which is favourable with regard to weed control, before their fructification, as it coincides with the end of lettuce vegetation. Analysis of the biological spectrum of the weed flora in all examined variants indicates the dominance of therophytes, which account for 82.61% (19 species) of the total flora.

Key words: weeds, flora, weed infestation, organic agriculture, lettuce

Introduction

Development and intensification of agricultural production is definitely a social imperative because of the rapid growth of the human population on Earth. However, there are numerous negative consequences associated with the conventional agricultural production. There is an increased need for acquainting agricultural producers with the principles of organic agriculture aimed at the production of safe food and biodiversity conservation in general, in accordance with ecological specifics of a given region (Znaor, 1996; Darnhofer et al., 2010; Cooper et al., 2010).

Organic agriculture is an integral system of management and production of food and other

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products, which includes a combination of good agricultural practices, high level of biodiversity, preservation of natural resources and use of natural substances (Znaor, 1996; Diver, 2001; Kovacevic, 2008; Manojlovic et al., 2010). The organic production insists on an exclusive use of organic and microbial fertilizers, while taking special care of mutual interactions between soil, plants, animals and humans (Kovacevic, 2008; Manojlovic et al., 2010; Oxouzi and Papanagiotou, 2010).

Recognizing the importance and specific characteristics of organic agricultural production, as a part of Ministry of Agriculture, Department for Organic Production was established in our country in 2005. Subsequently, precise conditions and principles of organic production were determined and specified in the Act on Organic Production and Organic Products (Official Gazette of the Republic of Serbia, No. 62/2006).

Starting from 2007, farms in Serbia can be registered as organic, providing that they pass through a certification process. At such a farm, registered for organic production of vegetables (the Vozar farm near the village of Kisac), we have studied weed flora occurring in the organic production of lettuce organized under different cropping systems. The obtained results are presented in this paper.

Identification and control of weeds in organic production poses a serious problem, mostly because of an almost complete exclusion of chemical measures of weed control (Barberi, 2002; Kovacevic, 2008).

Materials and Methods

The research of weediness in organic lettuce production was conducted during 2009 and 2010 growing season, at Vozar farm, registered for organic vegetable production, located near the village of Kisac (the Vojvodina Province, Serbia). The geographic position of the farm is 45°35' northern latitude and 19°72' eastern longitude, 85 m above the sea level.

In the study of the organic production of lettuce (*Lactuca sativa* L. subsp. *secalina*, fam. Asteraceae, Compositae), we used the lettuce cultivar Brezov list or Brezolist. The study was set up at an area of 156.6 m^2, where individual plots were 1.8 m wide, 3m long, with the space between plots of 0.3 m. In each plot lettuce was planted in 4 rows, 12 plants per row. The study included four variants of lettuce growing: cover cloth, straw mulch, cultivation and no cultivation (control). One half of the study involved the application of organic fertilizers, while in the other half of the study the lettuce was grown without the application of organic fertilizers.

In both years, the experimental plot was planted with the garden beet (*Beta vulgaris* L. subsp. *esculenta* Salisb.) which was the previous crop to lettuce.

The study included variants established on a chernozem soil of neutral reaction (pH), medium provided with available phosphorus and optimally provided with available potassium (Table 1). The surface soil (0-30 cm) was well-provided with humus (humous soil), while the lower layer (30-60 cm) was medium provided with humus (Table 1). Soil reaction was determined in a suspension with H_2O and 1 M KCl (ratio of 1:2.5, w/v), using a Metrel MA3657 pH-meter. $CaCO_3$ content was determined volumetrically, using Scheibler's calcimeter (Soil Survey Staff, 1993). Total C and N contents were determined with a CHNS analyzer (ELEMENTAR). After extraction with AL-solution (0.1 M ammonium lactate and 0.4 M acetic acid, pH 3.75), the ratio of soil: solution 1:20 (w/v) was determined according to Egner et al. (1960), phosphorus concentration was measured with a spectrophotometer, potassium concentration with a flame photometer.

Weed infestation assessment in lettuce was performed twice, the first time four weeks after transplanting, the second time two weeks later, just before lettuce harvest.

The determination of the registered taxa was done according to 'The Flora of SR Serbia' (Josifovic, 1970-1977) and 'Flora Europaea' (Tutin et al.,

Table 1
Main chemical soil properties in the location of the study of organic lettuce production

Years	Depth, cm	pH in KCl	pH in H_2O	$CaCO_3$, %	SOC, %	N, %	AL-P_2O_5, mg $100g^{-1}$	AL-K_2O, mg $100g^{-1}$
2009	0-30	6.61	7.57	0.36	1.96	0.23	13.8	29.7
	30-60	7.63	8.77	2.56	0.97	0.12	12.6	17.7
2010	0-30	7	7.7	3.53	2.42	0.27	26.1	30.4
	30-60	7.09	7.75	5.52	1.8	0.2	17.2	28.2

1964-1980). Life forms were determined according to Ujvarosi (1973), flowering time according to Canak et al. (1978) and weed site preferences according to Kojic et al. (1972). The number of weed species was analyzed by the quantitative method of squares (Kojic et al., 1972).

In order to study the differences in the number of weed species depending on the method of growing lettuce, we conducted the analysis of variance (ANOVA), t-test and Duncan-test at the significance levels of 5% and 1% for each assessment separately (Hadživuković 1991). Statistical analysis was performed using STATISTICA 10.0 (StatSoft).

Results and Discussion

The paper gives a review of weeds present in the organic lettuce production and reviews their biological characteristics. In addition, weed infestation was analyzed for different lettuce growth conditions: variants that received organic fertilizers and those that did not receive organic fertilizers, with application of non-woven agro textile mulch, straw mulch, cultivation and no cultivation (control). In the course of the floristic study of weeds accompanying the organic production of lettuce, 23 weed species were invariably registered in all variants of the study.

The present species belong to the same number of genera, they were classified in 16 families belonged to the phylum *Magnoliophyta*. The most represented species were from the family Asteraceae (5 species). The families Polygonaceae, Brassicaceae and Solanaceae were represented by two species each, while other 12 families had only one representative (Table 2).

Out of this number, 5 were weeds in the narrow sense (segetal plants), while most (17 species) belong to the category of weed-ruderal plants, and there is only one ruderal plant species (Table 2).

Most of the registered species flowered starting from June, while five species flowered from May. Two species flowered in March, two of April, while *Stellaria media* was an exception which, under the local agro-ecological conditions, flowered throughout the year. A little later, in July or August, only *Heliotropium europaeum* and *Ambrosia artemisiifolia* flowered. It can be concluded that in the period of salad growing (IV-V) the majority of the determined weed species do not flower, which is important for the possibility for their removal before fructification. This is especially important due to present invasive weed species (*Amaranthus retroflexus, Ambrosia artemisiifolia, Galinsoga parviflora and Sorghum halepense*), whose spreading is to be monitored and controlled.

Analysis of the biological spectrum of weed flora in all variants of the study indicated a therophytic character of the weed flora with predominance of therophytes which made up 82.61% (19 species), including also the majority of the species which affect weediness most. T_4 therophytes were dominant among the therophytes with 56.52% (13 species). They typically develop in spring and their seed matured in late summer. T_1 therophytes

Table 2

Weed flora present in all variants of organic lettuce production, their life forms, time of flowering and weed category (2009 and 2010)

Family	Genus	Plant species	Life form	Time of flowering	Category according to site
	Ambrosia	*A. artemisiifolia* L.	T4	VIII-IX	R
Asteraceae	Cirsium	*C. arvense* (L.) Scop.	G3	VI-VIII	WR
	Senecio	*S. vulgaris* L.	T1	III-XI	WR
	Sonchus	*S. oleraceus* (L.) Gou.	T4	VI-X	WR
	Galinsoga	*G. parviflora Cav.*	T4	V-X	WR
Polygonaceae	Bilderdykia	*B. convolvulus* (L.) Dum.	T4	VI-IX	WR
	Polygonum	*P. lapathifolium* L.	T4	VI-IX	WR
Brassicaceae	Capsella	*C. bursa-pastoris* (L.) Medik.	T1	IV-XI	WR
	Sinapis	*S. arvensis* L.	T3	V-IX	S
Solanaceae	Datura	*D. stramonium* L.	T4	VI-IX	WR
	Solanum	*S. nigrum* L.	T4	VI-X	WR
Caryophyllaceae	Stellaria	*S. media* (L.) Vill.	T1	I-XII	WR
Primulacae	Anagallis	*A. arvensis* L.	T4	V-X	WR
Amaranthaceae	Amaranthus	*A. retroflexus* L.	T4	VI-IX	WR
Chenopodiaceae	Chenopodium	*C. album* L.	T4	VI-IX	WR
Convolvulaceae	Convolvulus	*C. arvensis* L.	G3	VI-IX	WR
Euphorbiaceae	Euphorbia	*E. helioscopia* L.	T4	IV-XI	S
Fumariaceae	Fumaria	*F. officinalis* L.	T3	V-IX	S
Boraginaceae	Heliotropium	*H. europaeum* L.	T4	VII-IX	WR
Malvaceae	Hibiscus	*H. trionum* L.	T4	VI-VIII	S
Resedaceae	Reseda	*R. lutea* L.	H4	V-X	WR
Scrophulariaceae	Veronica	*V. hederifolia* L.	T1	III-V	WR
Poaceae	Sorghum	*S. halepense* (L.) Pers.	G1	VI	S
Total 16	23	23			

Legend: T-therophyta; G-geophyta; H - hemicryptophyta; R-ruderal species; WR-weed-ruderal species; S-segetal weeds

and T_3 therophytes were represented by 17.39% (4 species) and 8.70% (2 species), respectively. Geophytes were represented only by 13.05% (3 species). G_1 geophytes, characteristic for having rhizomes, made 4.35% of the flora (1 specie). G_3 geophytes, characteristic for having adventitious buds on the root, represented 8.70% of the flora (2 species). Only one hemicryptophyta was registered (4.35%) (Figure 1).

For all variants of the lettuce during the study period, it was possible to register the constant presence of seven common weed species which especially influence the studied lettuce crop, because they are the most common and most frequent, and have the greatest effect on weediness. These are therohytes, *Bilderdykia convolvulus* (L.) Dum., *Datura stramonium* L., *Hibiscus trionum* L., *Polygonum lapathifolium* L., *Sinapis arvensis*

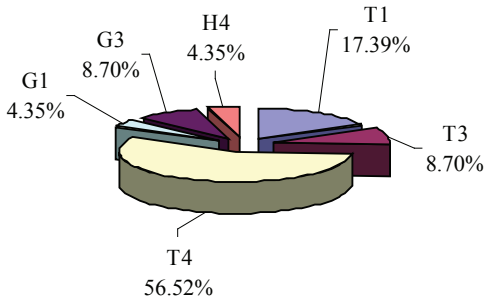

Fig. 1. Biological spectrum of the weed flora in all variants of organic lettuce production (2009 and 2010)

L., *Solanum nigrum* L. and geophyta *Sorghum halepense* (L.) Pers. (Table 3).

In terms of the floristic composition, certain variants of the experiment are relatively poor. Thus, the smallest number of species was recorded in variants with cultivation (9 species with fertilization, 10 species without fertilization), which is understandable, while the highest floristic richness was recorded in variants with cover cloth (14 species).

The weed infestation, i.e. average number of individuals per square meter (no. of ind/m^2) was the highest in the control variants with fertilization (28.9 ind/m^2), while both variants with non-woven agro textile mulch also had relatively high weed infestation (24.7 and 25.7 ind/m^2) (Table 3). It should be noted that the species that are most numerous and which affect weed infestation most (*Solanum nigrum, Datura stramonium* and *Sorghum halepense*) in the investigated period were in the early stages of development (seedlings, i.e. with 2 typical leaves). The lowest weed infestation was observed in variants with cultivation (average 7.1 ind/m^2 without fertilization and 7.8 ind/m^2 with fertilization).

In order to investigate the differences in weed infestation (no. of ind./ m^2) depending on growing conditions, analysis of variance (ANOVA), t-test and Duncan test were conducted at the levels of significance 5% and 1% (Hadzivukovic, 1991). On the basis of analysis of variance (completely random distribution), it was determined that there are statistically significant differences in weed infestation only with fertilized soil, between certain treatments ($F=3.67$; $p=0.012$). According to Duncan test, statistically significant differences in weed infestation were determined non-woven agro textile mulch and cultivation ($p=0.003$), as well as statistically significant differences in weed infestation determined between non-woven agro textile mulch and straw mulch ($p=0.048$) (Table 4).

The lettuce grew most vigorously in the plots with non-woven agro textile mulch and applied fertilizers; the weakest growth was registered in the variants with straw mulch (not shown).

Increased weed infestation has a negative effect on crop production because of intensified competition between cultivated plants and weeds for space, light, water, minerals, etc. (Sinzar and Misovic, 1978; Kovacevic, 2008).

In the organic agriculture too, weed incidence is a major problem that cannot be solved by the application of chemicals. Instead, intensive studies of the biological properties of weeds should be conducted, with emphasis placed on the competitive and allelopathic relationships between cultivated plants and weeds. Such approach would undoubtedly improve individual components of the overall integrated weed control strategy while taking into account the sustainability of agro-ecosystems (Znaor, 1996; Barberi, 2002; Kovacevic, 2008).

In the organic production in general (Barberi, 2002), including the organic production of lettuce, insufficient attention is paid to the problem of weeds (Davies 2001; Kaut et al., 2008). However, there are certain recommendations to be followed. For example, within the scope of indirect measures of weed control, lettuce transplanting is recommended instead of seeding, because the former practice reduces weed competition by slowing down growth and coverage rate in relation to lettuce (Schonbeck et al., 1991; Titley, 2000; Ngouajio et al., 2003). Concerning direct measures of weed control, manual weeding and between-row ploughing are recommended. These practices

Table 3
Weed abundance in the different variants of the study (no. of ind./m^2) (2009 and 2010)

Plant species	Fertilized				Not fertilized			
	Cover cloth	Straw mulch	Culti-vation	Control	Cover cloth	Straw mulch	Culti-vation	Control
Amaranthus retroflexus L.			1.3					
Ambrosia artemisiifolia L.						1.3		
Anagallis arvensis L.					1.3		1.3	
Bilderdykia convolvulus (L.) Dum.	1.3	4	2.7	5.3	5.3	2.7	2.7	4
Capsella bursa-pastoris (L.) Medik.								4
Chenopodium album L.	1.3				22.7	1.3		2.7
Cirsium arvense (L.) Scop.			1.3			8	1.3	
Convolvulus arvensis L.		14.7			4		1.3	
Datura stramonium L.	49	14.7	5.3	5.3	18.7	13.3	17.3	18.7
Euphorbia helioscopia L.				1.3				
Fumaria officinalis L.	2.7	2.7		4	1.3	1.3		2.7
Galinsoga parviflora Cav.	1.3	2.7		2.7	5.3			4
Heliotropium europaeum L.	1.3							
Hibiscus trionum L.	6.7	2.7	2.7	8	12	6.7	2.7	13.3
Polygonum lapathifolium L.	32	6.7	1.3	6.7	50.7	12	5.3	18.7
Reseda lutea L.				1.3				
Senecio vulgaris L.	1.3			1.3				
Sinapis arvensis L.	44	34.7	18.7	36	33.3	18.7	8	29.3
Solanum nigrum L.	144	124	9.3	221.3	125.3	71.7	14.7	78.7
Sonchus oleraceus (L.) Gou.					4			
Sorghum halepense (L.) Pers.	58.7	18.7	28	53.3	72	12	16	10.7
Stellaria media (L.) Vill.	1.3				4			
Veronica hederifolia L.	1.3							
Average number of ind./m^2	24.7	22.6	7.8	28.9	25.7	13.5	7.1	17
Total of plant species	14	10	9	12	14	11	10	11

certainly increase production costs, but the extra cost is justified in view of the importance of lettuce as a component of human food (Schonbeck et al., 1991; Bleeker and Van der Weide, 2000).

Conclusion

In our study, the weed flora in the organic production of lettuce (*Lactuca sativa* L. subsp. *secalina*, the cultivar Brezov list or Brezolist), in all production variants tested (non-woven agro textile mulch, straw mulch, cultivation, no cultivation, with or without addition of organic fertilizers), consisted of 23 weed species, 5 segetal, 17 weedy ruderal and only one ruderal species.

The analysis of the biological spectrum of the recorded species indicated that therophytes (Th) predominate with 82.61% (19 species). The majority of species that have the most influence on the weed of lettuce belong to therophytes, which is certainly due to strong anthropogenic influence, i.e. instability of the weed community (Kovacevic,

2008).

The most impact on weediness of lettuce was made by the most frequent weed species, therophytes: *Datura stramonium* L., *Hibiscus trionum* L., *Bilderdykia convolvulus* (L.) Dum., *Polygonum lapathifolium* L., *Sinapis arvensis* L., *Solanum nigrum* L. and geophyta *Sorghum halepense* (L.) Pers.

Due to the great importance of invasive species from ecological (Colautti, 2005; Inderjit et al., 2005) and agronomic aspects (Vrbnicanin et al., 2004; Harker et al., 2005) in weed flora of organic production of lettuce, we highlight the presence of four invasive species, *Amaranthus retroflexus, Ambrosia artemisiifolia, Galinsoga parviflora i Sorghum halepense*, whose spreading must be monitored and controlled due to potential negative impact on biodiversity of indigenous flora (Vrbnicanin et al., 2004).

Floristic diversity was the highest in treatments with cover cloth (14 species), while the variants with cultivation were floristically poorer (9 species, fertilized, 10 species not fertilized).

The highest level of weediness was recorded in the variant with cover cloth with organic fertilizers (average 28.9 ind/m^2). The lowest weediness was recorded in the variants with cultivation without fertilization (average 7.1 ind/m^2), which is confirmed by the results of statistical analysis.

The study showed that the highest number of weeds was registered in the variant with cover cloth, which obviously affected positively the growth of both lettuce and weeds, chiefly because of favourable moisture under the cloth.

On the basis of the above, it may be concluded that organic production of lettuce faces the problem of weed control and that an integrated approach is needed to solve this problem, which involves physical, mechanical and biological measures of weed control.

Lowering the weed infestation to a tolerable level would positively affect the efforts aimed at biodiversity conservation (Magliorini and Vazzana, 2007), especially of segetal weeds (Tyser et al., 2007). Cultivation practices such as previous tillage, seedbed preparation specifically for organic production and careful timing of planting or transplanting may greatly facilitate the organic production in terms of weed control (Barberi, 2002).

At the same time, the knowledge and monitoring of biological characteristics of weed are of great importance.

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