sciendo

Contemporary Agriculture, Vol. 72, No. 3 (2023): 89-97
DOI: 10.2478/contagri-2023-0012
UDC: 632.51

Original scientific paper

ISSN 2466-4774
https://www.contagri.info/

OPEN ACCESS

WEEDS AS BIOINDICATORS OF ECOLOGICAL CONDITIONS IN ORGANIC CARROT AND ONION CROP

LJILJANA NIKOLIĆ[1], SRĐAN ŠEREMEŠIĆ[1], DEJANA DŽIGURSKI[1], BOJAN VOJNOV[1], MARJANA VASILJEVIĆ[2]*

[1]University of Novi Sad, Faculty of Agriculture, Serbia
[2]Institut of Field and Vegetable Crops, National Institute of the Republic of Serbia, Novi Sad, Serbia
**Corresponding author*: ljiljana.nikolic@polj.uns.ac.rs

Submitted: 28.6.2023.
Accepted: 22.9.2023.

SUMMARY

The obtained results indicate the possibility of weed control in organic intercropping production systems of carrots and onions with the application of corn gluten, together with the ecological assessment of habitat based on bioindicator values of weed species. A total of 29 weed taxons are present in the intercoped and pure crops of carrots and onions, grown without (CO) and with the application of corn gluten (CO-G). Although floristically uniformed, 24 taxons (CO) and 23 taxons (CO-G), the total weediness on the CO-G variants was 24% higher. The highest value of fresh weed biomass was recorded on the treatment of pure onion crop with gluten application (2844.85 g/m2), while the lowest value was recorded on the treatment of intercropped carrot and onion (1004.99 g/m2). Ecological assessment of habitat, based on indicator values and abundance of weed species, indicates favorable climatic conditions with favorable temperature ($T_{\bar{x}}$ - 4) and light ($L_{\bar{x}}$ - 4) regime, which refers to temperate continental climate conditions ($K_{\bar{x}}$ - 2,7). Soil indicators indicate slightly drier conditions ($F_{\bar{x}}$ – 2,6), slightly acidic to neutral pH ($R_{\bar{x}}$ – 3,3), rich in nutrients ($N_{\bar{x}}$ – 4), with moderate humus content ($H_{\bar{x}}$ – 3), moderate aeration ($D_{\bar{x}}$ – 2,8) and locally salted (s) with the participation of salinity indicators in the amount of 54% (CO) and 40% (CO-G). The presence of heavy metals tolerance (m) indicators in the amount of 46% (CO-G) and 41% (CO) should not be neglected, which imposes the need for additional analysis of soil for heavy metal content. Based on the analysis of obtained indicator values, it can be concluded that these ecological conditions correspond to the development of carrots and onions and that the lowest values of fresh weed biomass were recorded on the treatment of intercropping of carrots and onions, without application of corn gluten.

Key words:
weed biomass, indicator values, corn gluten, intercropping, carrot, onion

INTRODUCTION

The specifics of the weed flora in vegetable production depend on the type of crop (density and covering value), as well as on the applied cultivation practices (Hassannejad & Navid, 2013). Vegetable crops are mainly grown as wide-row crops with a larger inter-row distance and different distances between plants in a row. Large inter-row space with favorable agro-ecological factors and slower crop germination enable intensive development of weeds and faster weed infestation of crops. Also, slower growth and low coverage of cultivated plants, especially in the early development stages, enable extreme weed growth and sometimes complete suppression of crops (Vrbničanin & Božić, 2021).

The problem of weeds is even more emphasised in organic production, which is based on organic principles, due to the fact that the use of synthetic pesticides, including herbicides, is completely banned (Dayan et al., 2009).

Although there are minor differences in the existing definitions of organic agriculture, according to IFOAM (The International Federation of Organic Agriculture Movements), the basic principles of organic agriculture are unique. The firste principle is the principle of health (for land, plants, animals, humans and the planet Earth as a whole). The second one is the ecological principle (organic production, which is based on dynamic ecological systems and cycles with interdependent relationships, contributes to biodiversity, survival and evolution). The third is the principle of righteousness (towards nature and life, respecting the common environment for achieving goals at all levels). The final, fourth, is the principle of care and responsibility (responsible production management, for the protection of the health and well-being of present and future generations and the environment) (Lazić, 2014a).

Research in finding the optimal way to grow plants according to organic agricultural principles is very important and current, because areas under organic production are increasing all over the world, including in our country, which reflects the overall increase in biodiversity (wild flora, fungi, microorganisms, soil fauna, etc.) (Rembiakowska, 2017). According to different research, the following actions are crucial for weed management in organic farming: proper crop selection, adequate crop rotation, balance between crops and weed communities, time and method for soil cultivation, and intercropping (Baumann et al., 2000; Liebman & Davis, 2000; Bond & Grundy, 2001; Lundkvist et al., 2008).

Intercropping of certain crops leads to a number of positive effects, such as better plant growth, biomass production and yield (Zhang et al., 2011), better use of resources (Betencourt et al., 2012), reduction of diseases, pests and weeds (Bàrberi, 2002; Ren et al., 2008). Intercroping contributes to diversity of products, but also ensures the safety of agricultural production, because unfavorable conditions can affect one crop more than another, so the one that is not endangered, provides a favorable yield and income (Dolijanović et al., 2009). Organic agriculture also uses biopesticides that are controlled as well as synthetic pesticides. But despite that, it is important for producers to get acquainted with the basic characteristics of biopesticides (concentration, time of application, waiting period, precautionary measures at work, danger to people, animals, beneficial organisms) (Lazić, 2014b). Dayan et al. (2009) state that for the control of weeds in organic agricultural production, natural agents, which are mainly used as bioherbicides, are based on corn gluten, vinegar, clove oil, cinnamon, lemon, etc. However, unlike conventional, natural herbicides are non-selective, used in large quantities, and there is not enough scientific data on the environmental impact of natural products in organic agriculture. Corn gluten (a by-product of industrial corn processing) is a non-selective, contact bioherbicide, protein in its nature, rich in vitamins and minerals. In addition, it contains 10% of nitrogen (Bingaman & Christians, 1995) and is used both as a biofertilizer and as a bioherbicide (Dayan et al., 2009). Corn gluten is used as a pre-emergent herbicide that inhibits the development of the root system of seedlings and causes weaker stem growth, therefore its use is recommended before germination end emergence, as it has no effect on already developed weeds (Dayan et al., 2009). Christians (1993) cites bioherbicidal activity of corn gluten on both broadleaf and narrowleaf weeds, while Bingam & Christians (1995) state that corn gluten is more effective in controlling broadleaf weeds than narrowleaf weeds.

Producution of vegetables according to organic principles is rising in our country, mostly on smaller certified organic farms, whose products are in high demand on the international market (Berenji et al., 2013). The group of important vegetable plants includes carrot and onion. Carrot (*Daucus carota* L.) is a biennial vegetable plant from the family Apiaceae, class Magnoliopsida (Dicotyledons), whose turnip root is used in nutrition. Due to its pleasant taste, high nutritional value, and medical traits, it is a very popular vegetable (Jančić & Stojanović, 2008; Leja et al., 2013). It contains a lot of sugar (sucrose and glucose), proteins, carotenoids, especially beta-carotene, which is transformed into vitamin A during metabolism. In addition, carrot also contains minerals, mostly K, Ca, Fe, and B vitamins, especially nicotinic acid (vitamin B3), essential oils, etc. (Lazić et al., 1993). Onion (*Allium cepa* L.) from the family Alliaceae, class Liliopsida (Monocotyledons), is one of the vegetable species widely in production, which also has a medical effect (Jančić & Stojanović, 2008). Onion contains the most carbohydrates (65%), the most common mineral elements are Ca, Si, Cl, Na, P, Cu, and it also contains essential oils, essential amino acids and vitamins (Lazić et al., 1993).

The aim of this research is the analysis of weed flora and fresh weed biomass in organic carrot and onion production. Namely, it is important to figure out the best approach to grow them without using pesticides and to keep balanced the relationship between cultivated plants and weeds. Intercropping, as well as the use of bioherbicides, are two options that are discussed in this research. Furthermore, the study considers the idea of using weeds as bioindicators, which can also be, as natural companions of crops, valuable as indicators of ecological conditions in which they develop and grow (Kojić et al., 1994).

MATERIAL AND METHODS

Weed flora research was performed on an field experiment set up on a certified organic farm Dolovac, Futog, Serbia (45.24°N, 19.72°E), Fig.1. The experiment was set up on an area of 100 m^2, with seed material from the Institute of Field and Vegetable Crops from Novi Sad. Used seeds were carrot (*Daucus carota* L., Apiaceae, Apiales), variety 'Nantes', and onion (*Allium cepa* L., Alliaceae, Amaryllidales), variety 'Kupusinski jabučar'. Both species are sown at a depth of 3 cm, with a distance of 5 cm in a row and 20 cm between rows. Sowing was performed in four-row strips 12 m long, with two protective rows on each side (40 cm wide). Carrots and onions were sown on plots of 2.4 m^2 (120 cm x 200 cm) in an intercropped and pure crop, in the following variants: pure carrot crop (C); intercropped crop – alternately sown a row of onions and a row of carrots (CO); intercropped crop – alternately sown in two rows (2CO), and pure onion crop (O). Within each variant of the experiment, there was also a variant with the corn gluten (G) in the amount of 300 g/m^2 and these are: C-G, O-G, CO-G and 2CO-G.

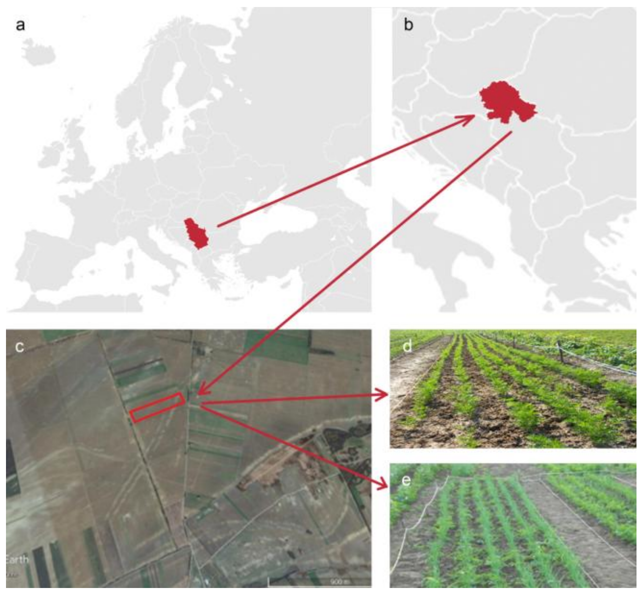

Figure 1. Study site: a) Europa – position of Serbia; b) North Serbia (Vojvodina province); c) Experimental area - part of the plots of the experiment with carrot (d) and onion (e)

On this experimental area, basic chemical soil properties indicate moderately alkaline - 8.07 (in H_2O), i.e., neutral to slightly alkaline conditions - 7.26 (in KCl). Furthermore, in terms of $CaCO_3$ content, the soil is medium carbonate (4.95%). Additionaly, it is moderately supplied with humus (2.48%), favourably supplied with total nitrogen (0.184%), easily accessible phosphorus (13.4 mg/100g), and well supplied with potassium (31.8 mg/100g) (Šeremešić et al., 2018).

The average temperature in the investigated period ranged from 7.5°C to 18.2°C, and the total amount of precipitation was 762 mm (Šeremešić et al., 2018).

Weed species were determined according to Josifović (1970-1986) and Tutin et al. (1964-1980). Regarding the species *Xanthium italicum*, some confusion appears because different synonyms are often used, which are therefore given for this taxon in Tab. 1.

Determination of the number of weed plants was performed twice during the vegetation period, in three replications, by counting plants on an area of 0.25 m^2, calculated on 1 m^2.

Fresh weed mass (aboveground biomass) was analyzed on the basis of collected weeds on the area of 0.25 m^2 from each variant of the experiment in three replications. After that, the collected samples were measured in the laboratory on a scale which has 0.1 g accuracy and the mass was recalculated to 1 m^2. The data were statistically accessed using the statistical software Statistica 13.2.

Ecological indices (bioindicator values) for the climate indicators (temperature – T, continentality – K and light – L) and soil indicators (moisture – F, reaction – R, nutrients – N, humus – H, aeration – D, salt tolerant – s and heavy metal tolerant – m) are given according to Landolt (2010). Only for the Matricaria inodora, which Landolt (2010) does not state, indices are given according to Knežević (1994). Plants were characterised by a specific value of the ecological index which determines the ecological optimum for the particular species compared with some habitat traits. Values of the ecological indices are expressed on the scale from 1 to 5, where 1 stands for minimum and 5 for maximum requirements. For gaining the better insight in the ecological conditions based on bioindicator values, abundance of present weed species was taken into account. Hence, values of ecological indices for every weed species were multiplied by the average number of individuals of that species in the given variant of the experiment.

RESULTS AND DISCUSSION

The results of this paper are a part of the research related to weed flora of organic crops of carrots and onions grown with the use of corn gluten (Nikolić et al., 2018).
In the area of only 100 m^2, a significant floristic diversity can be noticed, where the total weed flora in the investigated area consisted of 29 taxons. Out of that number, 23 weed taxons were recorded on all variants of the experiment with the use of corn gluten (CO-G), and 24 weed taxons were recorded on the gluten-free variant of the experiment (CO). However, although the floristic structure is almost equal, the total weediness on the variants with the use of corn gluten was 281 weed individuals per m^2 (24% higher), while on the variants without the use of corn gluten was 214 weeds per m^2 (Tab. 1). Regarding the floristic specificity of researched organic crops, it is important to point out that weed species were found (Tab. 1), characteristic for vegetable crops (Vrbničanin & Božić, 2021), and, also, earlier most of them were found in organic onion crops (Džigurski et al., 2013) and carrots (Ljevnaić et al., 2012) at other sites. In both variants of the experiment, the highest numbers were reached by *Ambrosia artemisiifolia* (79 ind/m^2 - CO-G and 78 ind./m^2 CO) and *Solanum nigrum* (46 ind./m^2 CO-G and 29 ind./m^2 CO). In addition, *Chenopodium album, Echinochloa cruss-galli* (35 ind./m^2) and *Matricaria inodora* (18 ind./m^2) are higher in the variants with the use of corn gluten, but in the gluten-free variant, *Datura stramonium* (19 ind./m^2) and *Polygonum convolvulus* (15 ind./m^2) are higer.
Of the total number of weed taxa, 6 of them (21%) are invasive in Serbia and neighboring countries (Stojanović & Jovanović, 2018). At the same time, they are also on the lists of alien plant species for Europe (EASIN and DAISIE) of which as many as 5 species (*Amaranthus retroflexus, Ambrosia artemisiifolia, Datura stramonium, Sorghum halepense* and *X. strumarium* L. ssp. *italicum*) have a high impact in terms of invasiveness, and are also on the global list of invasive species (CABI). Four invasive weed species were found on the crop variants with gluten, and 5 invasive weed species on the gluten-free variants, of which only *Ambrosia artemisiifolia* reached a high and uniformed abundance on both variants of experiment (CO-G 79 ind./m2 and CO - 78 ind./m^2). This species has been categorized as an invasive alien plant species with high impact on the European (EASIN ID: R00818) and global (CABI) level, so caution is required when it is present, and it is necessary to remove it from the field before flowering and fruiting, since is a therophyte and it reproduces exclusively sexually (by seed).

Table 1. Overview and number of weed species with ecological indices in organic carrot and onion crops with (DO-G) and without the use of corn gluten (DO)

Weed species	Crop		Ecological indices									
	CO – G No. ind./m^2	CO No. ind./m^2	T	K	L	F	R	N	S	M	H	D
Amaranthus retroflexus L. **Inv**	1	0	4	3	4	2.5	3	4	s	m	3	1
Ambrosia artemisiifolia L. **Inv**	79	78	5	2	4	2	3	4	s		3	3
Anagalis arvensis L.	4	1	4	3	4	3	3	3			3	3
Anagalis foemina Mill.	1	0	4	4	4	2	4	3			3	3
Capsella bursa-pastoris (L.) Med.	2	4	3	3	4	2	3	4		m	3	3
Chenopodium album L.	35	11	3	3	4	2	3	4		m	3	3
Chenopodium hybridum L.	1	0	4.5	4	4	3	4	4			3	3
Cirsium arvense (L.) Scop.	1	5	3.5	3	3	3	3	4	s	m	3	1
Convolvulus arvensis L.	7	7	4	4	4	2.5	4	4		m	3	1
Cuscuta sp. L.	0	1										
Datura stramonium L. **Inv**	3	19	5	2	4	3	3	4	s		3	3
Echinohcloa cruss-galli (L.) Beauv.	35	6	4	3	4	3.5	3	4			3	1
Lathyrus tuberosus L.	1	3	4.5	4	4	2	4	3			3	1
Matricaria inodora L.	18	4	3	3	4	3	3	4	s		4	4
Plantago media L.	2	1	3.5	4	4	2	4	3	s		3	3
Polygonum aviculare L.	0	3	4	2	4	3.5	3	4	s	m	3	3
Polygonum convolvulus L.	7	15	3.5	3	4	2.5	3	4		m	3	3
Polygonum lapathifolium L.	4	4	3.5	2	4	3.5	3	5	s	m	3	3
Rubus caesius L.	3	0	3.5	3	3	3.5	4	4	s	m	3	1
Setaria glauca P.B.	10	1	4	4	4	2	3	4		m	3	3
Setaria verticillata (L.)P.B.	1	0	5	4	4	2.5	3	4			3	3

Sinapis arvensis L.	8	11	4	3	4	3	4	4			3	3
Solanum nigrum L.	46	29	3.5	3	4	3	4	4		m	3	3
Sonchus arvensis L.	1	1	3.5	3	3	3.5	4	4	s	m	3	1
Sorghum halepense L. **Inv**	0	2	5	2	4	2	4	4			3	3
Stachys annua L.	0	5	4	4	4	2.5	4	4		m	3	1
Taraxacum officinale Web.	0	1	3	3	4	3	3	4		m	3	3
Veronica persica Poir. **Inv**	11	1	3.5	3	4	3	4	4		m	3	3
Xanthium italicum Mor. **Inv** (syn. *X. strumarium* L. ssp. *italicum* (Mor.) D. Löve; *X. strumarium* L. ssp. *strumarium* L.)	0	1	5	3	4	3	3	5	s		3	3
Total weediness	281	214										

Weed biomass

Analysis of the obtained data for fresh weed biomass (Tab. 2) shows that the highest value of fresh weed biomass was recorded on the variant with pure onion crop with gluten in the amount of 2844.85 g/m^2. Additionally, on the variant of intercropping of single row crops of carrots and onions with the use of gluten – the amount of fresh weed biomass is 1993.16 g/m^2. The lowest value of fresh weed biomass was recorded on the variant of intercropped crop of carrot and onion (1004.99 g/m^2) as well as in pure crop of carrot (1011.71 g/m^2). The statistically highly significant difference was observed between fresh weed biomass of pure carrot crop (C) and intercropped carrot and onion crop with gluten (CO-G, 2CO-G), Tab. 3.

Analyzing fresh biomass between the same crop combinations, with and without the corn gluten, showed that higher fresh weed biomass was observed in all variants with the corn gluten, although these differences were not statistically significant. A statistically significant difference in fresh weed biomass was observed only in fresh weed biomass between the intercropped two-row carrot and onion crops with (2CO-G = 1573.74 g/m^2) and without gluten (2CO = 1052.08 g/m^2), Tab. 2, Tab. 3.

Also, it is interesting to note that fresh weed biomass was almost equal between pure carrot crop with gluten (C-G = 1035.6 g/m^2) and two-row intercropping of carrot and onion crop without corn gluten (2CO = 1052.08 g/m^2).

In terms of fresh weed biomass, the best effect was shown on the variants of intercropped sowing of carrots and onions, without the addition of corn gluten. Intercropping as a measure also shows favorable effects in the case between pea-weat (Szumigalski & Van Acker, 2005), pea mixtures with cereals crops (Deveikyte et al., 2009), then corn and beans (Vasić et al., 2017).

Even though, in this case, corn gluten was analyzed as a potential natural "herbicide" (Christians, 1993; Bingaman & Christians, 1995), the fact that in certain concentrations it can have a stimulating effect on plant growth, as a biofertilizer, cannot be ignored, due to a significant content of N (Dayan et al., 2009) as well as other substances such as vitamins (ß-carotene, B12, B6, Biotin, Thiamine, etc.) which all together have a beneficial effect on microbiological activity in soil (Rodney & DeMuro, 2013).

Table 2. Fresh weed biomass (g/m^2) in different variants of the experiment

	Variant of the experiment							
	C-G	**C**	**2CO-G**	**2CO**	**CO-G**	**CO**	**O-G**	**O**
	559.12	893.28	1098.96	1106.76	1859.04	1088.4	2078.78	2293.08
	1563.60	1239.92	1648.56	788.40	1802.36	1484.04	3540.48	1688.32
	984.08	901.92	1973.72	1261.08	2318.08	442.52	2915.28	1114.40
$\bar{x}$	1035.6	1011.71	1573.74	1052.08	1993.16	1004.99	2844.85	1698.60

Table 3. The significance of differences in fresh weed biomass (g/m^2) in different variants of the experiment (t-test)

Variant of experiment	**2CO-G**	**2CO**	**CO-G**	**CO**	**O-G**
C-G	0.04*		0.04*		0.02*
C	0.00**		0.00**		0.01*
2CO-G		0.01*		0.04*	
2CO			0.01*		0.01*
CO-G				0.04*	
CO					0.02*

Legend: (**p< 0.01; *p< 0.05)

Weeds as bioindicators

For the purpose of ecological analysis, weed plants developed in carrot and onion crops were used as bioindicators. Namely, due to the small area (2.4 m^2), all plots with the application of corn gluten were taken as one variant -

carrots and onions with gluten were marked with CO-G, and the other plots without corn gluten, were marked with CO, as another variant in ecological analysis (Tab. 1). In order to obtain more precise data for each ecological index, the average number of individuals of each weed species on each variant of the experiment was also taken into account (Tab. 4).

In organic agriculture, one strives to find an appropriate balance between cultivated plants and weeds, looking for the positive effects of their inevitable presence. In addition to the positive impact of weeds on overall biodiversity (Rembiałkowska, 2017) and on pollinating insects (pollinators) as well as on predators, whose presence and abundance improve natural pest control (Kolling, 2010), their role as bioindicators is useful, too. Namely, on the basis of their requirements towards the basic ecological factors, expressed through ecological indices, a solid ecological assessment of the characteristics of the habitat, i.e., of the analyzed locality is possible (Kojić et al., 1994). This type of analysis was also conduced in this paper.

Table 4. Ecological analysis of weed flora

	Ecological Index	Values of ecol. index	No. of species/No. of ind. CO-G	%	$\bar{x}$	No. of species/No. of ind. CO	%	$\bar{x}$
Climate indicators	**T** $\bar{x}$=4	3	3/55	20	**3.9**	4/20	9	**4.2**
		3.5	8/75	26		7/56	26	
		4	7/66	23		7/34	16	
		4.5	2/2	1		1/3	1	
		5	3/83	30		4/100	47	
	K $\bar{x}$=2.7	2	3/86	31	**2.8**	5/106	50	**2.6**
		3	13/172	61		13/90	42	
		4	7/23	8		5/17	8	
	L $\bar{x}$=4	3	3/5	2	**4**	1/5	2	**4**
		4	20/276	98		22/208	98	
Soil indicators	**F** $\bar{x}$=2.6	2	7/130	46	**2.6**	7/100	47	**2.5**
		2.5	4/16	6		3/27	13	
		3	8/92	33		9/72	34	
		3.5	4/43	15		4/14	6	
	R $\bar{x}$=3.3	3	13/200	71	**3.3**	14/153	72	**3.3**
		4	10/81	29		9/60	28	
	N $\bar{x}$=4	3	4/8	3	**4**	3/5	2	**4**
		4	18/269	96		18/203	95	
		5	1/4	1		2/5	2	
	H $\bar{x}$=3	3	22/263	94	**3**	22/209	98	**3**
		4	1/18	6		1/4	2	
	D $\bar{x}$=2.8	1	7/49	17	**2.7**	6/27	13	**2.8**
		3	15/214	76		16/182	85	
		4	1/18	6		1/4	2	
	S	s	9/112	40	-	9/116	54	-
		-	14/169	60		15/97	46	
	m	m	12/128	46	-	13/87	41	-
		-	11/153	54		21/126	59	

Climate indicators

Temperature (T). Analyzing the values of the ecological index for temperature shows that on both variants of the sample the most represented species are indicators of very warm colline characterized by index T5 (CO-G 30%; CO 47%), followed by indicators of lower montane and upper colline, T3.5 (CO-G and CO 26%) and colline, T4 (CO-G 23%; CO 16%). In addition, on the variants with gluten, 20% of the indicators of montane (moderately warm habitats) marked with the index T3 are represented. Favorable temperature conditions of the habitat are also indicated by the mean values of this index on both test variants and slightly more thermophilic species were more present on the variants without gluten intake, where the mean value of this index was 4.2 (Tab. 4). The obtained values are slightly higher than the temperature index values recorded by Ljevnaić-Mašić et al. (2012) in organic carrot crop (T-4) and Džigurski et al. (2013) in organic onion crop (T-4.1).

Continentality (K). This ecological index indicates the degree of adaptation of certain plant species to the climatic conditions of the given area, i.e. characterizes the occurrence of a species with respect to the continentality of the climate, i.e. solar radiation, winter temperature and air humidity (Landolt, 2010). By analyzing this ecological index, it is noticeable that on the variant with gluten, the most numerous indicators are ones for suboceanic to subcontinental climate with as much as 61%, marked with index K3, and indicators of suboceanic climate (K2) are represented with 31%. On gluten-free variants, there are slightly more suboceanic climate indicators (K2 - 50%) in addition to a significant share of suboceanic and subcontinental climate indicators (K3 - 42%). On both variants of the research, indicators of subcontinental climate (K4) are less represented with a share of 8% (Tab. 4). Additionally, the average values of the index for continentality (2.8 CO-G; 2.6 CO) indicate that slightly continental conditions (suboceanic and subcontinental) prevail in the investigated locality, which is in accordance with the general climatic characteristics of the region of Serbia, which belongs to the zone of moderate continental climate, with pronounced local specificities (Lalić et al., 2021). According to this are the average values of temperature and total amount of precipitation in the researched area stated by Šeremešić et al. (2018).
Light (L). Index L4 marks indicators of well lit places, i.e. the places where the plant tolerates light shade only occasionally or for short periods marked. These indicators absolutely dominate in terms of their abundance in both sample variants (98%). The participation (2%) of the semi-shade indicator marked with the L3 index is insignificant. Finally, the average value of the brightness index ($L_{\bar{x}}$ - 4) indicates a well-lit habitat, with a favorable light regime (Tab. 4).
As stated by Landolt (2010), these three ecological indices (T, K, L) certainly interact and depend on each other, i.e., a well-lit places will have a favorable temperature regime, which is in accordance with milder climatic conditions, which favor the cultivation of carrots and onions (Lazić et al., 1993; Đurovka, 2008).

Soil indicators

Moisture (F). Analyzing the ecological index of moisture (Tab. 4), it can be concluded that the indicators of moderately dry habitat, marked by the F2 index, are almost equally represented in both samples (46% CO-G and 47% CO), as well as indicators of moderately moist soil marked with F3 (33% CO-G and 34% CO). On the gluten variants, moist soil indicators (F3.5) are represented with 15%, while on the gluten-free variants, fresh soil indicators (F2.5) are represented with 13%. Relatively drier conditions on the researched area are also indicated by the average value of this index for both variants in the amount of 2.6 (CO-G) and 2.5 (CO). The obtained values are in accordance with the values of the index ($F_{\bar{x}}$ - 2.55) recorded by Ljevnaić-Mašić et al. (2012) in the carrot crop, while Džigurski et al. (2013) in the onion crop, recorded slightly drier conditions ($F_{\bar{x}}$ - 2.31).
Reaction (R). Analyzing the ecological index of soil pH, indicators of weakly acid to weakly neutral conditions (R3) are dominant and evenly represented on both variants (71% CO-G and 72% CO). Almost one third of the weedy plants characterized by the R4 index, on both variants (29% CO-G; 28% CO), indicate neutral or alkaline soil conditions (Tab. 4). According to the abovementioned, the average values of the ecological index of the chemical reaction in the amount of 3.3 indicate favorable soil pH values, which also confirm the results of the soil analysis according to Šeremešić et al. (2018).
Nutrients (N). Indicators of fertile soil rich in nutrients (N4), especially nitrogen compounds, are absolutely dominant in their abundance, represented by 96% and 95%, on variants with and without gluten, respectively (Tab. 4). The average value of this ecological index indicates fertile soil, confirmed by chemical analyzes of the soil (Šeremešić et al., 2018), which indicate a relatively favorable supply of the soil with basic nutrients (N, P and K). Considering the almost equal percentage participation of the fertile soil indicator in both variants, it can be concluded that the applied gluten in the amount of 300 g/m^2 did not have a significant fertilization effect in these experimental conditions.
Humus (H). In terms of humus content (Tab. 4), indicators of moderate humus content (H3) dominate in the studied locality – with gluten 94% and without gluten 98%. Only one present species (*Matricaria inodora*) is an indicator of increased humus content (Knežević, 1994), marked with an index (H4), which had a 6% higher abundance on variants with gluten. Additionally, the average value of the ecological index for humus content ($H_{\bar{x}}$ - 3) confirms the fact that the soil is moderately provided with humus, which is in accordance with soil analyzes (Šeremešić et al., 2018).
Aeration (D). Regading soil aeration, the most common are indicators of moderately aerated soil marked with index D3 (76% CO-G and 85% CO). Indicators of bad aerated (compacted) soil with index D1 (17% CO-G and 13% CO) are significantly less present. Likewise, the mean values of the airiness index (2.7 CO-G and 2.8 CO) indicate a moderately aerated soil (Tab. 4). The values of this index indicate lighter soils that are favorable for the development of carrots and onions (Đurovka, 2008).

Salt tolerance (S). The obtained results showed that on the gluten-free variants, the indicators that tolerate increased level of Na+ ions in the soil are somewhat more dominant with 54%. Likewise, the variants with gluten have the significant percentage (40%) of indicators that tolerate the salinity of the substrate (Tab. 4). This significant participation of indicators tolerant to the elevated level of soil salinity on both variants of the experiment indicates soil with a slightly higher level of Na+ ions in places, which can be related to the earlier application of manure on these plots.

Heavy metal tolerance (M). Despite the larger share of weed individuals that do not tolerate heavy metals in the soil (54% CO-G and 59% CO), the presence of indicators that tolerate heavy metals in the soil should not be ignored either (46% CO-G and 41% CO) (Tab. 4). This information does not indicate the presence of heavy metals in the soil, but it may indicate the need for additional soil analyzes that would exclude suspicion and remove these indications.

CONCLUSION

Based on the overall analysis of the average values of bioindicator values, of all present weed species (T4 K2,7 L4 F2,6 R3,3 N4 H3 D2,8), it can be concluded that they are in accordance with the requirements and needs of cultivated plants, carrots (T4 K3 L4 F2,5 R4 N2 H3 D3 s m) and onions (T5 K3 L4 F2,5 R4 N4 H3 D3). Additionally, this shows the excellent adaptability of the weed synusia to the ecological conditions required by cultivated plants.

The most favourable variant of the experiment in terms of biomass and number of weeds was the carrot and onion intercropping without the use of corn gluten, which makes this principle of growing carrot and onion applicable in different localities wherever conditions of temperate continental climate are present.

In addition to this, in order to achieve better yields, the possibility of applying corn gluten as a bioherbicide should not be rejected. However, the research should be continued in the direction of finding the appropriate concentration and the most favourable time of its application in a certain crop, depending on the phenological phase of the crop, as well as on given agroecological conditions, which would contribute to the development of eco-friendly weed management.

Acknowledgements**:** This work was conducted in the course of Project No: 451-03-47/2023-01/200117.

Conflict of interest: The authors declare that they have no conflict of interest.

REFERENCES

Bàrberi P. (2002): Weed management in organic agriculture: are we addressing the right issues? *Weed Research*, 42: 177-193.

Baumann D.T., Kropff M.J., Bastiaans L. (2000): Intercropping leeks to suppress weeds. *Weed Research*, 40: 361-376.

Berenji J., Milenković S., Kalentić M., Stefanović E. (2013): Nacionalna istraživačka agenda za sektor organske proizvodnje. Beograd: Deutsche Gesellschaft für Internationale Zusammenarbeiten (GIZ) GmbH: ACCESS – program za razvoj privatnog sektora u Srbiji, 1-31.

Betencourt E., Duputel M., Colomb B., Desclaux D., Hinsinger P. (2012): Intercropping promotes the ability of durum wheat and chickpea to increase rhizosphere phosphorus availability in a low P soil. *Soil Biology & Biochemistry*, 46: 181-190. https://doi.org/10.1016/j.soilbio.2011.11.015

Bingaman B. & Christians N. (1995): Greenhouse Screening of Corn Gluten Meal as a Natural Control Product for Broadleaf and Grass Weeds. *HortiScience*, 30(6): 1256-1259.

Bond W. & Grundy A.C. (2001): Non-chemical weed management in organic farming systems. *Weed Research*, 41: 383-405.

CABI - Centre for Agriculture and Bioscience International - Invasive Species Compendium. Available at: https://www.cabidigitallibrary.org/product/qi (accessed 15.11.2022.)

Christians N.E. (1993): The use of corn gluten meal as a natural preemergence weed control in turf. *International Turfgrass Society Research Journal*, 7: 284-290.

DAISIE - Inventory of alien invasive species in Europe. Version 1.7. Research Institute for Nature and Forest (INBO). Checklist dataset. Available at: https://doi.org/10.15468/ybwd3x (accessed 15.11.2022.)

Dayan E.F., Cantrell L.C., Duke O.S. (2009): Natural products in crop protection. *Bioorganic & Medicinal Chemistry*, 17: 4022-4034. https://doi.org/10.1016/j.bmc.2009.01.046

Deveikyte I., Kadziuliene Z., Sarunaite L. (2009): Weed suppression ability of spring cereal crops and peas in pure and mixed stands. *Agronomy Research*, 7(Special iss. I): 239-244.

Dolijanović Ž., Kovačević D., Oljača S., Simić M. (2009): Types of interactions in intercropping of maize and soya bean. *Journal of Agricultural Sciences*, 54(3): 179-187. https://doi.org/10.2298/JAS0903179D

Džigurski D., Nikolić Lj., Ljevnaić-Mašić B. (2013): Weed flora in organic onion production - *Allium cepa* L. (Alliaceae Borkhausen 1797, Amaryllidales). *Journal on Processing and Energy in Agriculture*, 17(3): 130-133.

Đurovka M. (2008): *Gajenje povrća na otvorenom polju*. Poljoprivredni fakultet, Univerzitet u Novom Sadu.
EASIN - European Alien Species Information Network. Available at: https://easin.jrc.ec.europa.eu/spexplorer/search/searchpaged (accessed 15.11.2022)
Hassannejad S. & Navid S. (2013): Correlation between weeds and crops. *International Journal of Biosciences*, 3(5): 117-124.
Jančić R. & Stojanović D. (2008): *Ekonomska botanika*. Zavod za udžbenike, Beograd.
Josifović M. (ed.) (1970-1986): *Flora Republike Srbije* I-IX. SANU, Beograd.
Knežević A. (1994): Monografija flore vaskularnih biljaka na slatinama u regionu Banata (Jugoslavija). Matica srpska, Odeljenje za prirodne nauke, Novi Sad.
Kojić M., Popović R., Karadžić B. (1994): *Fitoindikatori i njihov značaj u proceni ekoloških uslova staništa*. Nauka: Institut za istraživanja u poljoprivredi Srbija.
Kölling A. (ed.) (2010): Organic food and farming. A system approach to meet the sustainability challenge. IFOAM EU GROUP, 1-24. Available at: https://www.organicseurope.bio/content/uploads/2021/02/ifoameu_policy_system_approach_dossier_2010.pdf?dd (accessed 21.06.2021.)
Lalić B., Ejcinger J., Dalamarta A., Orlandini S., Firanj Sremac A., Paher B. (2021): *Meteorologija i klimatologija za agronome*. University of Novi Sad, Faculty of Agriculture, Novi Sad.
Landolt E. (ed.) (2010): *Flora indicativa – Ecological Indicator Values and Biological Attributes of the Flora of Switzerland and the Alps*. Haupt Verlag, Bern-Stuttgart-Wien.
Lazić B., Đurovka M., Marković V. (1993): *Povrtarstvo*. Univerzitet u Novom Sadu, Poljoprivredni fakultet.
Lazić B. (2014a): Čudesan svet organske poljoprivrede. In: Čudesan svet organske poljoprivrede, Lazić, B (ed.), Zelena mreža Vojvodine, Novi Sad, 11-26.
Lazić S. (2014b). Pesticidi u prirodi. In: Čudesan svet organske poljoprivrede, Lazić, B (ed.), Zelena mreža Vojvodine, Novi Sad, 41-50.
Leja M., Kamińska I., Kramer M., Maksylewicz-Kaul A., Kammerer D., Carle R. (2013): The content of phenolic compounds and radical scavenging activity varies with carrot origin and root color. *Plant Foods for Human Nutrition*, 68(2): 163-170. https://doi.org/10.1007/s11130-013-0351-3
Liebman M. & Davis A.S. (2000): Integration of soil, crop and weed management in low-external-input farming systems. *Weed Research*, 40: 27-47. https://doi.org/10.1046/j.1365-3180.2000.00164.x
Lundkvist A., Salomonsson L., Karlsson L., Dock Gustavsson, A-M. (2008): Effects of organic farming on weed flora composition in a long term perspective. *European Journal of Agronomy*, 28: 570-578. https://doi.org/10.1016/j.eja.2008.01.001
Ljevnaić-Mašić B., Nikolić Lj., Džigurski D. (2012): Korovska flora u organskoj proizvodnji šargarepe – *Daucus carota* L. (Apiaceae, Araliales). *Acta herbologica*, 21(1): 41-50.
Nikolić Lj., Šeremešić S., Subašić A., Vasiljević M. (2018): Zakorovljenost združenih i čistih organskih useva šargarepe (*Daucus carota* L., Apiaceae, Apiales) i crnog luka (*Allium cepa* L., Alliaceae, Amaryllidales) uz upotrebu kukuruznog glutena. *Acta herbologica*, 27(1): 45-53. doi:10.5937/ActaHerb1801045N
Rembiałkowska E. (2017): Organic production can increase biodiversity of rural landscape and human nutrition. 3rd Intenational Conference Agrobiodiversity "Organic agriculture for agrobiodiversity preservation", Book of abstract, 1.-3. Jun, 2017, Faculty of Agriculture Novi Sad, University of Novi Sad, Serbia, pp. 10.
Ren L., Su S., Yang X., Xu Y., Huang Q., Shen Q. (2008): Intercropping with aerobic rice suppressed Fusarium wilt in watermelon. *Soil Biology and Biochemistry*, 40(3): 834-844.
Rodney St.J. & DeMuro N. (2013): Efficacy of corn gluten meal for common dandelion and smooth crabgrass control compared to nitrogen fertilizers. *Applied Turfgrass Research*, 10. https://doi.org/10.1094/ATS-2013-0426-01-RS
Stojanović V. & Jovanović V. (2018): The survey of invasive and potentially invasive plant species in Serbia and neighbouring countries for the purpose of determining their status at the national level. *Nature Conservation*, 68(1-2): 41-59. https://doi:10.5937/ZasPri1802041S
Szumigalski A. & Van Acker R. (2005): Weed suppression and crop production in annual intercrops. *Weed Science*, 53(6): 813-825. https://doi.org/10.1614/WS-05-014R.1
Šeremešić S., Manojlović M., Ilin Ž., Vasić M., Gvozdanović-Varga J., Subašić A., Vojnov B. (2018): Effects of intercropping on the morphological and nutritional properties of carrots and onions in organic agriculture. *Journal on Processing & Energy in Agriculture*, 22(2): 80-84. https://doi:10.5937/JPEA1802080S
Tutin G., Heywood V.H., Burges N.A., Valentine D.H., Walters S.M., Webb D.A. (eds.) (1964-1980): *Flora Europea*, 1-5, University press, Cambridge, UK.
Vasić M., Šeremešić S., Marinković J., Toman M., Babec B., Gvozdenović-Varga J., Milošev D. (2017): The efficiency of maize and beans intercropping in sustainable agricultural systems. 3rd Intenational Conference Agrobiodiversity "Organic agriculture for agrobiodiversity preservation", Book of abstract, Faculty of Agriculture Novi Sad, University of Novi Sad, Serbia, pp. 65.
Vrbničanin S. & Božić D. (2021): *Korovi*. Univerzitet u Beogradu, Poljoprivredni fakultet.
Zhang G., Yang Z., Dong S. (2011): Interspecific competitiveness affects the total biomass yield in an alfalfa and corn intercropping system. *Field Crops Research*, 124(1): 66-73. https://doi.org/10.1016/j.fcr.2011.06.006