Biblid: 1821-4487 (2018) 22; 2; p 80-84
UDK: 582.573.16

Original Scientific Paper
Originalni naučni rad

EFFECT OF INTERCROPPING ON THE MORPHOLOGICAL AND NUTRITIONAL PROPERTIES OF CARROTS AND ONIONS IN ORGANIC AGRICULTURE

EFIKASNOST ZDRUŽIVANJA MRKVE I CRNOG LUKA NA NJIHOVA MORFOLOŠKA I NUTRITIVNA SVOJSTVA

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ABSTRACT

A trial involving intercropped and pure stands of carrots 'Nantes' and onions 'Kupusinski jabučar' was conducted on a certified organic farm in Futog. The yield, morphological and nutritional properties of the crops analyzed were determined in the study. Furthermore, the biological efficiency of intercropping was assessed using the relative yield (RYT) and the land use efficiency index (LER). The mixture of crops had influenced the morphological properties examined. In both experimental plant species, the nutritional properties of onions and carrots exhibited a higher content of dry matter (DM) in the double-row growing system without maize gluten meal (onions - 11.42 %, carrots - 10.45 %) compared to single crops. The highest content of β-carotene was determined by alternating single rows of onions and carrots in a plot without the use of gluten (68.94 μg/g DM). The relative yield and the land use efficiency index have shown that there is a biological efficiency of combining carrots and onion as the values obtained are higher than 1. Carrots and black onions are favorable for intercropping because they are complementary, thus interactively contribute to increasing the yield per unit area and improving the nutritional properties.

Key words: *intercropping, carrot, onion, efficiency index, dry matter, β carotene*

REZIME

Ogled sa združenim i čistim usevima mrkve i crnog luka izveden je na organskoj parceli u Futogu. Određen je prinos sveže mase lukovica i svežeg korena mrkve, utvrđena su morfološka i nutritivna svojstva, a ispitivanjem je ocenjena biološka efikasnost združivanja numeričkim pokazateljima: relativni prinos (RYT) i indeks efikasnosti korišćenja zemljišta (LER). Združivanje useva statistički je značajno uticalo na ispitivana svojstva (masa lukovice, masa korena mrkve, udeo korena mrkve, dužina i broj listova mrkve). U ispitivanju nutritivnih svojstava kod crnog luka i mrkve, veći sadržaj suve materije (SM) kod obe proučavane biljne vrste ustanovljen je u dvoredom združenom usevu bez primene glutena (crni luk - 11,42%; mrkva - 10,45%) u poređenju sa čistim usevima. Najveći sadržaj β-karotena utvrđen je kod naizmeničnog združenog useva sa crnim lukom na parceli bez primene glutena (68,94 μg/g SM). RYT i LER su pokazali da postoji biološka efikasnost združivanja mrkve i crnog luka, jer su dobijene vrednosti > 1. Mrkva i crni luk predstavljaju pravilan izbor useva za zdurživanje jer su komplementarni i doprinose povećanju prinosa po jedinici površine i poboljšanju nutritivnih svojstava.

Ključne reči: *združivanje useva, mrkva, crni luk, indeksi efikasnosti, suva materija, beta karoten.*

INTRODUCTION

Organic production represents one of the most important sustainable agriculture systems, wherein higher nutritional values of food could be achieved alongside the preservation of biodiversity and agroecosystems (*Šeremešić et al. 2017*). An increasing demand for the safe food production has raised awareness of finding new solutions that will improve the organic system of vegetable production, create complementary relationships with the neighboring ecosystems, as well as preserve the environment. In the organic system of vegetable production, in addition to the proper selection of varieties / hybrids and crop rotation, intercropping could play an important role (*Ugrinović et al., 2014*). Companion crops create a part of the ecological and horticultural arrangement in the field called "Farmscaping", comprising vegetable crops, floral species, spice plants and medical plants in a crop combination (*Lazić and Šeremešić, 2010*). The cultivation of certain varieties in the intercropping systems leads to numerous positive effects (*Eskandari, 2012*) such as controlled plant growth, increased biomass production and yield (*Zhang et al., 2011*), better utilization of resources (*Betencourt et al., 2012*), reduced disease infestation (*Ren et al., 2008*) and decreased number of pests and weeds (*Dolijanović et al., 2008*). Due to the above-mentioned characteristics, the intercropping approach to vegetable production is of increasing importance and central interest to a large number of scientists in the field of agriculture and ecology (*Brooker et al., 2015*). Nevertheless, researchers mostly investigate the advantages of intercropping based on favorable biological relationships between crops and differences in exploiting available growth resources (*Kadžiulienė et al, 2011*). In addition to the most common intercropping species in the world (namely maize and beans), there are several combinations of crops that could be considered a viable option relative to the agroecological conditions in Serbia: carrots and onions, lettuces and onions (*Lazić et al, 2014*), as well as beans and radishes (*Ugrinović, 2015*). According to *Novaković et al. (2012)*, the areas devoted to onions in Serbia have been diminishing since the beginning of the 21st century, whereas a slight increase has been recorded in the areas devoted to carrots. The carrot (*Daucus carota*) belongs to a group of root vegetables. This group includes a large number of vegetable species that have morphological similarities, thus requiring similar cultural practices (*Ilin et al, 2004*). The carrot is considered one of the most important vegetables. It is grown for its enlarged root characterized by both nutritional and therapeutic properties (particularly rich in vitamin A) (*Bajkin et. al., 2014*). The intercropping of carrots and onions is considered relatively widespread on small family organic farms. However, the intercropping of carrots and onions in wider areas requires the following considerations: combined sowing, weed control, fertilization and harvest. Both vegetables are regarded as plants with a high content of essential oils, and their interaction is based on biochemical effects. It is believed that the aromatic substances and root exudates of carrots deter the onion fly (*Delia antique*), whereas onions could prevent the appearance of the carrot rust fly (*Chamaepsila rosae*) (*Lazić, 2008*). Furthermore, *Kocić-Tanackov et al. (2013)* argued the inhibitory effect of onion essential oils on microbial activity. A mixed cropping of carrots and onions (in two to four rows) is possible in the open field production because both species have small seeds, long periods of sprouting, and parallel times of vegetation (early spring) (*Cox, 1994*). The positive results of carrots and onions cultivation as companion crops is widespread and common on a small scale, but it is difficult to replicate those experiences on a larger scale. The purpose of this paper is to assess the efficiency of carrot and onion intercropping, and to investigate which of the combining methods used has a positive effect on the productivity and quality of selected plant species in the organic growing system.

MATERIAL AND METHOD

The trial was set up on a certified organic farm in Futog (Republic Serbia). For the purpose of the experiment, the seeds were obtained from the Institute of Field and Vegetable Crops, Novi Sad (carrot cultivar ‘Nantes’ and onion cultivar ‘Kupusinski jabucar’). Both species were simultaneously sown at a depth of 3 cm with an intra-row spacing of 5 cm and an inter-row spacing of 20 cm on 17th March, whereas both crops were harvested on 13th August. The preceding crop was soybean. The sowing was carried out in four-sided strips, 12 m long, with 2 protective lines on the side (40 cm). The size of the experimental plot was 120 cm x 200 cm and the unit for sampling was 2.2 m^2. The experimental intercropped and single crop stands

were treated with corn gluten meal (G) at a rate of 300 g m^2, whereas the control intercropped and single crop stands were not. Carrots and onions were sown as combined crops and a single crop in the following model: (i) **c** – carrot pure stand; (ii) **coco** – carrot + onion + carrot + onion in single rows, (iii) **ccoo** - carrot + carrot + onion + onion in double rows, and (iv) **o** – onion pure stand.

The vegetables analyses were performed at the Laboratory of the Agroecology, the Faculty of Agriculture in Novi Sad. Masses of fresh bulbs and fresh carrot roots were determined using the square method in three replicates. Morphological properties were determined on randomly sampled 10 plants per repetition. The following morphological properties were determined: onion bulb mass and bulb index, as well as the number and length of carrot leaves, carrot root mass and carrot periderm share. The following quality parameters were assessed: the dry matter content of both species and the content of β carotene in carrots. The dry matter (DM) determination in the carrots and onions analyzed was performed using a refractometer at the Faculty of Technology in Novi Sad. DM was determined by drying the samples at 103 ± 0.5 °C in a dryer to a constant mass. Calculations were done using the following equation:

$$x = \frac{\mathrm{M2} - \mathrm{M0}}{\mathrm{M1} - \mathrm{M0}} \cdot 100$$

M0 – mass the container (g)
M1 – mass of the container before drying (g)
M2 – mass of the container after drying

The content of β carotene was determined using column chromatography. The content of β carotene in the samples was determined in several stages. First, all carotenoids were extracted from the sample, and then the amount of β carotene from the extract was eluted using adsorption chromatography. The solution obtained was dissolved in a suitable solvent, and the maximum absorbance of the solution was determined (448 nm) (*Vračar, 2001*). The content of the β carotene (X) was determined according to the following equation**:**

$$\mathrm{X} = \frac{\mathrm{Amax} \cdot 10^8}{A_{1\%}^{lcm} \cdot \mathrm{l} \cdot \mathrm{m} \cdot DM} = \frac{\mathrm{Amax} \cdot 10^8}{2500 \cdot \mathrm{l} \cdot \mathrm{m} \cdot DM}$$

X - content of beta carotene (μg /g DM); $\mathbf{A^{1cm}_{1\%}}$ - specific (extraction) absorption coefficient for β carotene = 2500; **A max**- absorbency read on the spectrophotometer; **l** - width of the cuvette (cm); **m** - mass of the sample (g); **DM** – dry matter (%).

The biological effectiveness of intercropping was determined by examining the relative total yield (RYT) and RYT = DMYab/DMYaa + DMYba/DMYbb

DM – dry matter of sample, **ab** – performance of onions (a) mixed with carrots (b), **ba** – performance of carrots (b) mixed with onions (a), **aa** – onion as single crop, and **bb** – carrots in pure stands.

the land equivalent ratio (LER):

$$LER = (\frac{x_i}{x_j}) + (\frac{y_i}{y_j})$$

$\mathbf{X_i}$ – yield i-species per unit of area in intercropping;
$\mathbf{X_j}$ – yield j-species per unit of area in a pure stand
$\mathbf{Y_i}$ – yield i-species per unit of area in intercropping;
$\mathbf{Y_j}$ – yield j-species per unit of area in a pure stand

For the purpose of the research, the values of meteorological indicators were obtained from the Department for Alternative Crops of the Institute of Field and Vegetable Crops in Novi Sad (45°33' N; 19°67' E) (Figure 1). By analyzing the soil on which the experiment was established, the agrochemical properties of the soil were determined (Table 1). These properties exhibited no significant impediments to vegetable production.

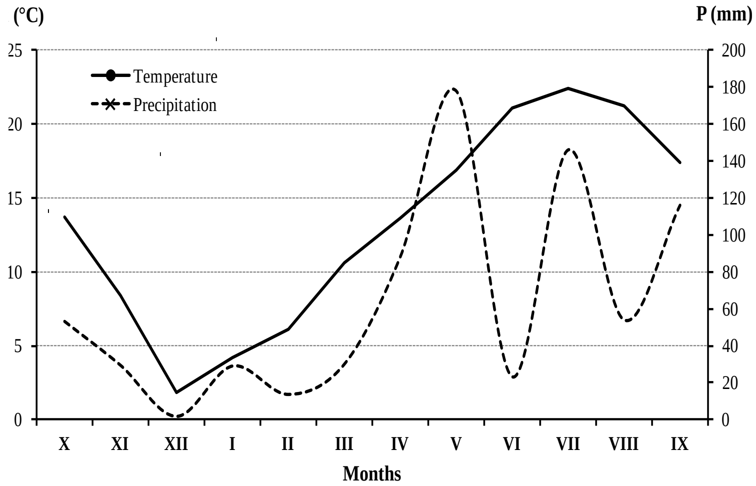

Fig. 1. Temperature and precipitation at the experimental site

Table 1. Soil agrochemical properties

Depth (cm)	pH		$CaCo_3$ (%)	Humus (%)	Total N (%)	Al-P_2O_5 (mg/100g)	Al-K_2O (mg/100g)
	KCl	H_2O					
0-30	7.26	8.07	4.95	2.48	0.18	13.4	31.8

The data obtained were statistically analyzed using the analysis of variance (ANOVA). The Fisher's LSD test was used to compare the means of the parameters examined at $p < 0.05$ level of significance. All the calculations were done using the software system STATISTICA 12.6, StatSoft, Inc.

RESULTS AND DISCUSSION

The analyses of climatic conditions showed that the above average precipitation in May and July affected the growth of onions and carrots, as well as the morphological properties examined (Figure 1). Furthermore, the higher temperatures and lower precipitation in Jun negatively affected the plant growth of the experimental crops and encouraged weeds infestation. According to *Pejić et al., (2011)*, the amount and distribution of precipitation considerably affected the soil water regime and successful vegetable production. The carrot growth was significantly influenced by intercropping. The carrot root mass ranged from 60.35 to 79.33 g per plant (Table 2). Higher values of root mass were obtained in a plot with alternating double rows of onions and carrots and addition of maize gluten (ccooG). Lower values of root mass in single carrots could be attributed to higher weed infestation. Ecological analyses of the weed flora on organic farms showed a wide range of weeds that influence organic crop production (*Džigurski et al. 2012*)

The comparison of carrot pure and intercropped stands showed positive effects of intercropping. This result could be accounted for by the fact that onions do not shade carrot, thier shallow root system does not compete for water and nutrients, and do not deform carrot roots (*Błażewicz-Woźniak and Wach, 2011*). The number of leaves per plant has been affected by intercropping and ranged from 6.78-8.33. A significantly higher number of carrot leaves were observed in a plot with mixed cropping and single crop alternations with onions. It appears that onions provide a favorable environment for the carrot leaf development in mixed cropping compared to the carrot pure stand. Conversely, the carrot leaf lengths proved higher in the carrot pure stand compared to the intercropped stand.

The selected combinations of intercropping and gluten application had no effects on the periderm share in carrots (Table 3). In our study, the dry matter of carrots ranged from 9.42 % to 10.28 %. β carotene is considered an important quality trait in carrots (*Smolen and Sady, 2009*). Higher content of β carotene was found in the intercropped carrot production compared to the single carrot production (66.29 μg /g DM).

The results obtained are consistent with the results of *Sink et al. (2017)*, who examined the organic and integral farming system. According to *Bogdanović et al. (2006)*, the β-carotene content is positively correlated with the application of fertilizers.

The onion is sensitive to germination, and precipitation deficits in March affected the pre-bulb growth stages. The bulb index represents a trait specific for each variety, and thus no significant effects were observed (Gvozdanovic-Varga et al., 1996). The largest bulb mass was measured in a two-row intercrop with gluten (25.87 g), while the smallest bulb mass of 18.59 g was recorded in the control plot (single crop of onion). The applied treatment had significantly influenced the mass of onion bulb (Table 4). Consequently, mixed onion crops exhibited statistically significant advantages compared to single onion crops.

At variance to our results, *Tardan at al., (2006)* and *Kabura et al., (2008)* reported that intercropping onion with carrot reduces the marketable bulb yield. With regard to the restricted management in organic agriculture, i.e. not using fertilization and pesticides, the obtained outcomes of the production were as anticipated. The experimental results demonstrated that the vegetable intercrops were also able to control plant diseases (downy mildew, purple bloch), as reported by *Narla et al. (2011).*

Table 2. Morphological properties of carrots

Crop mixture	Carrot		
	Root mass (g per plant)	Leaf number	Leaf length (cm)
c	64.99±6.73 ab	6.78±0.4c	43.9±2.6a
ccoo	67.79±11.2 a	7.47±0.6bc	43.7±3.7a
coco	70.82±5.11 ab	7.76±03ab	36.7±1.7b
cG	60.35±8.09 b	7.46±0.3bc	46.2±1.7a
ccooG	79.33±1.38a	7.26±0.7bc	43.9±2.4a
cocoG	76.53±16.6 ab	8.33±0.7a	43.5±3.6a
C	62.67±3.2 B	7.17±0.4B	45.07±1.6A
CCOO	73.56±4.0 A	7.37±0.1B	43.84±0.0AB
COCO	73.68±2.0 A	8.05±0.4A	40.01±2.3C

***c** – carrot pure stand; **coco** – single rows carrot + onion; ccoo – double rows carrot + onion; **o** – onion; **G** – corn gluten 300 g m^{-2}; **C** – carrot pure stand average; CCOO –average single rows carrot + onion; COCO – average double rows carrot + onion; ^{Aa}Data followed by the same letter within a column do not differ significantly at the P < 0.05 level;*

Table 3. Morphological properties of carrots

Crop mixture	Carrot		
	Periderm share (%)	DM (%)	β carotene (μg /g DM)
c	56.03±5.0	10.17	60.36
ccoo	57.57±1.9	10.28	64.85
coco	54.77±2.3	9.86	51.52
cG	59.07±1.7	10.45	40.14
ccooG	53.77±2.2	9.45	67.73
cocoG	53.40±2.9	9.42	68.94
C	57.55±2.1	10.31	50.25C
CCOO	55.67±2.6	9.87	66.29A
COCO	54.09±0.9	9.64	60.23AB

c – carrot pure stand; coco – single rows carrot + onion; ccoo – double rows carrot + onion; o- onion; G – corn gluten 300 g m-2; C – carrot pure stand average; CCOO – average single rows carrot + onion; COCO – average double rows carrot + onion; ^{Aa}Data followed by the same letter within a column do not differ significantly at the $P \leq 0.05$ level; ± SD – standard deviation

Table 4. Morphological properties of onions

Crop mixture	Onion		
	Bulb index	Bulb weight (g)	DM (%)
o	1.43±0.02a	18.68±0.8c	10.77
ccoo	1.48±0.00	19.59±2.5 bc	10.18
coco	1.44±0.02	25.87±0.6a	9.86
oG	1.43±0.05	23.77±0.8 ab	11.42
ccooG	1.32±0.06	22.0±1.0 abc	9.46
cocoG	1.48±0.02	22.81±2.5 ab	9.48
O	1.46±0.04	18.64±3.5 C	11.09A
CCOO	1.39±0.09	24.83±1.7 A	9.82B
COCO	1.46±0.02	21.32±2.16 B	9.67B

o – onion pure stand; coco – single rows carrot + onion; ccoo – double rows carrot + onion; o- onion; G – corn gluten 300 g m^{-2}; C – carrot pure stand average; CCOO – average single rows carrot + onion; COCO – average double rows carrot + onion; ^{Aa}Data followed by the same letter within a column do not differ significantly at the $P \leq 0.05$ level; ± SD – standard deviation

The dry matter content in onions ranged from 9.48 % - 11.42 %. The highest content of DM in onions was recorded in the pure stand of onion compared with the intercrop. It appears that intercropping of onions and carrots was more beneficial to carrots. This could be accounted for by the fact that carrots exerted a suppressive effect on onions featuring a faster crop establishment.

The total relative yield (RYT) and land equivalent ratio (LER) were used to measure the efficiency of intercropping. The values of both indicators have shown that there is a biological efficiency of combining carrots and onion since the results obtained are greater than 1 (Table 5 and 6).

Therefore, the RYT and LER values showed that the alternation of single rows of onion and carrot is more efficient than intercropping with double rows. This could be accounted for by the fact that the selected intercropping combinations provide favorable conditions for the growth and development of onions and carrots. The Beneficial effect of intercropping on the LER were also observed in *Amanullah et al. (2016).*

Table 5. Relative total yield of the onion-carrot intercrop

	Carrot		Onion		Σ
	ab	**bb**	**ab**	**aa**	
RYT_1	73,56	62,67	24,82	18,63	**2,5**
RYT_2	73,67	62,67	21,31	18,63	**2,3**

RYT_1-intercroping with single rows
RYT_2- intercropping with double rows

Table 6. Land equivalent ratio of the onion-carrot intercrop

	Carrot		Onion		Σ
	X_i	**Y_i**	**X_j**	**Y_j**	
LER_1	3089	5264	1042	1564	**1,25**
LER_2	3094	5264	895	1564	**1,16**

LER_1-intercroping with single rows
LER_2- intercropping with double rows

CONCLUSIONS

The intercropping of carrots and onions in organic farming increases the biological and resource efficiency. Carrots and onions represent a proper selection for intercropping because they are essentially complementary. In our study, a more beneficial effect of intercropping was observed in carrots compared to onions, particularly in the alternation of crops in single rows. The results obtained could contribute to the development of a suitable system of vegetable growing in organic agriculture, and to a more efficient utilization of available resources.

ACKNOWLEDGMENT: This paper is a part of the project TR 31030 financed by the Ministry of Education and Science of the Republic of Serbia.

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Received: 19. 03. 2018. Accepted: 30. 03. 2018.