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Morphological Characteristics of Some Pepper Genotypes (*Capsicum annuum* L.) Grown in Conventional and Organic Agricultural Systems: Comparative Analysis

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Authors' contributions

This work was carried out in collaboration among listed authors. Author OB planned and carried the field experimental work, performed the results analysis, literature collection and manuscript writing. Author FT participated in planning of the field experimental work, statistical analysis and manuscript preparation. Author LM was responsible for overall planning and supervision of the experiment and participated in manuscript preparation. All authors read and approved the final manuscript.

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ABSTRACT

Long-term research in pepper organic production are scarce in Republic of Macedonia. Plant and fruit morphological traits of important pepper varieties organically produced were compared to pepper produced in conventional systems. Conceivably, this is the first morphological traits comparative study of locally important pepper genotypes (*Capsicum annuum* L.) in Republic of Macedonia in organic and conventional open-field production. The aim of the research is to determine the differences in pepper morphological traits when produced organically in comparison to conventional production. Eight plants and fruits were used for morphological traits determination of plant and fruit in six locally important pepper genotypes (Strumicka Kapija, Strumicka Vezena,

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Piran, Zupska Rana, Duga Bela and Kurtovska Kapija) grown in an organic and conventional production system.

The traits number of branches per plant, fruit width and fruit index were significantly affected by the production manner resulting in less branches per plant, lower fruit width and lower fruit index in organic production. The traits fruit weight, pericarp thickness and fruit flesh percentage, which are the most important for pepper crop yield and utilisation of pepper fruits were not significantly affected by the production practice. Organic production has limited influence on pepper plant and fruit traits, but not in a manner to decrease the production, which generally is the main fear of conversion from conventional to organic production in vegetables. Appropriate selection of pepper varieties with application of suitable cultivation and management practices can contribute to successful organic production resulting in high quality pepper production.

Keywords: *Capsicum annuum L.*; conventional cultivation system; morphological characteristics; organic cultivation system; pepper.

1. INTRODUCTION

In Republic of Macedonia, there are excellent conditions for the development of horticultural production [1]. Because of decades-old tradition, climate and soil advantages, as well as the high and specific product quality, horticultural products from Macedonia have high reputation in the wider region [1]. According to its economic significance, the pepper is one of the leading economic horticultural crops in Republic of Macedonia [2,3]. There is almost no region in Macedonia where pepper is not grown, and in some regions besides favourable agri-ecological conditions, there is also a long tradition of cultivating this culture [3].

Increased interest in organic farming in recent years has encouraged numerous studies that compare different aspects of organic and conventional food production [4-9]. Most of these studies indicate certain advantages of organically produced agricultural products, primarily in terms of the impact of the production process on the environment, as well as in terms of quality properties of products [7-9]. Some studies, while acknowledging the positive organic production impact on the environment, suggest that there is no significant difference between the organic and the conventional production system in terms of qualitative properties, yield, and morphological agricultural products characteristics of agricultural products [10-14]. Apart from the variety or genotype and the climate and soil conditions, morphological characteristics of the pepper are strongly influenced by the agrotechnical measures applied in the production [1-2]. In Republic of Macedonia, methodical and long-term research in vegetable crops organic production, where important morphological and quality traits are compared to crops produced in

conventional systems are scarce. Thus, conceivably this is the first comparative study of morphological traits of locally important pepper genotypes (*Capsicum annuum L.*) in Republic of Macedonia in organic and conventional production.

2. MATERIALS AND METHODS

2.1 Experimental Design and Methodology

The experimental field was established at Kamnik in Skopje, on the organically certified production fields of Kamnik Bio Organic during three successive years.

The open-field experiment was set according to the random block system method in three repetitions in the organic production system and conventional production system for each examined genotype. Each genotype was represented by 15 plants at each repetition, a total of 45 plants from each genotype in the organic production system and a total of 45 plants in the conventional production system.

In the three experimental years, the sowing was carried out in the last week of March, while the seedlings were transplanted on the open field in the last week of May. The open-field experiment was carried out by applying appropriate agrotechnical measures in the organic and conventional production system, using standard agrotechnology for basic-soil and pre-soil preparation of the experimental field. Pre-soil preparation was performed by plowing and rotovating. For protection against high temperatures and direct sunlight, the experimental field was protected by a 30% shade protective net.

During the experiment, plant nutrition was performed twice, during the second half of June and July, respectively and adequately in the organic and conventional production system. Plant nutrition in the organic production system was performed with utilisation of organic fertilizers Tecamin max and Multi bloom applied through the irrigation system, as well as the application of foliar organic fertilizer from sea algae (*Ascophyllum nodosum*) and 12% humic acid. In the conventional production system, foliar plant nutrition with Controlphyt PK (30:20) and NPK (15:15:15) fertilisers were applied in combination with soil fertilisation with NPK magnesium pellets.

A preventive protection spraying of both systems was carried out 15 days after planting. The organic part was treated with fungicide (Copper oxychloride 50, active substance 50% copper of oxychloride copper) and insecticide Neemazal-T/S (active substance Azadiraktin), allowed for use in organic production. The conventional block was preventively treated with fungicide Ridomil Gold MZ pepite (active substance Mankozeb 64% and M-metalaksil 3.88%) and with insecticide Actara 25 WG (active substance Tiametoksam 250 g/kg). Although the experiment was conducted in open-field conditions, no diseases and pests were observed during the whole vegetation period, thus there were no additional sprays with pesticides either in organic or conventional production system.

Since different pepper genotypes were included in the experiment, first and last harvest were performed according to the biological traits of each genotypes, starting from mid of July and finishing during the first week of October.

2.3 Plant Material

Randomly selected, eight plants and eight fruits were used as study material for determination of plant and fruit morphological traits of six locally important pepper genotypes (Strumicka Kapija, Strumicka Vezena, Piran, Zupska Rana, Duga Bela and Kurtovska Kapija) grown in organic and conventional production system.

The plant and fruit morphological traits of genotypes under this research were measured in phase of plants maximum growth according to Descriptors for *Capsicum* (*Capsicum* spp.) [15]:

- **Morphological traits of plants**

- Plant height (cm);

- Number of branches per plant.

- **Morphological traits of fruits**

- Fruit length (cm);
- Fruit width (cm);
- Fruit index (fruit shape) - fruit index is mathematically calculated as a ration between fruit length and fruit width;
- Fruit weight (g);
- Pericarp thickness (mm);
- Fruit flesh percentage (%) - is mathematically calculated as a ratio of the fruit weight from which the stalk and the seeds are removed and the total fruit weight, expressed as a percentage. This property determines the utilization value (kitchen value) of the fruit.

2.2 Statistical Analysis of Data

Statistical analysis of univariate analysis of variance (ANOVA) was used for evaluation and comparison of the organic and conventional production practice on morphological characteristics of the pepper plants and fruits under study with IBM SPSS Statistics Software 19.0 [16].

3. RESULTS AND DISCUSSION

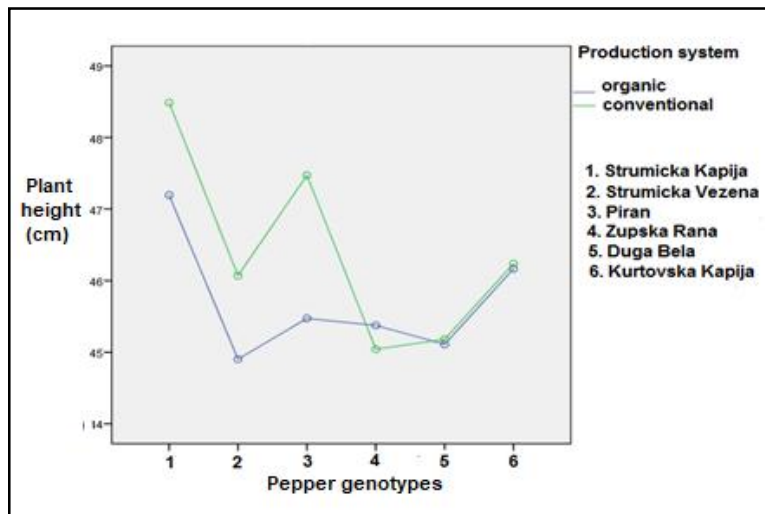
3.1 Morphological Traits of Plants

From all the investigated genotypes, the highest average plant height had the genotype Strumicka Kapija in the conventional system, and the smallest average height of the plants has Strumicka Vezena grown in the organic production system (Table 1).

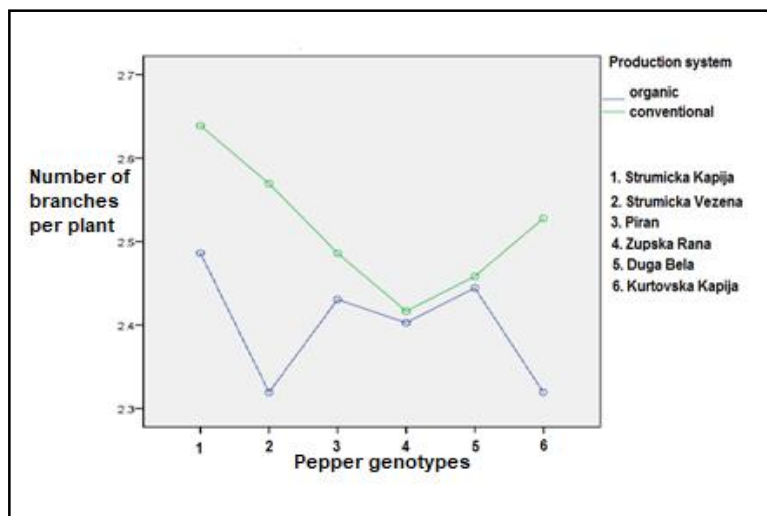
Strumicka Kapija and Zupska Rana genotypes had the highest (48.49 cm) and lowest (45.04) average plant height in conventional production, respectively (Table 1). Strumicka Kapija and Duga Bela had highest (47.19 cm) and smallest (45.11 cm) average plant height in organic production, respectively. In general, in all investigated genotypes, the average value for the number of branches per plant ranges from 2.32 to 2.64 in organic and conventional systems (Table 1). Kurtovska Kapija and Strumicka Vezena shown 2.64 and 2.57, as the highest average value for the number of branches obtained in the conventional production system, while the highest average number of branches per plant in organic production was noted for the genotype Strumicka Kapija (2.49) (Table 1).

Table 1. Mean values for plant height and number of branches of different genotypes in organic and conventional production system

Genotype	Production practice	Plant height (cm)	Number of branches per plant
Strumicka Kapija	organic	47.19±14.00	2.49±0.53
	conventional	48.49±13.59	2.64±0.76
Strumicka Vezena	organic	44.90±11.45	2.32±0.65
	conventional	46.07±11.46	2.57±0.69
Piran	organic	45.47±10.78	2.43±0.55
	conventional	47.47±13.77	2.49±0.56
Zupska Rana	organic	45.37±13.69	2.40±0.64
	conventional	45.04±13.71	2.42±0.62
Duga Bela	organic	45.11±13.96	2.44±0.67
	conventional	45.18±12.22	2.46±0.75
Kurtovska Kapija	organic	46.17±12.56	2.32±0.58
	conventional	46.24±12.21	2.53±0.56



(a)



(b)

Fig. 1. Influence of genotype and production system on a) plant height and b) number of branches per plant from different pepper genotypes

Higher plants were determined in the conventional system for the genotypes Strumicka Kapija, Strumicka Vezena and Piran. In the organic system of cultivation, higher plants were observed only in Zupska Rana, while for the genotypes Duga Bela and Kurtovska Kapija, the cultivation have showed no influence on the plant height (Fig. 1a). A comparative analysis of plant height values in organic and conventional system showed that plants grown in an organic system were shorter for 0.71 cm from conventionally grown pepper genotypes, without a statistically significant difference (Table 2a). The conventional production of all genotypes resulted in higher number of branches per plant compared to the organic production with statistically significant difference (Fig. 2b, Table 2b).

Stevanović 1977 [17] identified a similar average height of the plants and different results for average number of branches per plant, examining 5 varieties and 1 line of peppers (A1-12, P-26, Novosadska bela Babura, Šorokšari, Pobjelšana aleksandrička 59 and Line number 660) grown in a conventional system. The number of branches per plant differs from the average values for number of branches per plant obtained in this experiment, which is certainly due to the variety characteristics. Other researchers [18] reported an average plant height of Piran from 87.61 cm to 93.68, while for the genotypes Kurtovska Kapija the average height of plants was 97.33 [2]. These results differ from the results obtained in this experiment and it is due to the different way of cultivation, in a protected space and in the open, respectively.

3.1 Morphological Traits of Fruits

The longest pepper fruit was measured for Strumicka Vezena (16.99 cm), and the shortest fruit for genotype Strumicka Kapija (10.98 cm), both in the conventional system. In the organic production system, the highest average pepper length was measured for the genotypes Strumicka Vezena (15.23 cm) and the lowest value was observed for Strumicka Kapija (11.31 cm) (Table 3). The analysis of fruit width showed that Kurtovska kapija from the organic production system (5.13 cm), and the smallest fruit width has the genotype Strumicka Vezena produced in the conventional system (2.52 cm) (Table 3). The highest average fruit index was determined in Strumicka Vezena (6.81), while the lowest index of the fruit was registered for Strumicka Kapija (2.30), both from the conventional production

system. In organic production, the highest average fruit index was measured from Strumicka Vezena (5.50), and the lowest index of fruit was obtained in Strumicka Kapija (2.32) (Table 3).

The results of morphological traits fruit weight, pericarp thickness and fruit flesh from organic and conventional production system are presented in Table 4.

In relation to the fruit weight, the highest average value was achieved in Kurtovska Kapija (77.96 g) grown in the organic production system, while the smallest average weight of the fruit was registered in Piran (41.31 g) from the conventional production. In the organic production system, the smallest average fruit weight is found in the Strumicka Vezena genotype (45.35 g), while in the conventional production system the heaviest fruit was registered for Kurtovska kapija (77.35 g). The highest average thickness of the pericarp was measure for Kurtovska Kapija (4.46 mm), while the smallest average thickness of the pericarp in Strumicka Vezena (2.61 mm), both from the organic production system. In the conventional production system, the genotype Kurtovska Kapija was characterized by the highest average value for pericarp thickness (4.11 mm), while Strumicka Vezena had the thinness pericarp (2.86 mm). According to the results obtained for the average value of the fruit flesh, the highest value was observed for Kurtovska Kapija (83.18%) and the lowest average value for Piran (73.52%), both from the conventional production system. In the organic production, the genotype Kurtovska Kapija has the highest percentage of fruit flesh (82.94%), while the lower fruit flesh was determined for Strumicka Vezena (73.91%).

The influence of production system on the fruit length was very small compared to the genotype effect. However, the average length of the fruit in the genotype Strumicka Kapija and Zupska Rana was higher in the organic production. In genotypes of Piran, Duga Bela and Kurtovska Kapija, no influence of production practice on the average length of the fruit was observed and the differences in the fruit average length in these genotypes from the both production systems was very small (Fig. 2a). A comparative analysis of mean values of pepper fruit length grown in the organic and conventional system shows that the fruit of peppers grown in the organic system were shorter for 0.109 cm compared to the fruits of

peppers grown in the conventional system without statistically significant difference (Table 5a).

For the fruit width, a small differences in the average values with the advantage of organic production in all genotypes were found, except for the fruits of the genotype Zupska Rana, where the method of cultivation have not affect the average fruit width (Fig. 2b). Fruits from the organic system were significantly wider for 0.195 cm than the conventional fruits (Table 5b). The

cultivation practice had not impact on the average fruit index for fruits of Strumicka Kapija and the Kurtovska Kapija. In general, the differences of fruit index of other genotypes grown in both systems were very small (Fig. 2c). A comparative analysis of the average fertility index in the various genotypes of peppers grown in the organic and conventional system shows that the fruits of the genotypes in organic production had 0.291 significantly smaller fruit index than fruit of the genotypes in conventional production (Table 5c).

Table 2. Pairwise comparison between a) plant height and cultivation system applied and b) number of branches per plant and cultivation system applied

(A) Cultivation system	(B) Cultivation system	(A-B) Mean difference	Std. error	Significance ^a
a) Plant height				
Organic	Conventional	-0.71	0.87	0.416
b) Number of branches per plant				
Organic	Conventional	-0.116*	0.043	0.007

Based on estimated marginal means.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

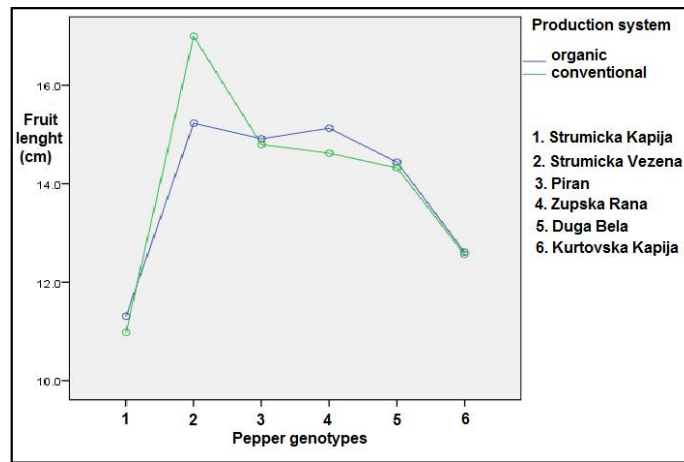
**. The mean difference is significant at the 0.05 level*

Table 3. Mean values for fruit length, fruit width and fruit index of different genotypes in organic and conventional production system

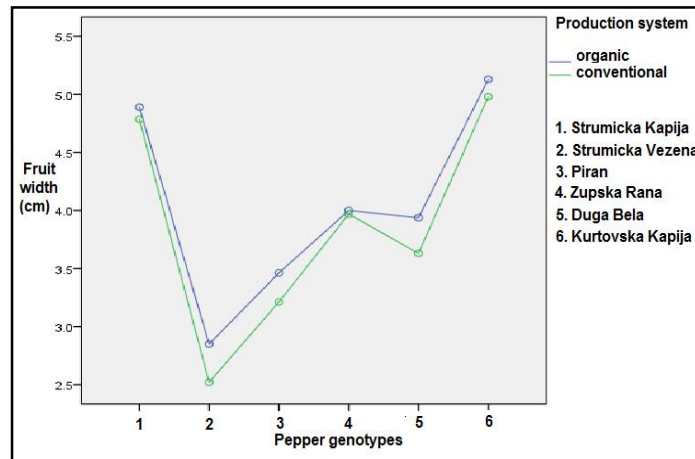
Genotype	Production practice	Fruit length (cm)	Fruit width (cm)	Fruit index
Strumicka Kapija	organic	11.31±1.03	4.89±0.44	2.32±0.19
	conventional	10.98±0.90	4.78±0.40	2.30±0.20
Strumicka Vezena	organic	15.23±1.70	2.85±0.47	5.50±1.20
	conventional	16.99±1.51	2.52±0.29	6.81±0.87
Piran	organic	14.91±1.47	3.46±0.52	4.39±0.73
	conventional	14.80±2.04	3.21±0.43	4.68±0.87
Zupska Rana	organic	15.13±1.51	4.00±0.63	3.84±0.48
	conventional	14.62±1.71	3.97±0.40	3.70±0.47
Duga Bela	organic	14.44±0.99	3.94±0.56	3.73±0.55
	conventional	14.32±1.04	3.63±0.34	3.96±0.32
Kurtovska Kapija	organic	12.61±1.80	5.13±0.47	2.46±0.32
	conventional	12.56±1.36	4.98±0.48	2.53±0.28

Table 4. Mean values for fruit weight, pericarp thickness and fruit flesh of different genotypes in organic and conventional production system

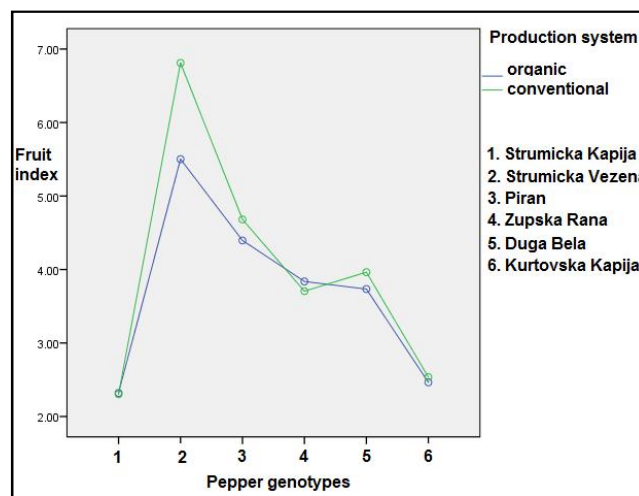
Genotype	Production practice	Fruit weight (g)	Pericarp thickness (mm)	Fruit flesh (%)
Strumicka Kapija	organic	66.98±15.00	4.06±0.55	80.95±3.34
	conventional	62.48±11.60	4.02±0.58	78.45±5.92
Strumicka Vezena	organic	45.35±12.21	2.61±0.46	73.91±8.11
	conventional	47.73±11.76	2.86±0.32	73.90±6.57
Piran	organic	47.83±13.37	3.46±0.62	76.97±7.80
	conventional	41.31±10.49	3.29±0.50	73.52±7.00
Zupska Rana	organic	59.33±17.35	3.65±0.63	80.20±5.97
	conventional	55.02±11.22	3.65±0.60	81.58±4.93
Duga Bela	organic	50.42±7.56	3.59±0.52	79.31±4.11
	conventional	52.77±9.29	3.57±0.63	79.48±3.68
Kurtovska Kapija	organic	77.96±15.97	4.46±0.46	82.94±3.57
	conventional	77.35±16.00	4.11±0.58	83.18±4.27



(a)

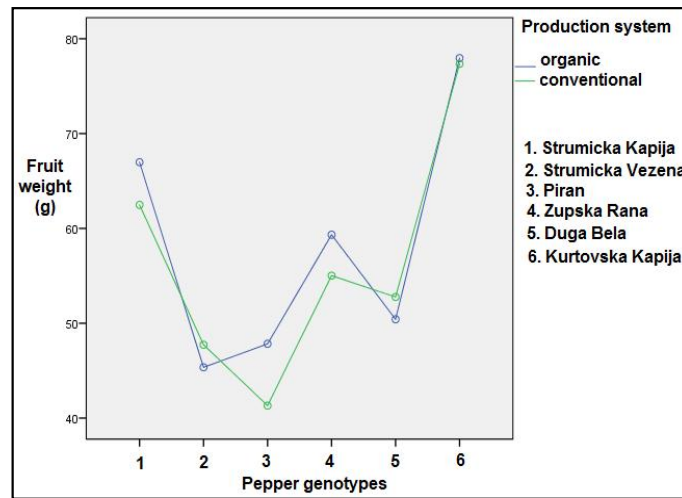


(b)

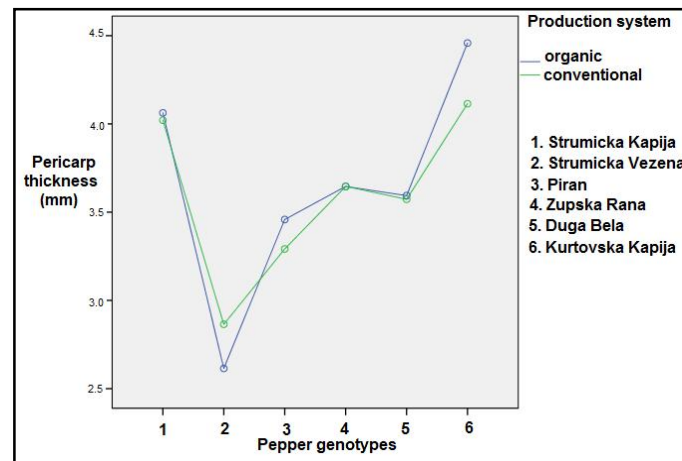


(c)

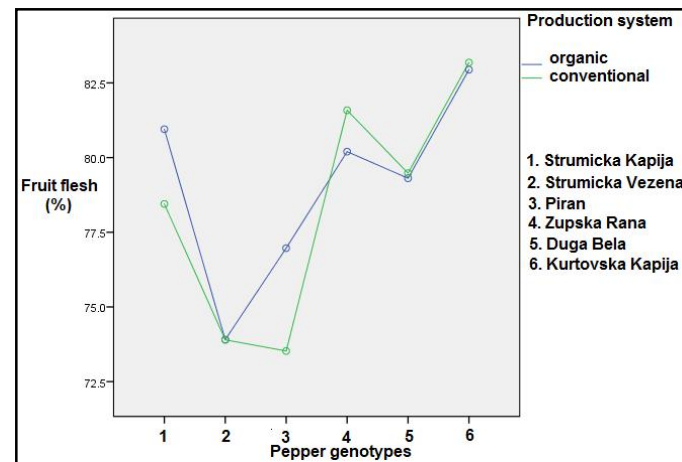
Fig. 2. Influence of genotype and production system on a) fruit length; b) fruit width and c) fruit index of fruits from different pepper genotypes



(a)



(b)



(c)

Fig. 3. Influence of genotype and production system on a) fruit weight; b) pericarp thickness and c) fruit flesh of fruits from different pepper genotypes

There was a higher average fruit weight measured for the fruits of Strumicka Kapija, Piran and Zupska Rana grown in the organic production system, while this trait showed higher average values for fruits of Strumicka Vezena and Duga Bela in the conventional production system. The cultivation practice did not show any influence on the average fruit weight for the genotype Kurtovska Kapija (Fig. 3a). The comparative analysis of the mean fruit weight values of peppers grown in organic and conventional system showed that the genotypes grown in the conventional system have a 1.688 g lower average fruit weight compared to the fruits of genotypes grown in the organic production system (Table 5d).

The analysis of the effect of cultivation practice on pericarp thickness shows that the genotypes Strumicka Kapija, Duga Bela and Zupska Rana have not affect the average thickness of the pericarp at all, while Piran and Kurtovska Kapija in the organic production system have an average thicker pericarp than in the conventional system of production. Only the Strumicka Vezena from the conventional production system had a higher average pericarp thickness compared to the organic production system (Fig. 3b). The fruits of the genotypes grown in the conventional system have 0.054 mm thinner pericarp wall as compared to the fruits of genotypes grown in organic system (Table 5e).

According to the statistical analysis, the organic production system resulted in higher average fruit flesh percentage for Strumicka Kapija and Piran, while for fruits of Zupska Rana, a higher

average value of fruit flesh was found in the conventional system. The cultivation practice had not affected the average value of fruit flash for the genotypes Strumicka Vezena, Duga Bela and Kurtovska Kapija (Fig. 3c). Fruits of the genotypes in the organic production system have 0.7% higher fruit utilization value as compared to the fruits of the genotypes grown in the conventional system (Table 5f).

Unfortunately, there are not many resources and available literature for comparison of pepper morphological traits in organic vs conventional production. Gjorgjievski et al. [19] determined an average 14.0 cm fruit length of the genotype Kurtova Kapija in an immature fruit phase, grown in the conventional open-field production system. The published results for Piran and Kurtovska Kapija grown under conventional conditions are in accordance to our results for length, width and index of fruit, whereas the authors reported a smaller fruit weight as compared to the results of this experiment [18,20-22]. The obtained results of this study are not in correspondence with the results of López et al. [23], investigating two genotypes of pepper grown in organic and conventional production because they found higher values in the fruit weight of conventionally grown peppers compared to the fruits of organic peppers. Gvozdenović and Milošević [24] published a wide range of values for fruit weight in conventional production. The influence of genotype and production system on the average weight of the fruit was investigated by Szafirowska and Elkner [8], which conducted two years research on 3 pepper varieties grown in organic and conventional system. According to

Table 5. Pairwise comparison between a) plant height and cultivation system applied and b) number of branches per plant and cultivation system applied

(A) Cultivation system	(B) Cultivation system	(A-B) Mean difference	Std. error	Significance ^a
a) Fruit length				
Organic	Conventional	-0.109	0.122	0.374
b) Fruit width				
Organic	Conventional	0.195*	0.038	0.000
c) Fruit index				
Organic	Conventional	-0.291*	0.052	0.000
d) Fruit weight				
Organic	Conventional	1.868	1.082	0.085
e) Pericarp thickness				
Organic	Conventional	0.054	0.045	0.237
f) Fruit flesh				
Organic	Conventional	0.694	0.473	0.143

Based on estimated marginal means.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

**. The mean difference is significant at the 0.05 level*

these authors, the average pepper fruit weight was higher in organic than in the conventional production system for two of researched genotypes.

The results in this study differ from the results published by López et al. [23] where the investigated genotypes produced in the organic production system have a higher fruit index compared to those in the conventional system. Also, Kurtovska Kapija and Piran have a lower index of fruit compared to the results of this experiment [18,20].

In two of the three comparatively examined varieties in the studies of Szafirowska and Elkner [8], the authors found thicker pericarp in the organically grown pepper varieties. The results of this study differ from the results obtained by López et al. [23], which reported higher pericarp thickness of genotypes grown in conventional production, than those cultivated in organic production. The results of other researchers showed that the average fruit flesh ranged from 76 to 77% for Piran and its two androgenic lines grown under protected conditions, which is in accordance with our results [18]. In the investigated lines of the Kurtovska Kapija (KK1 and KK2), this value was 78 to 79%, which is less than it is found in our experiment [20].

The results of this research are in compliance with fact that pepper genotype inheritance is the key factor determining the morphological traits, strongly influenced by local climate, soil conditions and agrotechnical measures applied in the production [1].

4. CONCLUSION

Generally, all pepper morphological traits in this research were characterised by lower average values in organic production as compared to the conventional one, although expressively different were only three traits as number or branches per plant, fruit width and fruit index. The traits fruit weight, pericarp thickness and fruit flesh percentage, which are the most important for pepper crop yield and utilisation of pepper fruits were not significantly affected by the production practice. In conclusion, organic production has limited influence on pepper plant and fruit traits, but not in a manner to decrease the production, which generally is main fear of conversion from conventional to organic production in vegetables. Appropriate selection of pepper varieties with the application of suitable cultivation and

management practices can contribute to successful organic production resulting in high-quality pepper production.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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