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The effect of different systems of growing tomatoes in a protected area on morphological properties and business results

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Abstract

We are witnessing negative consequences caused by the use of synthetic crop protection products and fertilizers in food production. Interest in the indoor farming of certain plant species has grown significantly. Organic and integrated farming imply the use of natural products, while limiting or completely eliminating the use of synthetic resources. The goal of the research is to study different farming systems in two types of tomatoes and their effect on the variability of certain tomato properties (the number of formed flower trusses, number of fruits per flower truss, and tomato yield). Furthermore, the gross margin of tomato production was calculated. Factor A comprised of different systems of agricultural production: integrated and organic. Factor B comprised two types of tomatoes (cherry and beef). The experiment was set up in a modern indoor space, in controlled microclimate conditions in randomized block design in four replications. The organic system of farming highly significantly affected the studied parameters. The reason for this was the use of a modern growing technology and the approach to the farming itself.

Key words: organic and integrated farming, safe food, plastic greenhouse, tomato, gross margin.

Introduction

Vegetable production is the most intensive branch of plant production with high accumulativeness and economic effects. In particular, the profit from vegetable production is greatly increased by growing plants in protected areas, which results in the continuous growth of this farming method . Tomatoes are one of the most important vegetables in the world, due to their economic importance, prevalence, and use, thus being a very significant crop. Many authors have concluded that tomatoes are rich in vitamins C, E and B, copper and iron, and minerals such as potassium, sodium, magnesium, and calcium (Setiarti et al., 2022). Tomatoes (*Solanum lycopersicum* L.) are grown in the world on over 5,000,000 ha with the total production of more than 180,000,000 tons (FAO, 2020), and in the Republic of Serbia tomatoes are grown on 7,347 ha, with the total production of 103,277 t/ha and the average yield of 14 t/ha (FAO, 2020). Organic vegetable production in Serbia is carried out on 121,559 t/ha, 4.24% of which (5,161 ha) are under tomatoes. Moravčević (2014) states that high plastic greenhouses allow growing tomatoes out of season. Key problems of growing tomatoes in integrated and organic systems, especially tomatoes for fresh consumption, are usually pest and disease management as well as weed management (Wiler, 2010). According to Bajagić et al. (2022), climate change adds to negative consequences of agricultural production on the environment and human health. A concept of sustainable agriculture implies and contributes to a great extent to ecological balance and stability of natural resources in an agricultural ecosystem. This kind of production comprises growing resistant cultivars and hybrids, integrated application of cropping practices, use of physical and mechanical measures, like organic mulching to sustain soil fertility and induced (acquired) systemic plant resilience, and use of biological measures, i.e., natural predators and bio pesticides (Momirović et al., 2021). Production of this vegetable is mostly affected by yield and price, which have a tendency of constant growth in the Republic of Serbia (Petrović et al., 2021). Tomato production has a seasonal character and its price varies depending on the period of the year, though it is possible to increase its yield by using modern technologies (Petrović et al., 2022). Growing consumer demands for quality and nutritive-rich products can increase the scope of organic tomato production, by using biological products that can contribute to increased yields, pathogen control, and higher quality of crops (Cvijanović et al., 2021).

The goal of the research was therefore to study different tomato hybrids grown indoors, in organic and integrated systems, in terms of variability of different properties (the number of formed flower trusses, number of fruits per flower truss during the growing period, and tomato yield).

Material and Methods

The research was carried out during one growing season in 2020, in controlled microclimate conditions, in order to examine the impact of integrated and organic growing systems on productivity, the number of tomatoes per flower truss, and the number of flower trusses in a protected area. The research was conducted on an experimental plot of the company ″Zeleni hit″, in ″13. maj″, in the area in the vicinity of Zemun Polje. The experiment was set up in an indoor facility with the total area of 320 m2 (8 m by 40 m), ridge height of 5 m, support height 2.6 m, which enabled continuous support to a larger number of flower trusses and implied descending of the plants.

The experimental part of the research was designed as two-factorial experiment:

- Factor A: growing system
  - integrated
  - organic;
- Factor B: chosen tomato genotypes, a total of 4 hybrids, two of each of the prevailing types of tomatoes
  - Cherry (hybrids: Sakura and Tomagino)
  - Beef (hybrids: Rally and Velocity)

Prior to seeding, the soil was prepared by using a standard technology: using organic and congenital mineral fertilizers for integrated farming and using only certified and approved organic and mineral fertilizers listed as the approved products for plant nutrition and protection to be used in organic farming (http://www.uzb.minpolj.gov.rs). For both systems, the basic fertilization was carried out in the amount of 120-140 kg ha^{-1} N; 100-110 kg ha^{-1} P_2O_5; 90-120 kg ha^{-1} K_2O, and 35-40 kg ha^{-1} MgO.

In both systems, the researchers used bio pesticide agents, useful microorganisms, and predators, as well as pheromone traps and systems of mass trapping to protect crops from pests and diseases. All that was done to harvest the final product without pesticide residues, which was confirmed by certified laboratories. When it comes to weed management, in the integrated farming system the researchers used silver polyethylene mulch, and in organic system a layer of organic matter for covering, which enables high thermal stability, as well as conservation of soil moisture and accessible nutrients in the soil.

At the end of the growing season, in the stage of technological maturity of the plants, samples of 10 plants were marked and taken using a random sampling method with all 4 replications and all variants for the analysis of the following properties: the number of formed flower trusses, the number of fruits per flower truss during the growing season, and tomato yield. The harvest was performed

manually from the beginning of tomato ripening in May-June to August-September, with a total of 8 harvests during the growing season.

The results were processed by using the analysis of variance for the two-factorial experiment, and the statistical significance of the differences was determined by the LSD test at 5% and 1% ("Statistica 10.0" statistics program). The results are shown in the tables given below.

Results and Discussion

Advanced systems for preserving soil fertility and phytosanitary status have enabled growing tomatoes in an integrated concept on a larger number of flower trusses, and this innovative approach has had an equal success in the organic farming, achieving high productivity and sustainability.

It is known that the formation of flowers is affected by light intensity, temperature, and nutrients. It is an important transition from vegetative growth to reproductive growth, and is also a stage in the formation of plant yield (Blackman, 2017).

The total average number of flower trusses in all hybrids was 20.20 (Table 1). The farming systems did not have any statistical significance. In the organic farming the number of flower trusses for both types of tomato hybrids was 20.40, which is 0.2% higher than in the integrated farming (20.00). Factor B tested tomato types had a high statistical significance, while the statistical significance of the hybrids within the types differed.

Sakura and Tomagino hybrids (cherry type) did not statistically affect the number of flower trusses during the growing season. In the cherry tomato type, the Sakura hybrid (27.75) had 11.32% higher number of flower trusses, compared to the Tomagino hybrid (24.75), which was statistically significant at the $p<0.05$ level.

There were no statistically highly significant differences between the hybrids within the beef type tomatoes: the Rally hybrid (14.25) had 0.2% higher number of flower trusses compared to the Velocity hybrid (14.25). The farming and hybrids interaction did not have any significance. Using side shoots can improve the production of high/quality tomato hybrids (Kusakawa et al., 2013).

Table 1. Number of formed flower trusses of tomatoes in two farming systems and with two different types of hybrids during the 2020 growing season.

Farming system (Factor A)	Factor B				□ **A**
	Cherry		Beef		
	Tomagino	Sakura	Velocity	Rally	
Organic	26.50	27,50	13.50	14.00	**20.40**
Integrated	23.00	28,0	14.50	14.50	**20.00**
□ **B**	**24.75**	**27.75**	**14.00**	**14.25**	**20.20**
	A^{nz}	**B****	**A x B^{nz}**		
F – test	**0.60**	**68.50**	**1.50**		
LSD 5%	**1.51**	**2.55**	**3.61**		
LSD 1%	**2.76**	**3.50**	**4.95**		

Source: (Authors' calculation)

The average number of formed fruits per flower truss by all investigated factors was 9.50 (Table 2). The farming systems had a statistically significant effect on the difference in the number of fruits per flower truss. On average, the integrated farming resulted in a higher number of fruits per flower truss (10.01), which is 11.22% more than in the organic farming (9.00). A significant improvement in terms of technology and conserving soil fertility with using black foil in the organic farming resulted in a higher number of flower trusses. During the growing season, the number of fruits differed depending on the hybrid at the level of statistical significance of $p<0.01$.

The Sakura tomato hybrid (cherry type) had a higher number of formed fruits (16.62), which is 5.99% more than the Tomagino hybrid of the same type. Differences in the number of fruits per flower truss in the beef-type hybrids amounted to 5.75% in favour of the Velocity (2.94), while the number of fruits per flower truss of the Rally hybrid was 2.78. The A and B interaction was not statistically significant. According to Iken et al. (2004), it has been determined that the differences in the number of fruits and yields were due to different genotypes of hybrids.

Table 2. Number of formed fruits per flower truss in two farming systems and with two different types of hybrids during the 2020 growing season.

Farming system (Factor A)	Factor B				□ **A**
	Cherry		Beef		
	Tomagino	Sakura	Velocity	Rally	
Organic	14.81	15.92	2.88	2.38	**9.00**
Integrated	16.55	17.33	3.00	3.18	**10.01**
□ **B**	**15.68**	**16.62**	**2.94**	**2.78**	**9.50**
	A*	**B****	**A x B****		
F – test	**14.94**	**2719.05**	**5.79**		
LSD 5%	**0.84**	**0.44**	**0.62**		
LSD 1%	**1.54**	**0.60**	**0.85**		

Source: (Authors' calculations)

The average yield for all examined factors was 5.93 (Table 3). The farming systems did not have a statistically significant effect on the tomato yields. The organic farming obtained a higher yield (6.25), which is 11.40% more than achieved in the integrated farming (5.61). The hybrids of both tomato types had a highly statistically significant effect on the yields. In the cherry varieties, the Tomagino hybrid had 11.32% higher yield (3.54) than the Sakura hybrid (3.18). For beef-type varieties, the Rally hybrid had a higher yield (8.96), which is 11.44% higher than the yield of the Velocity tomato hybrid (8.04). Similar results were reported by Enujeke et al. (2015), who concluded that differences in growth and yield of tomato hybrids can be attributed to different tomato hybrids. According to Kapoulas et al. (2011), it is possible to achieve significant differences in yields in organic farming. Moreover, the same authors stated there was a significant difference in the weight of ripe tomatoes from organic farming, which cumulatively affected the yields in organic farming to increase for 29.29% compared to the ones in conventional farming. There are also opposing opinions, where Oliveira et al. (2013) state that tomatoes from organic farming were smaller in size and the weight than the tomatoes from conventional farming, and had 40% lower yield, but their quality was significantly better in terms of concentrations of bioactive substances.

Table 3. Tomato yields in two different farming systems with two different types of hybrids during the 2020 growing season.

Farming system (Factor A)	Factor B				□ **A**
	Cherry		Beef		
	Sakura	Tomagino	Rally	Velocity	
Organic	3.40	3.64	9.69	8.28	**6.25**
Integrated	2.96	3.45	8.23	7.80	**5.61**
□ B	**3.18**	**3.54**	**8.96**	**8.04**	**5.93**
	A^{ns}	**B****	**A x B^{ns}**		
F – test	**7.65**	**88.33**	**1.83**		
LSD 5%	**6.85**	**8.81**	**12.46**		
LSD 1%	**12.57**	**12.,07**	**17.07**		

Source: (Authors' calculations)

The data from the experiments were used to calculate gross margins. It was determined that the highest gross margin was achieved in the production of organic beef tomatoes and amounted to 1,040,883.60 Serbian dinars (RSD) for the specified hectarage of the protected area, while the lowest gross margin was achieved in the integrated production of cherry tomatoes and amounted to 266,059.10 RSD (Table 4). Desalegne (2002) reports that many tomato varieties, including fresh and processed ones, are popular and economically important vegetable crops. By comparing the gross margins for cherry tomatoes in the two farming systems, it was determined that the gross margin of organic cherry

tomatoes was by 287.39% higher than in the integrated farming, while in the case of beef hybrids, the gross margin for organic beef tomatoes was 203.81% higher than in the integrated farming. Moreover, by comparing the hybrids used in the same farming system, it was found that the gross margin for production of beef tomatoes compared to the one for cherry tomatoes was 191.96% higher in the integrated farming, while in the organic farming that difference was 136.13%.

Table 4. Gross margin of tomato hybrid production in the integrated and organic farming, in a protected area, 8 by 40 m in size.

Tomato type	Gross margin	Tomato type	Percentage difference of the achieved gross margin in the organic/ integrated system within the same hybrid	Farming system	Percentage difference of the achieved gross margin for different hybrids within the same farming system
Cherry IPM	266,059.10	Cherry (ORG/IPM)	287.39%	IPM (beef/cherry)	191.96%
Cherry ORG	764,632.40				
Beef IPM	510,718.60	Beef (ORG/IPM)	203.81%	ORG (beef/cherry)	136.13%
Beef ORG	1,040,883.60				

ORG: organic; IPM: integrated.

Conclusion

Considering the results, it can be concluded that the obtained differences are justified, because the hybrids used in the research differ according to the genotype. Regarding the morphological parameters, it was found that the cherry-type hybrids (Sakura and Tomagino) had a higher number of flower trusses and a higher number of fruits per flower truss during the growing season, while the beef-type hybrid showed a higher yield, which was expected. The production of tomatoes in the organic farming system led to higher yields, due to top-quality certified fertilizers, bio stimulants, and organic mulch, which was later reflected in the overall economic benefits when comparing the two farming systems, whereas when comparing hybrids used in the same farming system, it was determined that beef-type tomatoes generated higher profits.

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Утицај различитих система гајења парадајза у заштићеним просторима на морфолошке особине и пословне резултате

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Сажетак

Свједоци смо негативних посљедица коришћења синтетичких средстава за заштиту биља и ђубрива у производњи хране. Значајно је порасло интересовање за узгој одређених биљних врста у затвореном простору. Органска и интегрисана пољопривреда подразумијевају употребу природних производа, уз ограничавање или потпуно елиминисање употребе синтетичких ресурса. Циљ истраживања је испитивање различитих система узгоја код два типа парадајза и њиховог утицаја на варијабилност појединих својстава парадајза (број формираних цвјетних грана, број плодова по цвјетној грани и принос парадајза). Надаље, израчуната је бруто маржа производње парадајза. Фактор А чине различити системи пољопривредне производње: интегрисани и органски. Фактор Б обухвата две врсте парадајза (чери и меснати). Експеримент је постављен у модерном затвореном простору, у контролисаним микроклиматским условима у рандомизованом блок дизајну у четири понављања. Органски систем пољопривреде је статистички веома значајно утицао на проучаване параметре. Разлог за то била је примјена савремене технологије узгоја и приступ самог узгоја.

Кључне ријечи органска и интегрисана производња, безбједна храна, пластеници, парадајз, бруто маржа.

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