AI ASSISTED ECONOMIC ANALYSIS OF GREENHOUSE AND OPEN FIELD SWEET PEPPER PRODUCTION

Emhemed Daw[1], Gordana Dozet[2], Marija Bajagić [3], Milan Ugrinović [4]

**Corresponding author E-mail: daw.emhemed.bg@gmail.com*

ARTICLE INFO

Original Article

Received: *24 May 2024*

Accepted: *15 October 2024*

doi:10.59267/ekoPolj260113D

UDC 004.89:330.131]:65.649

Keywords:

Economic analysis, sweet pepper cultivation, yield, horticulture, greenhouse

***JEL**: O13, Q14, R15*

ABSTRACT

Sweet pepper is a valued vegetable, both among producers and consumers. During the 2017 and 2018 greenhouse experiments and a field trials with different microbiological fertilizers were used to analyze the yields and profitability of sweet pepper production. Contrary to the yields obtained in the greenhouse (14.23 and 13.42 t/0.1ha), the yields in the open field had significantly lower values (4.324 and 4.877 t/0.1ha). Also, the key difference is in the number of realized harvests and their dynamics during the production season which is also connected to market prices and profit. The coefficients of cost-effectiveness were 1.88 and 1.99 in the greenhouse, and 1.39 and 1.45 in the open field, in 2017 and 2018 respectively. Producers should be opted to the greenhouse production because of the higher yields and number of harvests outside the main season, when product prices are higher.

Introduction

Regardless of the time frames, it is considered that pepper (*Capsicum annuum* L.) reached the Old World, especially Europe and Asia, from the region of original domestication, Mesoamerica and the Andes (Tripodi et al., 2021). Between 16th and 18th century, the cultivation of pepper, predominantly chilly varieties, spread rapidly

1 Emhemed Daw, Ph.D student, Faculty of Biofarming Bačka Topola - Megatrend University, Marshal Tito street 39, 24300 Bačka Topola, Serbia, E-mail: daw.emhemed.bg@gmail.com, ORCID ID (https://orcid.org/0009-0004-4323-9262)

2 Gordana Dozet, Ph.D, Full professor, Faculty of Biofarming Bačka Topola - Megatrend University, Marshal Tito street 39, 24300 Bačka Topola, Serbia, E-mail: dozetg@gmail.com, ORCID ID: (https://orcid.org/0000-0001-5358-7739)

3 Marija Bajagić, Ph.D, Assistant Professor, University Bijeljina, Faculty of Agriculture, Pavlovića put bb, 76300 Bijeljina, Republic Srpska, Bosnia and Herzegovina, Phone:+381638858185, E-mail: bajagicmarija@yahoo.com, ORCID ID (https://orcid.org/0000-0001-9537-8302)

4 Milan Ugrinović, Ph.D, senior scientific associate, Institute for vegetable crops, Karadjordjeva street 71, 11420 Smederevska Palanka, Serbia, E-mail: milan.ugrinovic@gmail.com, ORCID ID: (https://orcid.org/0000-0002-1590-4489)

from Spain thru the neighboring countries, and chilies became popular in the whole Europe and Asia. Previously, cultivation was promoted rapidly because chilly varieties were cheaper substitute for expensive black pepper spice (Madala & Nutakki 2020). In recent decades, the selection of peppers is increasingly focused on the creation of new sweet pepper varieties with a higher yield, which is often related to the thickness of the pericarp fruit and other characteristics with which they are correlated (Danojević et al., 2016). Except for the shape of the fruit and the taste (spicy and sweet varieties), the main difference between the genotypes is the time of harvesting, i.e. maturation, especially technological maturation. Some varieties are harvested at the stage of technological maturity (yellow or pale green color of the fruit, or dark green exceptionally for some foreign markets) and those that are grown for harvesting at the stage of biological maturity (red or orange color of the fruit). In the case of varieties that are harvested in the stage of technological maturity, a greater number of partial harvests are performed, which are more frequent in terms of dynamics. In this way, a larger number of fruits per plant is produced and, therefore, a higher yield in case the harvesting costs do not exceed the earnings (Lin et al. 2009; Jang et al., 2023).

At the same time, the technology of pepper cultivation was improved, and one of the main directions of development is pepper cultivation in a controlled environment (protected area). Protected areas include glasshouses and plastic greenhouses. Greenhouses represent an expensive investment, however, with some species it is possible to achieve, under certain conditions, up to 10 times higher yields during the year, comparing to average yields of open field production (Marcelis et al., 2019).

Despite the inefficient use of energy and materials (from the ecological point of view), production in the greenhouses area is increasingly expanding due to the high price of products that are achieved outside the regular ripening season of cultivated species (Farfan et al., 2019; Marcelis et al., 2019; Naderi et al., 2019). Using a remote sensing, around 3019 million hectares in the world are marked as an area covered with plastic materials. This includes mulched fields and greenhouses, as well as facilities intended for other agricultural and non-agricultural purposes (Jimenez-Lao et al., 2020). More than 80 % of these areas are placed in China. Some other data suggested that within the 2000–2020 period, the area covered by agricultural plastic greenhouses in China expanded from 159,466.0 to 1,183,877.0 ha (Liu & Xin, 2023). According to some other sources, about 586,000.0 ha globally was under plastic greenhouses (Lamont, 2009) and total global area covered by greenhouse vegetables was approximately 5.6 million ha in the year 2018, with 4.67 million ha or 83% only in China (Qasim et al., 2021; Pantović et al., 2026).

In Serbia, areas under greenhouse production are significantly smaller and, according to some estimates, they were around 5,000 ha in 2017, with a tendency for a slight increase (Červenski et al., 2020). In the course of the last 10 years, pepper production has been carried out on 9915 to 17386 ha (open field and greenhouses), with a tendency to decrease the area under this crop. Contrary, the yields were with slight tendency of increment during the last decade, with average value of 11.96 t/ha (SORS 2024) and

with an illogically large difference compared to experimental results in recent research (Pavlović et al., 2010; Parađiković et al., 2011; Praća et al., 204; Parađiković et al., 2013; Adžić et al., 2023).

Modern pepper production in the open field and in greenhouses in the agroecological conditions of Southeastern Europe can be very profitable. Recent research indicates that by choosing new varieties and applying the most modern agrotechnical measures, high yields and profit can be achieved (Pavlović et al., 2010; Parađiković et al., 2011; Parađiković et al., 2013; Adžić et al., 2023; Georgiev, 2025; Avakumović & Avakumović, 2025; Jang et al., 2023). Although the yields that can be achieved are very often much more above the world average, product prices are correct for most of the season, and thus the potential profit is at a satisfactory level, producers timidly decide to produce pepper on larger areas, primarily because of the large investments per unit of area and on the other hand, due to the great risk involved in the production of sweet pepper. The fact that even seemingly insignificant errors can significantly reduce yields and thus put the entire production into question must not be overlooked.

During the same period worldwide, an innovative technology (artificial intelligence AI) is included in almost all human activities, including food production, i.e. research activities related to agricultural products (Sánchez et al., 2020; Jung et al., 2021).

The aim of the work is to determine more efficient and profitable sweet pepper production systems, with the help of readily available artificial intelligence tools. The parameters for the required analysis were obtained by an experimental trial in which the influence of various cheap microbiological fertilizers in the production of sweet pepper (in the greenhouse and open field) on the height of the yield and the time of harvest was examined, in order to evaluate the economic profitability of the new integral methods.

Materials and methods

Open access artificial intelligence tool (ChatGPT 3.5, 2024) was used as an assistance in the selection of the activities that need to be applied in order to calculate the profitability and effective way of improvement of pepper production in the protected area and in the open field. Considering the implementation of those measures, only affordable agrotechnical procedures of yield improvement were taken into account. For the purposes of this work, in order to rate the yields and profitability of integral sweet pepper production, an earlier performed greenhouse experiment (2016-2018) was used as well as the results from the open field experiment performed a year later. The data collected from the mentioned experiments and local producers were used for calculations. The first experiment was set up in the greenhouse of the Secondary Agricultural School in Bačka Topola, located at the school's demonstration farm (N: 45°47'41'', E: 19°35'58'', 93m above sea level). It is an high block greenhouse covered with plastic film with usable soil surface of about 800 square meters. The three-year experiment included two treatments with different microbiological fertilizers (EM active and Vital Tricho) and control in three repetitions. Yellow sweet pepper cultivar

Blondy F1 (Syngenta; S&G Vegetables) was grown. A number of quantitative and qualitative indicators were monitored, but for the purposes of this work, only yield and harvest time for different treatments were used in order to evaluate the economic profitability of new integral methods of pepper production in tall block greenhouses. Except microbiological fertilizers all agrotechnical measures were applied, as with other producers (tillage, application of basic farmyard manure, placement of plastic mulch film, transplanting, watering, basic chemical protection, tying, harvesting) and according to contemporary cultivation techniques (Kelley et al. 2009). Collected data concerning pepper yields were analyzed using an ANOVA method (STATISTICA 10), and LSD test was performed.

In a two-year trial in an open field, in the immediate vicinity, peppers were grown in approximately identical conditions, except for those that are tied to a protected area (greenhouse). The results of this two-years trial were used as a control and compared with the results collected during the last two years of the greenhouse trial (2017-2018). Among the 43 selected vegetable producers who had pepper production on an area larger than 0.2 ha in an open field or in an open field and in a greenhouse simultaneously, 4 of them who grow sweet pepper (of the same variety) on the open field and who applied agrotechnical measures and irrigation comparable to the experimental environment of the greenhouse in Bačka Topola were selected. Average yield values from the second experiment and from the selected subcontractors and producers were calculated for comparation. The list of subcontractors of the Institute for Vegetable Crops Smederevska Palanka was used for these purposes as well as contacts achieved through the network of Agricultural Advisory and Expert Services under the authority of the Institute for the Application of Science in Agriculture (IASA) (https://www.psss.rs).

Greenhouse and open field sweet pepper production costs per area unit were collected thanks to the accounting values of the Institute for Vegetable Crops Smederevska Palanka and the publication of the Cooperative Union of Vojvodina Price list of machinery services in agriculture 2018 as well as via interview of Secondary Agricultural School's stuff and local sweet pepper producers. The cost of greenhouse construction and plastic sheeting were calculated by dividing their market prices (and accounting values) by the predicted lifetime expressed in years (Table 1), according to previous trials concerning greenhouse vegetable production (Pavlović, 2014).

The economic analysis has been performed using a method of analytical calculations for the purpose of determining the costs and calculating basic indicators of the profitability of production for the pepper in the open field and greenhouse production, i.e. the total costs (EUR), value of pepper production (EUR/0.1 ha), cost price (EUR/kg), financial results (EUR/0.1 ha), border of profitability i.e. break-even analysis (kg/0.1 ha), business rate of profitability i.e. return on investment (ROI) (%) and coefficient of cost-effectiveness (e) (Bošnjak & Rodić 2010; Pavlović et al., 2010; Pavlović et al., 2014).

Serbian Agriculture Market Information System was used to obtain information about pepper prices on the wholesale market, during the 2017 and 2018 production seasons.

(STIPS 2024). The Monte Carlo method (Johansen et al., 2010) was used to calculate the selling price, as stated in previous research (Mladenović et al., 2016). The calculation was performed with the help of Excel 2007 using the function *=NORM.INV(RAND(),M ,STDV)* via 100 iterations for each value, where M are the mean sales price at a given time (STIPS 2024) and STDV is the standard deviation of sales prices (Yen, 2024).

Results and Discussion

In agriculture, the search for higher net profit, particularly the decrease of expenses and the total income increase, is the main challenge in the economy of the producer. (Padrón et al., 2016). According to AI assistance's step-by-step guide on how to predict financial results in open field and greenhouse pepper production, the prediction of profit in sweet pepper production is based on analysis of various factors that affect both costs and revenue via already performed trials (ChatGPT, 2024). On the base of collected data and results of performed trials, significantly higher costs were generated in the production of peppers in greenhouses. During 2017, the costs of greenhouse pepper production were 3757.0 euro/0.1ha (37570.0 euro/ha). In the same year, production costs per unit area in the open field were 1509.2 eur/0.1ha (15092.0 eur/ha). Production costs in 2018 were higher and amounted to 4631.3 eur/0.1 ha for production in the high block plastic greenhouse, i.e. 1733.9 eur/0.1 ha for production in an open field. As the majority of production inputs, originating from imports, the increase in their prices and trade margins influenced the growth of the costs of their use in 2018. (Table 1).

Table 1. Costs of greenhouse and open field sweet pepper production per area unit (EUR/0.1 ha**)** for two consecutive seasons (2017-2018)

Costs	**Greenhouse (Eur/0.1 ha)**		**Open field (Eur/0.1 ha)**	
	2017	**2018**	**2017**	**2018**
Fixed costs				
Taxes and rents	15.8	15.6	15.8	15.6
Local administration taxes	5.2	7.4	5.2	7.4
GH costruction - amortization	1367.0	1367.0	0.0	0.0
Plastic cover - amortization	185.0	193.7	0.0	0.0
Irrigation pipes and tapes	74.0	88.6	74.0	88.6
Insurance and banking services	189.6	212.2	78.6	98.3
Variable costs				
Tillage and soil preparation	41.1	48.9	22.4	28.7
Fertilizers	122.7	158.0	122.7	158.0
Irrigation	165.0	183.1	133.2	156.1
Plastic mulch film	64.4	72.1	64.4	72.1

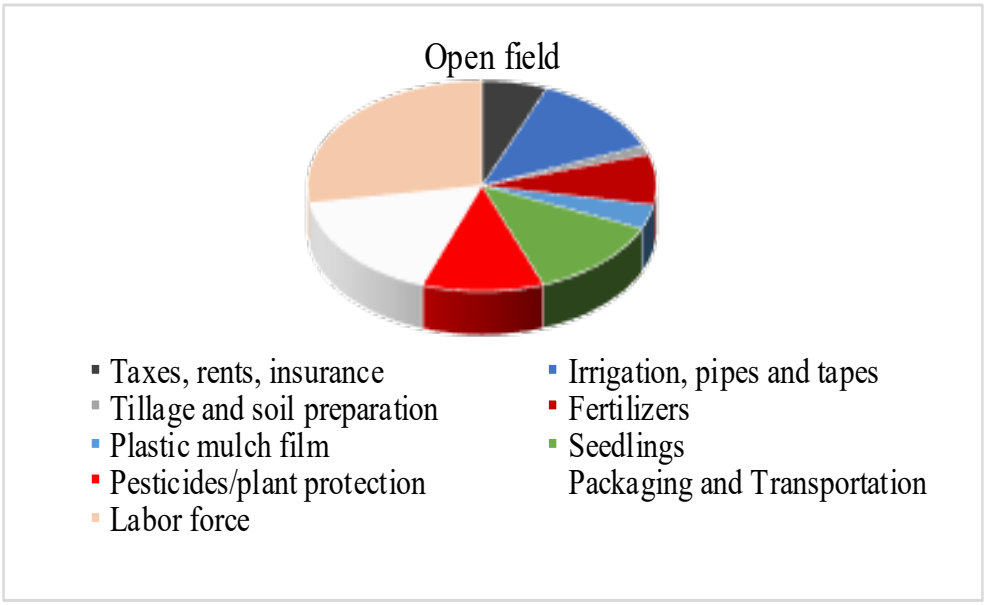
Costs	Greenhouse (Eur/0.1 ha)		Open field (Eur/0.1 ha)	
	2017	2018	2017	2018
Seedlings	1595.5	1904.0	203.4	255.5
Ropes, nets and ties	163.4	175.1	0.0	0.0
Pesticides/plant protection	164.7	182.4	189.3	220.0
Packaging	331.3	342.5	102.7	115.8
Transportation	398.9	450.2	191.1	202.7
Labor force	710.0	765.0	480.0	525.0
Total costs	3757.0	4631.3	1509.2	1733.9

The significant difference between the costs of pepper production in the open field and in the greenhouse was made by the additional costs of depreciation of greenhouse construction (1367.0 and 1367.0 Eur/0.1 ha i.e. 0.0 and 0.0 Eur/ha respectively for 2017 and 2018 growing season) and plastic film foil (185.0 and 193.7 Eur/0.1 ha i.e. 0.0 and 0.0 Eur/ha respectively for 2017 and 2018 growing season). On the other hand, although watering in a protected area is necessary to compensate for precipitation that occurs during vegetation in an open field, the difference in irrigation costs is not significantly higher because in the greenhouse, electricity was available, which as a source of energy is cheaper compared to fossil fuels that were used to run water pumps in the open field where there were no other options.

The production costs of sweet peppers were very high and in the presented research they were significantly higher even compared to the production of peppers in the open field in the organic production system (Pavlović et al., 2010), which can be partly attributed to the difference caused by multi-year inflation. In the structure of production costs, there is also a discrepancy with the results of some previous researches that related to the production of peppers in the open field or the production of other vegetables in the greenhouse conditions (Pavlović et al., 2010; Pavlović et al., 2014; Petrović et al., 2021).

When it comes to particular costs share for the open field production, labor costs accounted for the largest share of the total costs of sweet pepper production (31.0%). The costs share of packaging and transportation (18.9%), transplants acquisition (14.2%), pesticides and plant protection costs share (12.6) and irrigation costs share (14.2%), were slightly lower but still very significant (Figure 1).

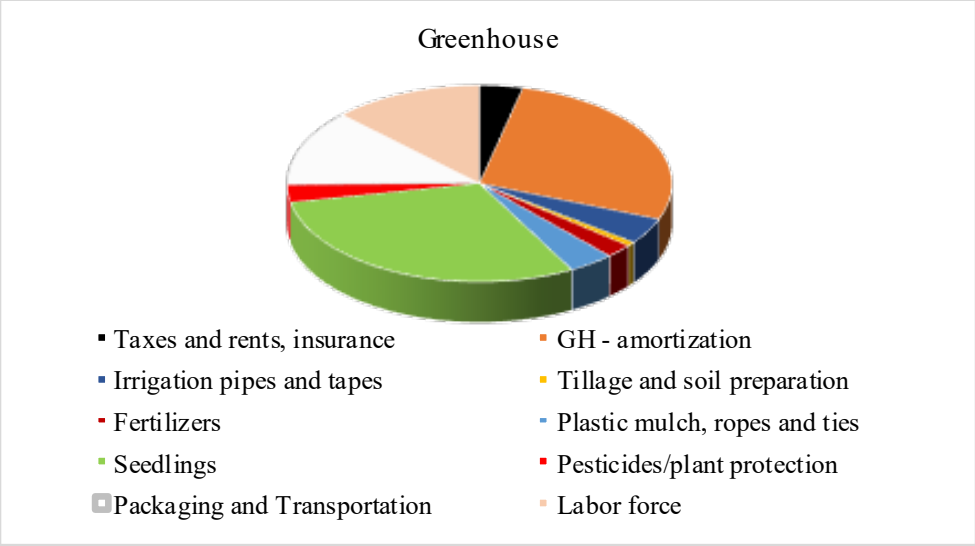
Figure 1. Average share of costs (%) of the open field production for examined period (2017-2018)



Source: Daw E., 2024

Depreciation costs of greenhouse and plastic film, as expected, accounted for a significant portion of the costs of pepper production in greenhouses (23.66%). A no less share, and possibly a higher (depending of the moment of procurement), in the total costs also belonged to the procurement of transplants (up to 29.84%), which in the late winter and early spring period has a significantly higher price comparing to late spring procurement (especially for the open field production). Since the high level of depreciation costs and transplant cost shares, the shares of labor force (12.7%) and packaging and transportation costs (12.53%) were relatively low. The share of every other cost was less than 5% (Figure 2). It was a little bit different ratio compared to previous research (Pavlović et al., 2010), probably due to inflation and changes in the labor market.

Figure 2. Average share of greenhouse production costs (%) for examined period (2017-2018)



Source: Daw E., 2024

As a result of the experimental activities in the greenhouse, statistically significant differences were recorded by microbiological treatments and year (Table 2). Higher yields were achieved in the treatments compared to the control without microbiological fertilization.

Table 2. The analysis of variance for pepper yield per unit area in greenhouses during the experimental period (2016-2018)

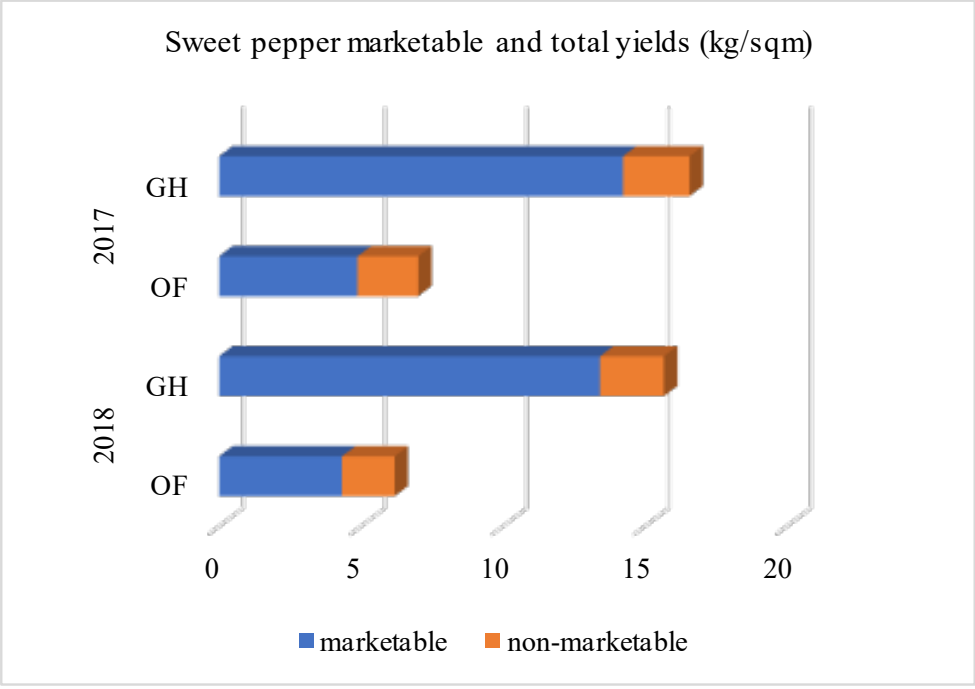
Source of variation	*degrees of freedom*	Sums of squares	Mean squares	F value	p-value
Blocks	2	11.152	5.576	1.38	
Year (A)	2	29.191	14.595	3.62	0.041*
Treatments (B)	2	37.15	18.575	4.61	0.026*
Interaction (AxB)	4	5.481	1.37	0.34	0.847^{ns}
Error	16	64.533	4.033		
Total	26	147.506			

Source: Daw E., 2024

Total average yields of sweet pepper grown in the greenhouse varied from 14.47 t/0.1ha to 17.81 t/0.1ha for different treatments and seasons with average values of 16.57 t/0.1ha and 15.66 t/0.1ha for 2017 and 2018 growing season respectively. During the same period, average yields of sweet pepper grown in the open field were 6.01 t/0.1ha and 4.98 t/0.1ha. Also lower marketable yields of both production models were

recorded in this period i.e. 14.23 and 13.42 t/0.1ha in the greenhouse and 4.324 and 4.877 t/0.1ha in the open field (Figure 3). Recent research indicated that by choosing suitable varieties and applying the most modern agrotechnical measures and different approach in production, high yields of sweet pepper and higher profit could be achieved (Pavlović et al., 2010; Parađiković et al., 2011; Parađiković et al., 2013; Adžić et al., 2023; Jang et al., 2023). Among the large number of pepper varieties, there are those that are used mainly for processing into local specialties and dishes (which are harvested in the phase of physiological i.e. biological maturity) and those that are used for preparing salad or for pickling (which are harvested multiple times in the phase of technological maturity when the fruits are light green or white to white yellow and still not fully biologically ripe (The variety used for this trial was classified in this group). Using such variety, the recorded yields were contrary to the results of experiments performed in Bosnia (Salkić et al. 2020) and Macedonia (Bogevska et al., 2008) but similar to results of experiments performed with the same variety in the relative vicinity of our experimental field (Parađiković et al., 2011; Parađiković et al., 2013).

Figure 3. Average marketable and nonmarketable yields per area unit (t/0.1ha) in the greenhouse (GH) and open field (OF) for the two experimental seasons (2017-2018)



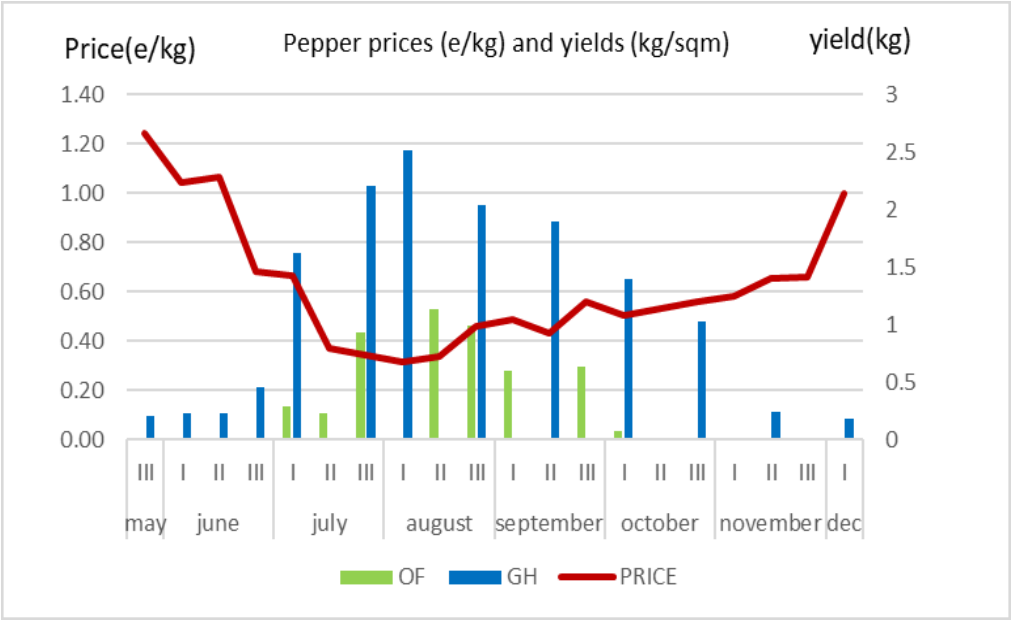
Source: Daw E., personal data, 2024

The prices of sweet pepper as well as other products depend on product's offer and its demand in the market and in the case of fresh sweet pepper market can be characterized as a competitive. That means that no one of growers has production large enough to

influence the market price, and that the price received by growers is due to factors that include consumer demand and supply from other parts of the country and import (McCoy et al., 2013). Since producers cannot significantly influence the average prices of sweet pepper, the only way to increase the financial result, apart from reducing production costs, is to influence the increase in yield.

McCoy et al. (2013) also emphasized the influence of extended season and greater number of harvests in the greenhouse on yield increase. In the production season of 2017, 13 harvests in the greenhouse and 8 in the open field were performed. The highest market price per kilogram of sweet peppers (1.24 euro/kg) was recorded in the third decade of May, when the first harvest in the greenhouse took place (0.22 t/0.1 ha). On the other hand, the lowest price of sweet pepper was in the first decade of August (0.31 euro/kg). In that period, the highest yield harvest was recorded in the open field (1.5 t/0.1 ha). The highest yield harvest in the greenhouse was occurred about 10 days earlier, during the third decade of July (2.57 t/0.1 ha) (Figure 4).

Figure 4. Pepper prices (e/kg) and yields per area unite (kg/sqm) during the 2017 harvest season in the open field (OF) and grenhouse.

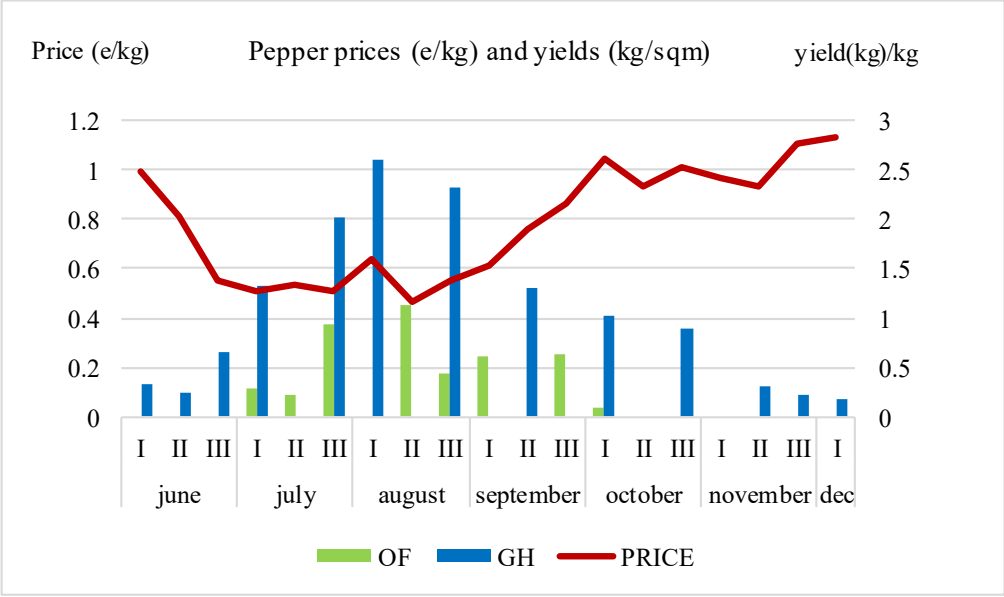


Source: Daw E., personal data, 2024

During the 2018 production season, the same number of harvests were performed in both greenhouse and open field productions. However, the market prices fluctuations were lower, and the highest price of sweet peppers (1.14 euro/kg) was recorded in the first decade of December, when the last and lowest yield harvest in the greenhouse was occurred (0.18 t/0.1 ha). Similarly to the previous season, the lowest prices of sweet pepper were during the summer period, especially during the second decade of August

(0.47 euro/kg). Again during the august, the highest yields harvests were achieved both in the open field (1.13 t/0.1 ha) and in the greenhouse (2.6 t/0.1 ha) (Figure 5).

Figure 5. Pepper prices (e/kg) and yields per area unite (kg/sqm) during the 2018 harvest season



Source: Daw E., personal data, 2024

This arrangement of harvests and marketable yields as well as prices (Figures 4. and 5.), resulted in slightly lower realization prices (0.495, 0.688, 0.43, and 0.58 Eur/kg consecutively for realization prices in the greenhouse in 2017 and 2018 growing season, and the same years in the open field, Table 3.) compared to the average prices of peppers during the production seasons (0.618, 0.787, 0.45, and 0.648 Eur/kg consecutively greenhouse producrtion season in 2017 and 2018, and for the average prices during the open field seasons of both years).

For all analyzed indicators, in both years of research, better results were achieved in greenhouse production. On the other hand, despite lower yields and higher production costs in 2018, better financial results were achieved. In the same time, lower breakeven prices were achieved in the greenhouse (0.26 and 0.35 Eur/kg in 2017 and 2018 respectively) comparing to open field (0.31 and 0.40 Eur/kg in 2017 and 2018 respectively). On the contrary, higher values of the border of profitability were achieved in the grenhouse production (7585.3 and 6729.11 kg/0.1 ha in 2017 and 2018 respectively) comparing to the open field production (3509.76 and 2987.1 kg/0.1 ha). Higher values of this parameter are related to greenhouse production due to the significantly higher costs of this type of production, primarily in terms of depreciation of the greenhouse construction and plastic film for the cover (Table 3.).

In the end, the true result of production is best described by parameters such as Business rate of profitability and Coefficient of cost-effectiveness. In the presented research, the Business rate of profitability was 46.70 and 49.87% in 2017 and 2018 in the greenhouse. In the same period, the values of this parameter were 28.03 and 30.92% in the open field production. In the Greenhouse, the Coefficient of cost-effectiveness values were 1.88 and 1.99 in 2017 and 2018, respectively. At the same time, the values of this parameter in pepper production in the open field were 1.39 and 1.45 (Table 3.). The values of the Business rate of profitability and Coefficient of cost-effectiveness stated by Pavlović et al. (2010) for the production of organic peppers in the open field were 43.33% and 1.76, while for the salad cucumbers in the protected area were 18.9% and 1.23 (Pavlović et al., 2014).

Table 3. Costs of greenhouse and open field sweet pepper production per area unit (EUR /0.1 ha**)** for two consecutive seasons (2017-2018)

	Greenhouse (Eur/0.1 ha)		**Open field (Eur/0.1 ha)**	
	2017	2018	2017	2018
Total costs (Eur/0.1 ha)	3757	4631.3	1509.2	1733.9
Yields (kg/0.1 ha)	14231	13422	4877	4324
Average price (Eur/kg)*	0.495	0.688	0.43	0.58
Income (Eur/0.1 ha)	7048.61	9237.68	2097.11	2509.92
Financial result (Eur/0.1 ha)	3291.61	4606.37	587.9	776.02
Breakeven price (Eur/kg)	0.26	0.35	0.31	0.40
Border of profitability (kg/0.1 ha)	7585.3	6729.11	3509.76	2987.1
Business rate of profitability (%)	46.70	49.87	28.03	30.92
Coefficient of cost-effectiveness	1.88	1.99	1.39	1.45

As stated by some researchers, modern sweet pepper production in the greenhouse and open field in the agroecological conditions of Southeastern Europe can be very profitable (Lončarić et al., 1999; Parađiković et al., 2013). However, the highest demand for sweet pepper in Serbia was in the late summer, early and mid-autumn for decades. In the last few decades, with better and long-lasting offers on the market, demand is increasing each season. When it comes to pricing, there is an upward trend in prices, but this is related to the extension of the supply period and high off-season prices when only imported sweet pepper is available on the market. During the season, the highest prices are in the late winter early spring period when only imported sweet pepper is available (SORS, 2024). During the period when greenhouse sweet pepper from domestic production is available, the prices are slightly lower but still relatively high. As a rule, the lowest prices are in the middle and at the end of summer, as well as at the beginning of autumn, when peppers produced in the open field are widely available on the market.

Conclusions

The production of sweet pepper is associated with high costs and investments. Sweet pepper prices are highest in spring and late autumn, while they are lowest in mid-summer. As it is impossible to significantly and directly influence the price on the market and its fluctuation, the producers have to gain higher yields, as well as to extend the supply season and try to aim the maturation of the products at a time when the price of sweet peppers on the market is higher. According to achieved values of business rate of profitability and coefficient of cost-effectiveness, the sweet pepper production is profitable regardless of whether the production is performed in an open field (on average 29.47% and 1.42) or in a greenhouse (on average 48.28% and 1.94). Based on the results of the research, it can be concluded that sweet pepper producers should be opted to the production of pepper in a greenhouse because of the high yields that can be achieved outside the main season, when product prices are significantly higher, and by 194% (total greenhouse yield for the test period 16.14 t/0.1ha) compared to production in the open field (5.49 t/0.1ha). However, every other sweet pepper production season can have different production costs (starting from the costs of greenhouses, seeds or seedlings, up to the establishment of yield dynamics, packaging and transport), which adversely affects accurate cost forecasting, creating the need for further research and analysis. sensitivity. Different production inputs whose prices change from year to year (eg fuel, pesticides, fertilizer) have an influence on the change in costs. In this regard, it is necessary to define integral methods of plant production and protection according to different production systems and the needs of production seasons, which favorably affect high, healthy and stable yields, so that the product is constantly available on the market.

Acknowledgements

The authors owe a great debt of gratitude to the Embassy of the State of Libya in Belgrade as well as the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, which made this research possible. The article is part of the research project number 451-03-66/2024-03/200216, 200189.

Conflict of interests

The authors declare no conflict of interest.

References

1. Adžić, S., Cvikić, D., Živković, I., Šević, B., Pavlović, N., Rakić, I., & Đurić, N. (2023). Ekonomska opravdanost proizvodnje semena paprike. *Zbornik radova: Nacionalni naučni skup sa međunarodnim učešćem Biotehnologija i savremeni pristup u gajenju i oplemenjivanju bilja*, Smederevska Palanka 2. novembar, 60-69. https://rivec.institut-palanka.rs/handle/123456789/725

2. Avakumović, J., & Avakumović, J. (2025). Digitalno marketing i „VI“ u digitalnom okruženju. *Finansijski Savetnik*, *30*(1), 7-39. https://fa-journal.com/index.php/fa/article/view/1

3. Bogevska, Z. V., Trpeski, V., Jankulovski, D., Dimovska, M., & Agic, R. (2008, September). Bio-stimulating effect of some fertilizers on the yield of pepper. In *IV Balkan Symposium on Vegetables and Potatoes* 830, 651-656. https://doi.org/10.17660/ActaHortic.2009.830.94

4. Bošnjak, D., & Rodić, V. (2010). Economic analysis of soybean production in Vojvodina. *Ratarstvo i povrtarstvo/Field and Vegetable Crops Research*, 47(1), 193-202. https://scindeks-clanci.ceon.rs/data/pdf/1821-3944/2010/1821-39441001193B.pdf

5. Červenski, J., Medić-Pap, S., Danojević, D., Savić, A., & Bugarski, D. (2020). The importance of crop rotation in Intensive vegetable production in a greenhouse. *Journal of Agricultural Sciences (Belgrade)*, 65(3), 199-212. https://doi.org/10.2298/JAS2003199C

6. ChatGPT 3.5 (2024) https://chat.openai.com/ (accessed: 17.03.2024)

7. Danojević, D., Medić-Pap, S., Savić, A., & Červenski, J. (2016). Fruit traits of pepper genotypes originating from open pollination. *Ratarstvo i povrtarstvo/Field and Vegetable Crops Research*, 53(2), 69-73. https://doi.org/10.5937/ratpov53-9761

8. Farfan, J., Lohrmann, A., & Breyer, C. (2019). Integration of greenhouse agriculture to the energy infrastructure as an alimentary solution. *Renewable and Sustainable Energy Reviews*, 110, 368-377. https://doi.org/10.1016/j.rser.2019.04.084

9. Georgiev, M. (2025). Examining the correlation between cloud technology, the improvement of IFRS development, and the efficiency of accounting functions. *BizInfo Blace*, *16*(2), 75-84. https://doi.org/10.71159/bizinfo250017G

10. Jang, W. D., Jeon, S. J., Choi, K. Y., & Na, J. K. (2023). Evaluation of the Growth and Yield Characteristics of Six Domestic Sweet Pepper Cultivars. *Horticultural Science and Technology*, 41(3), 271-284. https://doi.org/10.7235/HORT.20230025

11. Jimenez-Lao, R., Aguilar, F. J., Nemmaoui, A., & Aguilar, M. A. (2020). Remote sensing of agricultural greenhouses and plastic-mulched farmland: An analysis of worldwide research. *Remote Sensing*, 12(16), 2649. https://doi.org/10.3390/rs12162649

12. Johansen, A. M., Evers, L., & Whiteley, N. (2010). Monte carlo methods. *International encyclopedia of education*, 296-303. https://people.bordeaux.inria.fr/pierre.delmoral/teaching-notes-levers-johansen.pdf

13. Jung, J., Maeda, M., Chang, A., Bhandari, M., Ashapure, A., & Landivar-Bowles, J. (2021). The potential of remote sensing and artificial intelligence as tools to improve the resilience of agriculture production systems. *Current Opinion in Biotechnology*, 70, 15-22. https://doi.org/10.1016/j.copbio.2020.09.003

14. Kelley, W. T., Boyhan, G. E., Harrison, K. A., Granberry, D. M., Langston, D. B., Sparks, A. N., Culpepper S., Hurst W. C. & Fonsah, E. G. (2009). *Commercial pepper production handbook,* University of Georgia, SAD. https://hdl.handle.net/10724/12339

15. Lamont, W. J. (2009). Overview of the use of high tunnels worldwide. *HortTechnology,* 19(1), 25-29. https://doi.org/10.21273/HORTTECH.19.1.25

16. Lin, W. C., Frey, D., Nigh, G. D., & Ying, C. C. (2009). Combined analysis to characterize yield pattern of greenhouse-grown red sweet peppers. *HortScience*, 44(2), 362-365. https://doi.org/10.21273/HORTSCI.44.2.362

17. Liu, X., & Xin, L. (2023). Spatial and temporal evolution and greenhouse gas emissions of China's agricultural plastic greenhouses. *Science of The Total Environment*, 863, 160810. https://doi.org/10.1016/j.scitotenv.2022.160810

18. Lončarić, Z., Teklić, T., Lončarić, R., Vidović, I., & Jug, D. (1999). The plant population influence on yield and market price influence on profit of high tunnel grown bell pepper. *Poljoprivreda*, 5:53-59.

19. Madala, N., & Nutakki, M. K. (2020). Hot pepper-history-health and dietary benefits & production. *International Journal of Current Microbiology and Applied Sciences,* 9(4), 2532-2538. https://doi.org/10.20546/ijcmas.2020.904.303

20. Marcelis, L., Costa, J. M., & Heuvelink, E. (2019). *Achieving sustainable greenhouse production: present status, recent advances and future developments.* In L. Marcelis, & E. Heuvelink (Eds.), Achieving sustainable greenhouse cultivation (1 ed., pp. 1-14). Burleigh Dodds Science Publishing.

21. McCoy, S. R., Hochmuth, R. C., Laughlin, W. L., Gazula, A., & Fenneman, D. K. (2013). Economic analysis of fresh green bell pepper (*Capsicum annuum*) production under shade structures. *In Proceedings of the Florida State Horticultural Society*, 126, 101-106. https://svaec.ifas.ufl.edu/media/svaecifasufledu/docs/pdf/agribusiness/McCoy2013_EconAnalShadePeppers.pdf

22. Mladenović, J., Pavlović, N., Ugrinović, M., Pavlovic, R., & Zdravković, J. (2016). Analysis and forecasting of profit by using simulation models for growing pea in conventional and organic plant production in Serbia. *Economics of agriculture*, 63(3), 987–995. https://doi.org/10.5937/ekoPolj1603987M

23. Naderi, S. A., Dehkordi, A. L., & Taki, M. (2019). Energy and environmental evaluation of greenhouse bell pepper production with life cycle assessment approach. *Environmental and sustainability indicators*, 3, 100011. https://doi.org/10.1016/j.indic.2019.100011

24. Padrón, R. A. R., Swarowsky, A., Schons, A., Cánepa, P., & Gamazo, P. (2016). Economic analysis in bell pepper crop on open field production system and under irrigation depths. *Acta Iguazu*, 5(1), 11-21. (https://doi.org/10.48075/actaiguaz.v5i1.14190) https://e-revista.unioeste.br/index.php/actaiguazu/article/view/14190/9638

25. Pantović, D., Lojanica, N., Bojnec, Š., & Gričar, S. (2026). Assessing Disparities in Climate and Energy Agri-Environmental Indicators Among EU Countries Using the PROMETHEE–GAIA Method and the Entropy Index. *Agriculture*, 16(4), 463. ;https://doi.org/10.3390/agriculture16040463
26. Parađiković, N., Vinković, T., Vinković Vrček, I., Žuntar, I., Bojić, M. & Medić-Šarić, M. 2011. Effect of natural biostimulants on yield and nutritional quality: an example of sweet yellow pepper (*Capsicum annuum* L.) plants. *Journal of the Science of Food and Agriculture* 91:2146−2152. https://doi.org/10.1002/jsfa.4431
27. Parađiković, N., Vinković, T., Vrček, I. V., & Tkalec, M. (2013). Natural biostimulants reduce the incidence of BER in sweet yellow pepper plants (*Capsicum annuum* L.). *Agricultural and food science*, 22(2), 307-317. https://doi.org/10.23986/afsci.7354
28. Pavlović, N. (2014). *Personal survey*, Unpublished data, Smederevska Palanka, Serbia.
29. Pavlović, N., Ugrinović, M., & Zdravković, M. (2010). Economic and agronomic analysis of organic production of tomato and pepper. *Economics of agriculture*, 57 (Spec. num. 2), 153-157. https://rivec.institut-palanka.rs/bitstream/handle/123456789/227/bitstream_540.pdf?sequence=1&isAllowed=y
30. Pavlović, N., Ugrinović, M., Vojnović, B., & Rudež, J. (2014). Economic and agronomic analysis of conventional and organic concept of cucumber growing. *Economics of agriculture*, 61(4), 895-902. https://rivec.institut-palanka.rs/bitstream/handle/123456789/149/146.pdf?sequence=1&isAllowed=y
31. Petrović, M., Savić, B., & Cvijanović, V. (2021). Financial aspects of pepper (*Capsicum annuum* L) production on family farms in Serbia. *Economics of agriculture*, 68(4), 1015-1028. https://doi.org/10.5937/ekoPolj2104015P
32. Praća, N., Krstić, S., & Božić, N. (2024). Vrste i metode povećavanja viška vrednosti. *Održivi razvoj*, *6*(2), 35-47. https://doi.org/10.5937/OdrRaz2402035
33. Qasim, W., Xia, L., Lin, S., Wan, L., Zhao, Y., & Butterbach-Bahl, K. (2021). Global greenhouse vegetable production systems are hotspots of soil N_2O emissions and nitrogen leaching: A meta-analysis. *Environmental Pollution*, 272, 116372. https://doi.org/10.1016/j.envpol.2020.116372
34. Salkić, B., Čerkezović, N., Imširović, E., Aličić, D., & Hodžić, A. (2020). Growing forms of peppers. *World Journal of Biology Pharmacy and Health Sciences*, 3(1), 029-037. https://doi.org/10.30574/wjbphs.2020.3.1.0045
35. Sánchez, J. M., Rodríguez, J. P., & Espitia, H. E. (2020). Review of artificial intelligence applied in decision-making processes in agricultural public policy. *Processes*, 8(11), 1374. https://doi.org/10.3390/pr8111374
36. SORS (2024) – Statistic Office of Republic of Serbia, https://data.stat.gov.rs/Home/Result/130102?languageCode=en-US (Accessed 15.03.2024.)
37. STIPS (2024). Sistem tržišnih informacija poljoprivrede Srbije za 2017. i 2018. godinu. https://www.stips.minpolj.gov.rs/ (accessed: 20.03.2024.)

38. Tripodi, P., Rabanus-Wallace, M. T., Barchi, L., Kale, S., Esposito, S., Acquadro, A., Schafleitnerd, R., van Zonnevelddd, M., Prohense, J., José Dieze, M., Börnerb, A., Salinierf, J., Caromelf, B., Bovyg, A., Boyacih, F., Pasevi, G., Brandtb, R., Himmelbachb, A., Portisc, E., Finkersg, R., Lanteric, S., Paranj, I., Lefebvref, V., Giuliano, G., & Stein, N. (2021). Global range expansion history of pepper (Capsicum spp.) revealed by over 10,000 genebank accessions. *Proceedings of the National Academy of Sciences*, 118(34), 1-9, https://doi.org/10.1073/pnas.2104315118

39. Yen L. (2024). How to Run a Monte Carlo Simulation in Excel: 5 Key Steps. Datamation. https://www.datamation.com/big-data/how-to-run-monte-carlo-simulation-in-excel/ (accessed: 20.03.2024.)