HISTORICAL DEVELOPMENT OF SOYBEAN PRODUCTION DEPENDING ON THE AGROECOLOGICAL CONDITIONS OF SERBIA

Zlatica Mamlić[1], Vojin Đukić [2], Petar Čanak [3], Ana Uhlarik [4], Sanja Vasiljević [5], Marija Bajagić [6], Jegor Miladinović [7]

**Corresponding author E-mail: zlatica.miladinov@ifvcns.ns.ac.rs*

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ABSTRACT

In order for the production of a plant species to take a significant place in the crop structure, in addition to favorable agro-ecological conditions, there must be a national strategy. After the state implemented the "action" plan, the processing sector and breeding, i.e. the development of high-yielding domestic varieties, with good adaptability and stability, intensified. This implied that Serbia would become the only country in Europe that produces enough soybeans for its own needs. The aim of the research is the influence of agro-climatic conditions on soybean production in the province of Vojvodina. High-yielding soybean varieties contributed to an average yield of over 3,000 kg ha-1 for the period 2010-2019. Intensive development of new soybean varieties is aimed at addressing climate change, which has become increasingly unfavorable. Data indicate that interest in soybean production in Serbia is growing and this trend is expected to continue in the future.

1 Zlatica Mamlić, Senior Scientific Advisor, Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia, Email: zlatica.miladinov@ifvcns.ns.ac.rs, ORCID ID (https://orcid.org/0000-0002-8564-8249)

2 Vojin Đukić, Scientific Advisor, Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia, Email: vojin.djukic@ifvcns.ns.ac.rs, ORCID ID (https://orcid.org/0000-0002-6615-805X)

3 Petar Čanak, Senior Scientific Advisor, Maize Research Institute "Zemun Polje", Slobodana Bajića 1, 11185 Belgrade, Serbia, Email: pcanak@mrizp.rs, ORCID ID (https://orcid.org/0009-0001-8661-8965)

4 Ana Uhlarik, Scientific Associate, Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia, Email: ana.uhlarik@ifvcns.ns.ac.rs, ORCID ID (https://orcid.org/0000-0002-7587-2247)

5 Sanja Vasiljević, Scientific Advisor, Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia, Email: sanja.vasiljevic@ifvcns.ns.ac.rs, ORCID ID (https://orcid.org/0000-0003-2042-1542)

6 Marija Bajagić, Assistant Professor, University Bijeljina, Faculty of Agriculture, Pavlovića put bb, 76300 Bijeljina, Republic of Srpska, Bosnia and Herzegovina, Email: bajagicmarija@yahoo.com, ORCID ID (https://orcid.org/0000-0001-9537-8302)

7 Jegor Miladinović, Scientific Advisor, Institute of Field and Vegetable Crops, Maksima Gorkog 30, 21000 Novi Sad, Serbia, Email: jegor.miladinovic@ifvcns.ns.ac.rs, ORCID ID (https://orcid.org/0000-0002-4061-4037)

Introduction

Soybeans originate from China. Most scientists believe that the origin of this plant species is the Yunnan-Guizhou plateau. Also, it is widely believed that modern cultivated soybean was domesticated from wild soybean (*Glycine soja* Sieb. & Zucc.) in East Asia 6,000-9,000 years ago (Milojević et al., 2020; Kim et al., 2012). The recent history of soybeans began in the 19th century in America, where it spread across the globe and took on a significant role in modern agriculture (Pantić et al., 2022; Whigham, 1983). It was brought to Europe in 1692, thanks to botanist Engelbert Kaempfer. Its cultivation in Europe began in the 19th century, with the first planting in France in 1840. Until then, soybeans were only grown in botanical gardens. From France, it spread to Austria and other European countries. Significant soybean cultivation in America and Europe began between the two world wars, initially for producing bulk animal feed and increasingly for grain production (Penjišević et al., 2024; Davydenko et al., 2004). Today, soybeans are grown in all parts of the world, with the main production centers being South and North America. The share of Europe in total world soybean production is 1-2%, and this plant is important only for certain countries. Significant fluctuations in areas, primarily in EU countries, result from reduced subsidies and lower profits for the producers, despite record yields. Due to these factors, Russia and Ukraine have emerged as the primary producers of soybeans in Europe. The four largest soybean-producing countries in Europe are the Russian Federation, Ukraine, Italy, and Serbia, followed by France and Romania (FAOSTAT, 2022).

Serbia is the only country in Europe that produces enough soybeans for its needs. Soybean has been present in Serbia since the beginning of the 20th century, but the areas varied greatly. Poor knowledge of the use value of soybeans and their products by agricultural producers meant that it could not occupy a significant place in the structure of agricultural production (Bošković, 1966). Soybean is mainly grown in Vojvodina. Today, the areas under soybeans in this area make up about 93% of the total area of this crop in Serbia (Mihajlović et al., 2024; Bošnjak and Rodić, 2010). In Vojvodina, the grain yield of soybean is dependent on RGS (the amount and distribution of rainfall during the growing season) because production is exclusively organized under dry land farming conditions. Information on the amount and distribution of rainfall is a very important strategy for soybean productivity because it is estimated that extreme weather conditions (drought and heat waves) will become even more intensive in the future (Lalić et al., 2011).

Therefore, it is crucial to analyze the soybean production trend over a span of seven decades (1950-2019) in the region of Serbia. This analysis aims to establish the potential impact of weather conditions, precipitation levels, and average monthly air temperature on the production specifically in the province of Vojvodina, which accounts for 93% of the total production of this plant species.

To analyze soybean production in Serbia, data for harvested area, production, and yield of soybean were used from the Agriculture in Serbia, 1947-1996 (1998) and Statistical Yearbook of the Republic of Serbia from 1997 to 2019.

Materials and methods

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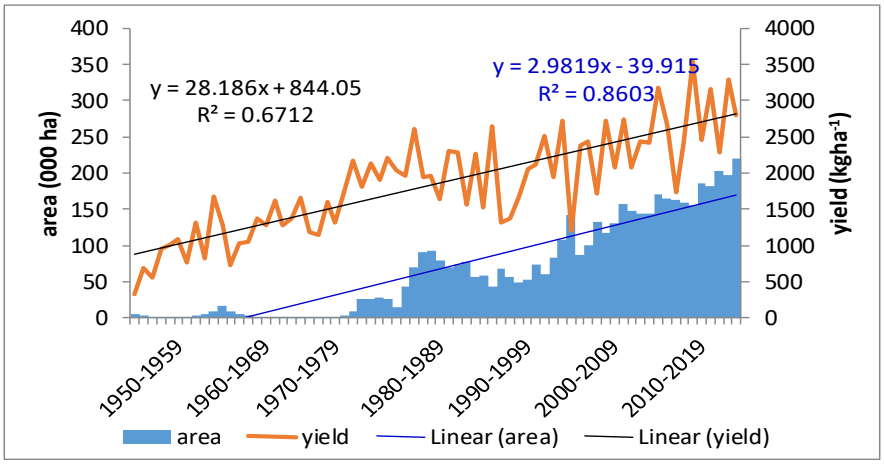
Results and Discussions

Trend of soybean production in the Serbia from 1950-2019

The results showed that from 1950-2019, the area under soybeans increased from 4,312 ha to 220,000 ha, i.e. 51 times more with a tendency for further growth (*Figure 1*). In this way, Serbia has become a significant producer of soybeans in Europe. In Serbia, the production of genetically modified soybeans is not allowed (Official Gazette of the RS", No. 41/2009), which enables Serbia to export this plant species to markets that exclude the use of GMOs and for soybeans produced in Serbia to be in high demand on the European market. According to data According to the European Commission (2013)[8], about 90% of the total soybean production in the world comes from genetically modified varieties. Since European consumers are distrustful of GMO technology and taking into account that there is a growing interest in products that do not contain GMOs, retail chains and other relevant institutions support sustainable compositions in the production of soybeans that are not genetically modified (Rizov and Rodriguez-Cerezo, 2015). In addition to the area, the average soybean yield also increased significantly. In 1950, the average yield was 336 kg ha^{-1}, and in 2019 it was 2800 kg ha^{-1}. In seventy years, the soybean yield has increased more than 8 times. However, in some years of the last decade, significantly higher yields were achieved than in 2019. The maximum yield was achieved in 2014. It amounted to 3539 kg ha^{-1}, which is more than 10 times compared to 1950.

Figure 1. Areas and yields by decades in the period from 1950-2019



Source: https://www.hidmet.gov.rs/index_eng.php

8 https://commission.europa.eu/publications/annual-activity-reports-2013_en

Analysis of production by decades

In accordance with *Table 1*, where data are summarized by decade, a detailed analysis of the impact of various factors on yield increase is described for each year. The yield increase was influenced by several factors, but the most important was the choice of genotype and the applied agricultural production techniques.

Table 1. Correlations of areas and yields by decades in the period from 1950-2019

Decades	Average areas (ha)	Average yield (kg ha^{-1})	Correlation coefficient of average areas	Correlation coefficient of average yields
1950-1959	1390	917	Y= 330,8x-429,8 R^2= 0,4126	Y=119,27x+261,2 R^2=0,7475
1960-1969	1372	1187	Y= -634,83x+4863,7 R^2= 0,4074	Y= 14,352x+1108,1 R^2= 0,0169
1970-1979	10599	1763	Y= 3553,1x-8942,9 R^2= 0,8352	Y= 115,45x+1128,4 R^2= 0,6248
1980-1989	59287	1995	Y= 2780,3x+43995 R^2= 0,1629	Y= 19,4x+1888 R^2= 0,0446
1990-1999	58444	2001	Y= 4477,5x+33818 R^2= 0,5425	Y= 89,121x+1510,7 R^2= 0,259
2000-2009	121342	2309	Y= 3992,8x+99381 R^2= 0,34	Y= 76,333x+1888,7 R^2= 0,2083
2010-2019	165778	2806	Y= 5427,8x+135925 R^2= 0,6697	Y= 43,309x+2567,4 R^2= 0,0541

Source: Authors

Soybean has been present in Serbia since the beginning of the 20th century. In the beginning, it was cultivated as a substitute for coffee, because agricultural producers were not sufficiently educated about its utility value. Observing the period from 1950 to 1959, it can be seen that the area under soybeans in Serbia ranged from 857 ha in 1953 to 8443 ha in 1959, and the average yields ranged from 336 kg ha^{-1} in 1950 to 1675 kg ha^{-1} in 1959. In the period from 1959-1961, another attempt to expand the area under soybeans was recorded. However, a significant decline was recorded in the following period. At the beginning of the seventies, in 1972, soybeans were sown on only 625 ha. The reason for the weak spread of this plant species is the lack of tradition, i.e. insufficient knowledge of soybean, weak economic motivation, and a lack of capacity for processing high-quality products (Bošković, 1966). A significant increase in the area under soybeans began in 1975, when the state adopted an action plan and opened processing capacities. That year, 9,683 ha were sown under soybeans, and 25,944 ha the following year. In the next few years, a moderate increase in areas was recorded, except in 1980, when there was a significant decrease in areas. What characterizes the next two decades of production (1980-1989 and 1990-19999) are large oscillations in surfaces. After the adoption of the action plan by the state, yields above 2000 kg ha^{-1} were achieved for the first time. In 1982, an average yield of 2606 kg ha^{-1} was achieved, which shows not only that there are favorable natural conditions for growing soybeans, but also that agricultural producers have learned and mastered the production technology (Miladinović et al., 2008). In the

mid-seventies, intensive work on soybean breeding and cultivation technology began at the Institute for Crop and Vegetable Farming in Novi Sad. The first soybean variety was registered in 1979 (NS Kasna). However, only introduced, American soybean varieties are present in production: Evans, Hodgson, Hark, Amsoy, and Corsoy. In 1983, the soybean processing factory in Bečej began operating, which contributed to the further increase of the area under soybeans in Vojvodina. With the introduction of high-yield domestic soybean varieties (NS-6, NS-9, NS-10, NS-16 and NS-21), which suppressed foreign, introduced soybean varieties, the average yield of soybeans per hectare continued to increase. During the 1990s, varieties selected at the Institute of Agriculture, i.e. domestic varieties Ravnica, Balkan, and Vojvođanka very quickly occupied a significant place in the sowing structure and completely suppressed the introduced American soybean varieties. In the next two decades, along with corn, wheat, and sunflower, soybean became the leading plant species in the fields, and Serbia became one of the most important producers of this plant species in Europe. In the period from 2010 to 2019. There were four years with a yield above 3000 kg ha^{-1}, which speaks in favor of the fact that soybean producers have mastered the production technology of this plant species well and that they have at their disposal top-quality, high-yielding soybean varieties with good adaptability and stability. Also, the above data indicate that interest in soybean production in Serbia is still growing and that this trend will continue in the coming years.

Analysis of the influence of weather conditions on soybean yield in the province of Vojvodina - Serbia

Vojvodina - Serbia is a production area recognizable by its favorable natural conditions for organizing agricultural production. This statement is primarily supported by the available funds of arable land, which makes up nearly 90% of the total agricultural land in this area (Bošnjak and Rodić, 2011). If we take into account the fact that over 43% of the total territory of Vojvodina consists of chernozem (Hadžić et al., 2005), then Vojvodina is certainly an area with significant land production potential.

For the analysis of agrometeorological conditions on soybean production, data taken from Meteorological yearbooks (Republic Hydrometeorological Service of Serbia) including seven meteorological stations that have data on monthly rainfall (*Table 2*) were used. Selected rainfall stations are equally distributed in the region of Vojvodina (one station per 3000 km^2).

Table 2. List of meteorological stations included in the study

Station	Latitude	Longitude	Amplitude (m)
Novi Sad	45° 15’ 46”	019° 51’ 07”	84
Palić	46° 06’ 11”	019° 45’ 31”	102
Sombor	45° 47’ 00”	019° 07’ 00”	89
Kikinda	45° 49’ 41”	020° 27’ 55”	81
Zrenjanin	45° 21’ 55”	020° 24’ 13”	81
Banatski Karlovac	45° 02’ 58”	021° 01’ 00”	99
Sremska Mitrovica	44° 59’ 00”	019° 37’ 00”	82

Source: Authors

Data during the growing season of soybeans (April-September) on the sum of precipitation and average air temperature are shown in *Table 3*. Sum of precipitation in the growing season from 1950 to 2019 was 365.3 mm, while the average air temperature was 18.2°C. When looking at rainfall by decade, a significant difference can be seen.

Table 3. The sum of precipitation (mm) and average mean temperature (°C) for the multi-year period 1950–2019

Year / Mounth	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2009	2010-2019
The sum of precipitation (mm)							
April	53.3	42.7	46.6	55.3	42.3	46.3	50.7
May	64.8	52.4	57.3	67.6	59.8	61.6	105.8
June	88.0	69.2	88.0	84.4	83.5	97.5	86.3
July	60.4	74.8	66.9	44.6	88.6	56.3	57.0
August	52.6	42.9	72.9	51.5	58.3	53.0	57.3
September	35.5	37.1	35.6	33.7	56.2	63.0	54.7
Sum	**354.6**	**319.1**	**367.2**	**337.0**	**389.6**	**377.6**	**411.7**
Average mean temperature (°C)							
April	11.1	11.9	10.9	11.3	11.3	12.6	13.4
May	16.1	16.4	16.5	16.6	16.8	18.0	17.3
June	20.0	19.9	19.6	19.2	20.2	20.8	21.5
July	22.2	21.1	20.7	21.4	21.7	22.5	23.1
August	21.4	20.7	20.2	20.8	21.7	22.1	23.3
September	17.1	17.2	16.0	17.6	16.7	16.7	18.1
Average	**18.0**	**17.9**	**17.3**	**17.8**	**18.1**	**18.8**	**19.4**

Source: Authors

The maximum amount of precipitation during the growing season was recorded in the period from 2010 to 2019, 411.7 mm, and the minimum in the period from 1960 to 1969, 319.1 mm. In the period from 2010 to 2019, there was 92.6 mm, or 22.40%, more precipitation during the growing season than in the period from 1960 to 1969. Also, in the last three decades, from 1990 to 2019 there was more precipitation per decade than in the period from 1950 to 1989.

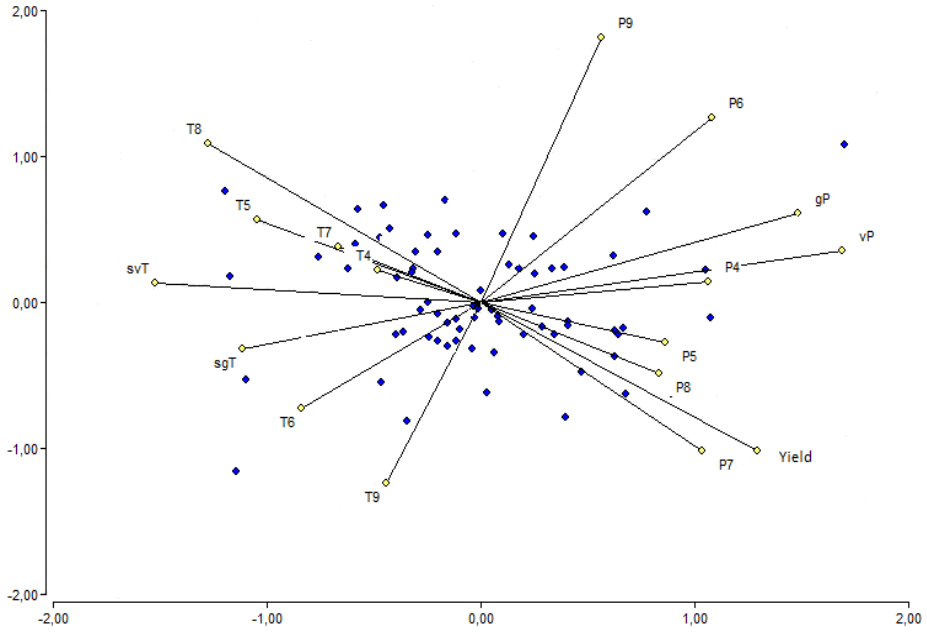
A significant difference was also found in the average air temperature if observed by decades. The maximum average temperature was determined in the period from 2010 to 2019, 19.4°C, and the minimum in the period from 1970 to 1979, 17.3°C. In the period from 2010 to 2019, the average air temperature was 2.1°C higher than in the period from 1970 to 1979. Also, there has been a significant increase in average temperatures in the last three decades, from 1990 to 2019, than in the period from 1950 to 1989.

Soybean is one of the most important oil and protein crops in the world and is grown under a wide range of environmental conditions, where climate factors such as temperature, photoperiod, and moisture stress exert a detrimental effect on plant growth and metabolism (Khan et al., 2007; Shirazi et al., 2024). There is a lot of research on the topic of the critical period of soybean development. Some authors point out that the

lack of rainfall and high temperatures in the flowering phase have the greatest impact on soybean yield (Foroud et al., 1993), while others have come to the conclusion that weather conditions during pouring have a greater effect on yield (Shadakshari et al., 2014; Giordani et al., 2019). In general, weather conditions during the entire generative period of soybeans have a significant impact on soybean yield (Miladinov et al., 2020; Mamlić et al., 2024). In the Republic of Serbia, that is, in its province Vojvodina, the generative period of soybeans begins at the end of June and ends at the end of August. When it will start and how long the generative period will last depends primarily on weather conditions, the soybean ripening group, and the sowing date. In *Figure 2*, you can see that connection-that is, a very strong positive connection between yields and precipitation during the months of July and August.

Figure 2. Dependence of yield on agrometeorological conditions during the growing season

(T4-T9 average monthly air temperatures from April to September; P4-P9 average monthly rainfall, gP-annual sum of rainfall; vP-sum of precipitation during the growing season; gT-average annual air temperature; vT-average temperature during vegetation)



Source: Authors

Somewhat weaker, but also positively, it was affected by precipitation in April. In addition to the reproductive period, germination and initial growth also affect yield because they determine crop composition and uniformity (Cheng and Bradford, 1999; Đukić et al., 2017). In Vojvodina, the optimal time for sowing soybeans is during the

month of April, so soil moisture or rainfall has an impact on the yield. However, this connection is not as strong as in the reproductive period, which can be seen in the graph. The rainfall in June had very little, and the rainfall in September had no effect on the soybean yield because it was already in the ripening phase. When soybeans suffer high temperatures during the seed-filling stage, their yields are reduced, and their seed compositions change (Nakagawa et al., 2020). The same conclusion, about the influence of high temperatures on the yield of soybeans, can be made in these studies by looking at *Figure 2*. The most negative impact on the yield was the high temperature in the month of August when soybeans were mostly in the seed-filling phase. Also, a very strong negative impact of high temperatures in April, May, and July can be observed. Djanaguiraman and Prasad (2010) determined that temperatures higher than optimal during the vegetative period reduce photosynthetic activity and increase the rate of ethylene production, which leads to aging of the leaves. The consequence of all this is a decrease in yield. Puteh et al., (2013) point out that in the flowering phase at temperatures above the optimum, the intensity of photosynthesis and pollen germination decrease, which results in a lower number of pods and weight of 1000 seeds. In the research conducted by Lobell and Asner (2003), it is stated that with each increase of the mean vegetative temperature by 1°C compared to the optimum, the soybean yield decreases by as much as 17%.

Conclusions

Soybean cultivation in Serbia does not have a long tradition, although there are favorable agroecological conditions for it. In order for a plant species to establish itself in production, there must also be an economic interest in its cultivation. Therefore, only with the adoption of the action plan by the state did this plant species begin to occupy a significant place in the sowing structure. Today, soybean is in fourth place in Serbia, after corn, wheat, and sunflower. In addition to the establishment of factories for obtaining final products from soybeans, a great contribution to this success was made by the Institute for Crop and Vegetable Agriculture, i.e. the creation of domestic high-yielding varieties with good adaptability and stability. The research results also show that the interest in soybean production in Serbia is still growing, and this trend will continue in the coming years.

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Conflict of interests

The authors declare no conflict of interest.

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