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THE INFLUENCE OF CLIMATE CONDITIONS ON MAIZE YIELD IN THE SOUTHEREN PART OF SERBIA

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ABSTRACT

Precipitation and temperatures are of particular importance for maize production. The aim of these studies was to analyze the yields of different maize hybrids in years that were both favorable and unfavorable for their production. Thus, the yield of maize in 2020 and 2021 was analyzed in the area of Southern Serbia (Leskovac). The year 2020 can be considered favorable for the production of maize, primarily due to the amount of precipitation during the vegetation (436 mm) and its proper distribution in the summer months. The year 2021 can be considered unfavorable for the production of maize, which is especially evident by the small amount of precipitation during the growing season (219 mm). The influence of the year, especially the climatic conditions of the year, was very pronounced. Thus, the average yield in 2021 was lower by 36% compared to 2020. The influence of hybrids on yield was pronounced, and differences in yield were statistically very significant. Hybrids with a shorter vegetation period had good yields in the unfavorable (dry) year, all due to the earlier passing of silking, fertilization, and grain formation phases. In years favorable for maize production, such as 2020, hybrids with a longer vegetation period showed their genetic potential for yield and were more dominant than hybrids with a shorter vegetation period. If maize is grown on dry soil, it is recommended to sow more hybrids of different vegetation lengths, for safer production.

Key words: maize, precipitation, temperatures, yield.

INTRODUCTION

Maize grain yield is not only conditioned by climatic factors, but also by the potential of hybrids, soil conditions, as well as the way of management. Maize has a large vegetative mass and a long period of vegetation, so it is considered to consume a large amount of water (Bošnjak & Pejić, 1997). Although it is quite resistant to drought and consumes water economically, in conditions of lack of precipitation, it gives lower yields. Precipitation and temperatures are of particular importance for maize production. Thus, the amount of accessible water in the soil depends on precipitation. Pejić et al. (2009) point out that maize is most sensitive to soil water deficit during the period of vegetative growth, flowering, fertilization, and grain filling. The expected increase in temperatures and reduced annual precipitation in the coming period are the result of global warming, which may result in the reduced production of quality food. Thus, maize yields in such conditions can be reduced by up to 50-80% compared to yields under irrigation conditions (Božić et al., 2007). Based on some research, it is assumed that the climate in Serbia will continue to be suitable for agricultural production, with the lack of precipitation being one of the limiting factors for crop production (Lalić et al., 2013). Numerous researches show that the need for water in certain cultures in Serbia will increase by the end of the century (Stričević et al., 2019b) and that the area of Southeast Europe will be affected by climate change

(Weber et al., 2018). If the assumptions about future global warming are realized, it is predicted that the yield of maize may decrease by 20-40% and 40-60%, respectively, with an increase in temperature of 2 and 4 ^{0}C (Tigchelaar et al., 2018). Due to such circumstances, Stričević et al. (2021) point out that crop production will need to be adapted to such conditions, primarily through irrigation, harmonization of sowing dates, and selection of appropriate plant species, varieties, and hybrids. Lobell et al. (2013) point out that temperatures above 30 ^{0}C in the period June-August, in the US maize belt, lead to a significant reduction in maize yield, more than the lack of precipitation in that period. The importance of temperature and precipitation for maize yield is shown by the data that the yield is negatively correlated with temperatures in July and August and positively correlated with precipitation in the same period (Maitah et al., 2021). According to the models that predict future climate change, the increase in the average annual temperature by 1.5^{0}C, which will happen in approximately 2020, stands out. It is predicted that in 2030 the temperature will rise by 2^{0}C and then many production regions will be affected by heat stress and drought such as has not been seen before (Zampieri et al., 2019). It is assumed that due to global warming, by the end of the 21st century, corn yield will fall by 15-50%, meaning that each average increase in air temperature of 1^{0}C per season will reduce maize yield by 6%. The same authors point out that regardless of the required precipitation, due to the increase in temperature, the yield will decrease (Xu et al., 2016).

These studies aimed to analyze the yields of different maize hybrids in favorable and unfavorable years for its production.

MATERIAL AND METHODS

The research was conducted in the South of Serbia. The experiment was set up in 2020 and 2021 on the territory of the municipality of Leskovac, on the land of the Smonica type. Samples of soil for chemical analysis were taken from the plots before the survey was set up. The experiment was set up according to the plan of the block system in three repetitions. The previous crop was winter wheat. The experiment included the following hybrids sown in densityes adapted to the given locality:

Table 1. Hybrids and plant density

Hybrids	FAO group	Plant density (p ha^{-1})
ZP 388	FAO 300	57.000
Bc 418	FAO 400	57.000
Bc 525	FAO 500	52.000
ZP 606	FAO 600	51.000
AS 72	FAO 700	51.000

The standard agricultural technique, characteristic of the given area, was applied in the experiment. The preparation of the soil included autumn plowing to a depth of 30 cm, where 300 kg of ha^{-1} NPK was added (16:16:16), while another 200 kg of ha^{-1} KAN was added in the top-dressing. Pre-sowing preparation was performed immediately before sowing with a seed drill. Sowing was done in the second half of April. The treatment against seed weeds was performed the day after sowing, with *Basar* and *Rezon*. The treatment against broadleaf and narrow-leaf weeds was performed with *Siran* and *Maton*. Feeding with KAN was done in the phase of 3-5 leaves, after the first inter-row cultivation. No diseases or pests were present during the vegetation. Maize was harvested at technological maturity. The yield was calculated on each plot and reduced to 14% moisture. Data on precipitation and temperatures were taken from the meteorological station in Leskovac. Maize yield depending on the year was statistically processed through the analysis of variance using WASP 1.0 software.

Climatic and soil characteristics

Table 2 shows the total monthly precipitation and average monthly temperatures during the maize vegetation period. The total amount of precipitation in the vegetation period, in 2020, was 436 mm. It should be noted that in the months of June, July, and August, 290 mm of precipitation fell, which is very important for the process of forming the yield of maize. If we add to this that the average temperatures were also favorable (during the vegetation of maize they were 18.7^{0}C), it can be considered that this year was favorable for the production of maize.

Table 2. Precipitation (mm) and mean temperatures (^{0}C) in Leskovac

	Apr.	May	June	July	Avg.	Sep.	Apr./Sep
			The 2020 growing season				
mm	47	69	121	49	120	30	436
^{0}C	11.6	16.6	19.6	22.4	22.5	19.7	18.7
			The 2021 growing season				
mm	45	47	55	44	4	24	219
^{0}C	10.3	17.4	19.6	24.5	23.7	18.1	18.9
			Multi-year average 1985-2014				
mm	48	46	37	25	24	30	210
^{0}C	12.5	16.5	19.5	22.0	22.5	18.0	18.5

The total amount of precipitation in the vegetation period, in 2021, was 219 mm, which is 217 mm less than in 2020. In the same year, in the months of June, July and August, there was only 103 mm of precipitation (187 mm less than in 2020), so this year can be considered less favorable for maize production. The average temperatures during maize vegetation were 18.9^{0}C and can be considered favorable for maize production.

Compared to the multi-year average (210 mm), both years had a higher amount of precipitation and approximately the same average air temperature. Total precipitation during the vegetation was higher by 226 and 9 mm, respectively, compared to the multi-year average. This is especially true for precipitation in critical months, such as June, July, and August. Average temperatures during the vegetation, in both years, compared to the multi-year average, were similar.

Table 3. Chemical properties of the soil

Type of soil	pH		Humus	Nitrogen	Available (mg/100g of soil)	
	H_2O	KCl	(%)	(%)	P_2O_5	K_2O
Smonica-Vertisol	6.77	5.89	2.18	0.15	20.5	27.3

Soil acidity was determined by the Kapen method, humus was determined by the Kotzman method, total nitrogen by the Kjeldahl method, and available phosphorus and potassium by the Engner-Riehm Al method.

According to the pH values in KCl (5.89), the soil belongs to the group of moderately acidic soils. According to the humus content in the arable layer (2.18), the soil belongs to the group of poorly humus soils (Škorić, 1991). According to the content of total nitrogen (0.15), the soil is moderately provided with this element. The phosphorus content of 20.5 mg/100 g shows that the soil with this element is optimally provided. Furthermore, the potassium content of 27.3 mg/100g indicates the optimal security when this element is in question. Although these soils belong to the group of potentially fertile soils, their intensive use mainly requires the application of reclamation measures.

RESULTS AND DISCUSSIONS

The composition of plants is one of the elements on which the future yield depends. Thus Mandić et al. (2016) emphasize the importance of an optimal set for each hybrid, because only with such a number of plants do hybrids achieve the highest yields, while Sadras and Calderini (2009) note that a good set of plants is the main barrier to the presence of weeds in maize. One of the important factors that determine the density of sowing is the amount and distribution of precipitation. Starčević and Latković (2005) believe that the optimal density is variable and that it should be adjusted to the conditions of the year and the area. The following table shows the yield of different maize hybrids achieved in two years that had different climatic conditions for production.

In our research, the composition of plants was adjusted to the length of hybrid vegetation and area conditions. Thus, hybrids of somewhat shorter vegetation were sown within 57.000 plants per hectare, hybrids of medium length vegetation within 52.000 plants per hectare, and hybrids with a longer period of vegetation within 51.000 plants per hectare.

The moisture content of the grain at the time of harvest is very important from the aspect of safe storage of grain. The average moisture content of grains at harvest time in 2020 was 14.28% and in 2021 13.56%. The lower moisture content in the grain in 2021 is the result of drought during the summer and higher temperatures. In both years, hybrids with a longer vegetation period had higher moisture content in the grain compared to hybrids with a shorter vegetation period.

Table 4. Yield maize (kg ha^{-1}) and moisture (%) of some hybrids depending on the year

A.Hybrids	Plant density (p ha^{-1})	Moisture (%)		B.Year		Average
		2020	2021	2020	2021	
ZP 388	57.000	12.60	12.10	10.560	8.670	9.615
Bc 418	57.000	13.20	12.90	9.087	5.170	7.129
Bc 525	52.000	15.75	14.40	11.400	6.330	8.865
ZP 606	51.000	14.40	13.90	12.070	7.201	9.636
AS 72	51.000	15.48	14.50	10.125	6.705	8.415
Average	53.600	14.28	13.56	10.648	6.815	8.732
			LSD	A	B	A x B
			0.05	618	391	874
			0.01	847	535	1.197

The influence of hybrids on yield was very pronounced so that the average two-year yields between hybrids had statistically very significant differences. The average yield of maize for both years ranged from 7.129 kg ha^{-1} in hybrid Bc 418 to 9.636 kg ha^{-1}, in hybrid ZP 606. The lowest average yield (7.129 kg ha^{-1}) had hybrid Bc and it was quite lower than the yields of other hybrids. Hybrids ZP 606 and ZP 388 had similar yields (9.636 and 9.615 kg ha^{-1}) and they were quite higher than the yields of other hybrids. No statistically significant differences in grain yield were found between hybrids Bc 525 and AS 72. It is noticed that the hybrid ZP 606 had a significantly higher average yield than the hybrids Bc 418, Bc 525 and AS 72.

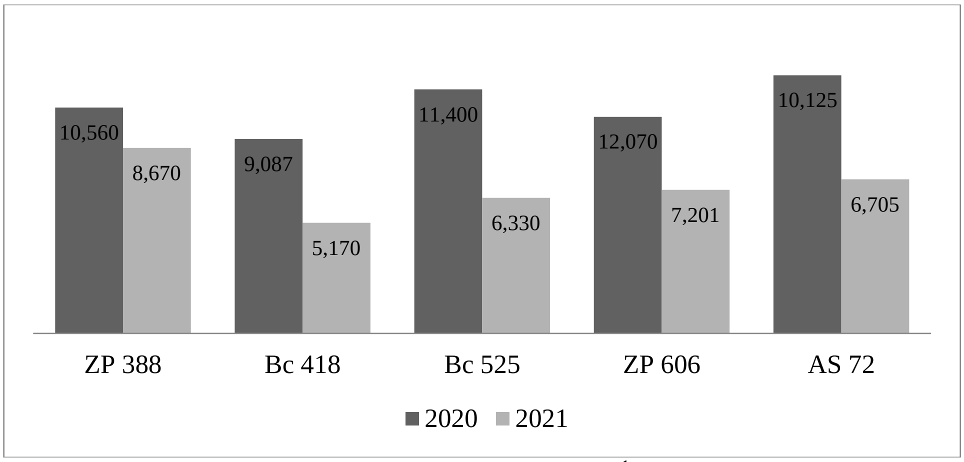

Figure 1. Yield maize of some hybrids (kg ha^{-1}) depending on the year

The influence of the year, primarily the climatic conditions of the year, was very pronounced. If it is known that these two years were different in terms of benefits for maize production, then large differences in yield are expected. Thus, the average yield of maize hybrids in 2020 was 10.648 kg ha^{-1} and in 2021 6.815 kg ha^{-1}. The difference in yield depending on the year was 3,833 kg ha^{-1}. The year 2020 can be considered favorable for corn production, as shown by the yields in our research. The total amount of precipitation, with a good schedule, especially in June, July, and August (290 mm), with favorable average temperatures, contributed to high yields, ranging from 9,087 kg ha^{-1} (Bc 418) to 12,070 kg ha^{-1} (ZP 606). These results are in line with the statements of Bella et al. (2014) that point out that the amount and distribution of precipitation during the vegetation period, especially during flowering and grain filling, play an important role in the manifestation of the yield potential of hybrids.

In favorable years, such as 2020, hybrids with a longer vegetation period show their genetic yield potential and are more dominant than hybrids with a shorter vegetation period.

The year 2021 can be considered unfavorable for the production of maize, which is especially evident in the amount of precipitation during the growing season (219 mm). Reddy and Boykin (2010) point out that maize needs 600–700 mm for optimal growth and development during the growing season. Dietzel et al. (2015) believe that the amount of 400-450 mm during the season is sufficient for successful corn production. The amount of precipitation in June, July, and August should be especially emphasized because this is the period when maize is in the phase of broom and pollen formation, fertilization, and grain filling (Bassey et al. 2019). Not only the lack of precipitation but also higher summer temperatures, highly affect the yield. Thus Lobell and Burke (2010) point out that an increase in temperature of 2 ° C causes a greater reduction in yield than a lack of precipitation of 20%. The amount of precipitation of 103 mm in June, July, and August, with higher average temperatures (2.1 and 1.2 ° C, respectively, for July and August) had a negative impact on the yield of maize. Thus, the average yield in 2021 was lower by 36% compared to 2020. Hybrids with a shorter vegetation period are less sensitive to drought during the summer, so the differences in yield are smaller (17.9%), in contrast to hybrids with a longer vegetation period where these differences amounted to 44.5%. Usually in conditions when the summers are dry, hybrids of shorter vegetation periods achieve higher yields than hybrids of longer vegetation periods. Thanks to the fact that the stages of silking, fertilization, and grain formation pass earlier and thus avoid the dry period and high temperatures, they also have higher yields. This was also shown in our research, where the hybrid ZP 388 had a significantly higher yield than other hybrids. The allegations of Stričević et al. (2019 a) indicate that, in the last two decades, frequent droughts and increased air temperatures in Serbia have drastically reduced the yields of many field crops. Lui et al. (2019) point out that in China, in the corn production regions, in the period from 2000 to 2009, maize yields decreased by 40 to 47% in years when air temperatures were high and seasonal rainfall was less than 450 mm, especially in the stages of flowering and grain filling. The production of maize in dry farming is unstable, so several hybrids of different vegetation lengths should be grown for that, to make the production safer.

CONCLUSION

The amount of precipitation during the vegetation, especially in the months of June, July, and August in 2020, contributed to the fact that this year is characterized as favorable for the production of maize, which was not the case in 2021 when climatic conditions were much worse. The influence of the year, primarily climatic conditions, had a strong effect on the yield of maize. Thus, the average yield in 2021 was lower by 36% compared to 2020. The difference in yield depending on the year was 3.833 kg ha^{-1}. The influence of hybrids on yield was very pronounced, and differences in yield were statistically very significant. Differences in yield between favorable and unfavorable years, in hybrids of shorter vegetation periods, are less pronounced (17.9%), in contrast to hybrids of longer vegetation periods where these differences amounted to up to 44.5%. Hybrids with a shorter vegetation period had good yields in the dry year because they had previously gone through the stages of silking, fertilization, and grain formation, thus avoiding the dry period and high temperatures. In a year favorable for production, such as 2020, hybrids with a longer vegetation period showed their genetic potential for yield and were more dominant than hybrids with a shorter vegetation period. If maize is grown in dry farming, it is recommended to sow more hybrids of different vegetation lengths, for safer production.

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