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The impact of irrigation on yield components of maize

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Abstract

Maize is the most widely cultivated crop on arable land in Bosnia and Herzegovina. Yields are quite inconsistent due to several factors, with one of the most significant being the lack of moisture during the growing season, particularly during the pollination period. Irrigation is a measure taken to mitigate the harmful effects of drought. A maize field trial was conducted over two growing seasons (2022/2023) with three replications. The local hybrid BL-43 was sown in three irrigation treatments and two fertilization variants. During the season, morphometric parameters of maize plants were measured. Statistically highly significant differences were observed between yields and yield components. The greatest differences were found in plant height among the irrigation treatments, as well as between the two years of study. Maize yield showed high variability under the influence of the applied treatments. The highest yield (11,031 kg ha^{-1}) was achieved with the 100% irrigation treatment combined with a higher rate of mineral fertilizer. Irrigation treatment had a much greater effect on yield components and total maize yield than fertilization. Applying irrigation at 50% and 100% of the required norm increased the values of yield components and overall maize yield in 2023 by about 27%. In the drought year (2022), the increase was 27% with 50% irrigation and 37% with 100% irrigation. In the dry year of 2022, when total precipitation was 35% lower compared to the multi-year average, irrigation had a stronger effect on maize yield components. Besides the irrigation, further research should consider the improvement of soil organic matter content and soil health as tools for improved drought resistance.

Key words: *Zea mays* L., yield components, irrigation, drought

INTRODUCTION

In Bosnia and Herzegovina, maize occupies the largest area in the cropping structure. Unstable and variable yields are primarily associated with a lack of moisture during the growing season. Due to climate change and the increasing frequency of drought years, as well as the overall recurrence of such events, we can expect even greater yield instability if no measures are taken. The extremely dry years in Bosnia and Herzegovina during the period from 2011 to 2024 were 2011, 2012 and 2017 (Kovačević et al., 2020). One of the main measures that can mitigate the effects of drought in dry and extremely dry years is irrigation.

Climate change affects the stability of agricultural production due to frequent drought periods and elevated temperatures, especially during the growing season (IPCC, 2023). Increased water requirements for crops and limited water availability, along with prolonged heat stress, can significantly reduce transpiration and photosynthesis rates, shorten the growing season, and consequently reduce biomass and yield (Jovanović et al., 2020; Čereković et al., 2024). The countries of Southeast Europe, including Bosnia and Herzegovina (BiH), are particularly vulnerable to climate change (Knežević et al., 2018; Stricević et al., 2018; Srdić et al., 2023).

Many researchers emphasize that a lack of moisture causes water stress, which affects the reproductive phase of maize growth, resulting in reduced biomass accumulation and grain yield (Sah et al., 2020; Abeledo et al., 2020; Sheoran et al., 2022). Monteleone et al. (2022) highlight that water deficit is particularly critical during the flowering and grain-filling stages. Numerous studies on maize have focused on examining the interaction between yield and its components (Reizai, 2004). Rather et al. (2003) observed high genetic and morphological variability in maize regarding yield per plant and ear height. The genetic potential of maize is much higher than the yields currently achieved. The limiting factor in hybrid maize production is the lack of moisture, while irrigation presents an alternative where conditions allow. The timing, method, and quantity of water application are specific to each agroecological region and are crucial for maize production.

MATERIAL AND METHODS

The experiment was conducted over two years (2022 and 2023) at the Aleksandrovac site (44°58'27.25" N, 17°18'08.43" E, altitude 125 m), at the Experimental Educational Center of the University of Banja Luka in Aleksandrovac, which is located in the lowland part of the Sava River basin, in the municipality of Laktaši. The two-year experiment (2022–2023) was carried out using the domestic hybrid BL-43 of the FAO 400 group. The trial was set up using a randomized block design with three replications and three irrigation treatments: control (no irrigation – N1), 50% irrigation (N2), and 100% irrigation (N3). Irrigation was performed using a drip irrigation system with plastic tubing laid alongside each row after maize emergence. An automatic weather station was installed in the field. The collected data were input into the Irrigation Tool, which was used to monitor irrigation, specifically to determine the timing and amount of irrigation (Todorović, 2006; Čereković et al., 2024).

Fertilization was carried out using the "drop by drop" system through top dressing in the 6-leaf phenotypic phase, and the second top dressing at the beginning of flowering (14 leaves). The first variant used 2x120 kg ha-^{1} (33% ammonium nitrate), and the second variant used 2x220 kg ha-^{1} (33% ammonium nitrate). Irrigation was carried out based on soil moisture, air parameters and plant parameters with two watering rates.

The size of each experimental unit was 400 m² (20 x 20 m). The plant spacing within rows was 0.2 *m*, and the row spacing was 0.7 m. Sowing was done in the third decade of April. Yield component measurements were taken from the fifth to the seventh row on 10 plants, and the yield was calculated based on representative samples. The following yield parameters and components were determined: plant height (cm), height to the ear, number of leaves, total plant weight (g), and grain yield (t ha^{-1}).

Long-term meteorological data used in this study were obtained from the Hydrometeorological Institute of the Republic of Srpska. Based on multi-year averages, the average temperature during the growing season at this site is 17.7°C, and the total precipitation is 558 mm. Climatic data for the Aleksandrovac site are presented in Table 1. Total precipitation varied significantly from the long-term average, and the average temperature during the growing season was considerably higher than the long-term average. In 2022, the total precipitation was much lower, and temperatures were much higher compared to both 2023 and the multi-year average.

Table 1. Weather condition at Aleksandrovac area (2022/2023)

Aleksandrovac	Month						Total/ average
	IV	V	VI	VII	VIII	IX	
Sum of monthly precipitation in *mm* (2022)	76.0	60.6	49.0	37.8	42.8	94.0	360.2
Sum of monthly precipitation in *mm* (2023)	93.8	145.4	74.6	180.4	50.8	81.8	626.8
Monthly sum of precipitation in *mm* (1961-2020)	87.0	101.0	105.0	87.0	84.0	94.0	558.0
Average monthly temeprature in °C (2022)	11.2	18.0	22.5	22.9	22.8	19.9	19.6
Average monthly temeprature in °C (2023)	10.2	15.6	21.0	23.3	22.0	19.3	18.6
Average monthly temeprature in °C (1961-2020)	11.5	16.2	19.8	21.5	20.9	16.3	17.7

The total amount of water required for a maize crop during the growing season varies between 500 and 750 mm. The amount of water needed depends on several factors, such as weather conditions, plant density, soil fertility and type, FAO maturity group, and other variables. A lack of moisture at any stage after emergence can affect plant development and reduce the potential yield.

Table 2 presents data on the chemical analysis of the soil where the experiment was conducted. The results show that the soil is acidic, which is typical for many areas in Bosnia and Herzegovina. The soil has low phosphorus availability and low organic carbon content, while the potassium content is satisfactory.

Table 2. The chemical characteristics of the soil profile at Aleksandrovac experimental location

Location	Soil depth (cm)	pH in H_20	pH in KCl	Organic matter (%)	Organic C (%)	P_2O_5 (mg/100 g)	K_2O (mg/100 g)
Aleksandrovac	0-30	5.55	4.20	1.90	1.10	10.50	18.20
	30-60	5.40	4.10	1.70	0.99	9.00	16.50

The statistical analysis of the data was performed using an analysis of variance (ANOVA) for a three-factor experiment (year, irrigation, fertilization). Duncan's Multiple Range Test was used for mean comparison, employing the SPSS software (version 17.0).

RESULTS AND DISCUSSION

The effect of irrigation rate was statistically significant for plant height, ear height, total plant mass, and yield between the years of investigation (Table 3). Similar results using the drip irrigation method were obtained by other researchers (Akdeniz et al., 2016). The effect of 100% irrigation in both the first and second year was statistically highly significant compared to 50% irrigation and the control. For the number of leaves, no significant difference was found, as this trait is influenced by major genes.

Table 3. Influence growing season and irrigation on components of grain yield of maize

Year	Irrigation			Average
	N1	N2	N3	
		Plant height (*cm*)		
2022	148.0^{c}	176.5^{b}	210.4^{a}	178.3^{B}
2023	206.9^{c}	212.7^{b}	224.1^{a}	214.5^{A}
		Height until ear (*cm*)		
2022	69.3^{c}	79.8^{b}	100.3^{a}	83.1^{B}
2023	89.8^{c}	93.1^{b}	98.7^{a}	93.9^{A}
		Number of leaves		
2022	9.7^{a}	10.0^{a}	9.9^{a}	9.9^{A}
2023	11.5^{a}	11.1^{a}	11.4^{a}	11.4^{A}
		Total plant mass (*g*)		
2022	375.2^{c}	497.8^{b}	598.8^{a}	490.6^{B}
2023	565.0^{c}	571.7^{b}	613.3^{a}	583.3^{A}
		Grain yield ($t\ ha^{-1}$)		
2022	6446.2^{c}	9145.6^{b}	10231.9^{a}	8607.9^{B}
2023	8016.6^{b}	8081.5^{b}	11031.0^{a}	9043.0^{A}

Note: Means followed by the same letter are not significantly different at the p = 0.01 level using Duncan test

Maize yield in the dry year of 2022 was higher under 100% irrigation (3785 kg ha^{-1}) and under 50% irrigation (2699 kg ha^{-1}) compared to the control. In 2023, which had more rainfall, the yield was higher than in 2022. No significant difference was found between the control and the 50% irrigation treatment, but yields under the 100% irrigation treatment were around 3 *t* ha^{-1} higher.

Maize grain production is unstable without irrigation. It primarily depends on the amount and distribution of rainfall. Stable yields can only be achieved under irrigation conditions (Pejić and Vujkov, 2002; Čereković et al., 2024).

Table 4 presents the significance data based on Duncan's multiple range test between irrigation levels and fertilization levels. Fertilization levels did not show statistical significance compared to a given irrigation level. A highly significant statistical difference was observed only in the total plant mass. However, when analyzed partially within a single fertilization level, statistically significant differences were observed between the applied irrigation treatments. The yield in the control (6739.3 kg ha^{-1}) was significantly lower from the yield with the higher irrigation level (10498.4 *kg* ha^{-1}). The effect irrigation showed a similar trend as the lower fertilization levels. Similar results were obtained by other researchers, because in conditions of higher water content (80–85% PVK), corn yield was highest (15.08 kg ha^{-1}), but also nitrogen mobility along the depth of the profile, as well as nitrate retention in the humus horizon, (Kresović at al., 2012).

Differentiation of intervals (Duncan's test) occurred between fertilization and irrigation levels regarding total plant mass. It was shown that the fertilization level had a highly significant effect on plant mass. For both fertilization levels, as well as across different irrigation levels, highly significant intervals of plant mass were observed.

Table 4. Influence fertilization and irrigation on components of grain yield of maize

Fertilization	Irrigation			Average
	N1	N2	N3	
		Plant height (*cm*)		
I	190.8^{b}	200.2^{a}	211.5^{a}	200.8^{A}
II	192.6^{b}	202.2^{a}	211.5^{a}	202.1^{A}
		Height until ear (*cm*)		
I	78.8^{c}	85.7^{b}	102.0^{a}	88.8^{A}
II	80.3^{c}	87.2^{b}	97.0^{a}	88.1^{A}
		Number of leaves		
I	10.3^{a}	10.0^{a}	10.5^{a}	10.3^{A}
II	11.0^{a}	11.2^{a}	10.8^{a}	11.0^{A}
		Total plant mass (*g*)		
I	439.8^{c}	512.8^{b}	615.2^{a}	522.6^{B}
II	500.3^{c}	556.7^{b}	597.0^{a}	551.3^{A}
		Grain yield (*t* ha^{-1})		
I	6739.3^{c}	8417.5^{b}	10498.4^{a}	8551.7^{B}
II	7723.5^{c}	8809.7^{b}	10764.5^{a}	9099.2^{A}

Note: Means followed by the same letter are not significantly different at the p = 0.01 level using Duncan test

In 2022, most parameters had lower values compared to 2023 (Table 5). The effect of the fertilization level showed the same trend for most parameters. The greatest effect of higher fertilization levels was observed in total plant mass and plant height. For total plant mass, the higher fertilization level showed an interaction effect in the drought year of 2022. Plant height showed a statistically highly significant difference in 2023 with the higher fertilization level. The optimal amount of water has a positive effect on corn plant height (Abeledo et al., 2020).

Maize yield did not show significance differences between the year of cultivation and fertilization level based on overall indicators. However, when analyzed partially, the yield was higher with the higher fertilization level in the year with more precipitation (2023), when the yield was higher by about 1 ton, and there was a statistically highly significant difference.

Table 5. Influence of growing season and fertilization on components of grain yield of maize

Year	Fertilization		Average
	Fertilization 1	Fertilization 2	
	Plant height (*cm*)		
2022	179.0 ^{a}	177.6 ^{a}	178.3^{B}
2023	210.6^{b}	218.5^{a}	214.5^{A}
	Height until ear (*cm*)		
2022	84.3 ^{a}	82.0 ^{a}	83.1 ^{A}
2023	93.4 ^{a}	94.3 ^{a}	93.9 ^{A}
	Number of leaves		
2022	9.7 ^{a}	10.0 ^{a}	9.9 ^{A}
2023	11.5 ^{a}	11.1 ^{a}	11.4 ^{A}
	Total plant mass (*g*)		
2022	496.3 ^{a}	484.9 ^{a}	490.6^{B}
2023	548.9^{b}	617.8^{a}	583.3^{A}
	Grain yield ($t\ ha^{-1}$)		
2022	8529.8 ^{a}	8686.0 ^{a}	8607.9 ^{B}
2023	8573.6^{b}	9512.4^{a}	9043.0 ^{A}

Note: Means followed by the same letter are not significantly different at the p = 0.01 level using Duncan test

The extreme drought years in the period from 1990 to 2020 were: 1991, 1992, 2000, 2003, 2007, 2011, 2012 and 2017. These years were accompanied by high temperatures, low relative humidity, and poor precipitation distribution during the growing season, which caused significant damage to maize during pollination and grain filling (Kovačević et al., 2016; Kovačević et al., 2020; Čerekovič et al., 2024). Results of this research, as well as previous ones, suggest application of appropriate irrigation and fertilization levels can significantly improve the maize yields and reduce the negative effects of drought. However, some other measures to improve the drought resistance should also be considered, like the improvement of soil organic matter content and soil health (Mahmood et al., 2023).

CONCLUSION

Based on the examination of three factors (year, irrigation rate, and fertilization rate), there was found that the year of production, along with a specific irrigation rate, significantly influences the yield components and maize yield of the hybrid BL-43. With optimal irrigation, yield losses in maize can be significantly reduced, especially in dry years like 2022. The fertilization rate effect was directly related to the availability of water; if there is insufficient water during certain maize growth stages, the effect of fertilizers is reduced. The applied irrigation methods demonstrate that significantly higher production results can be achieved in maize cultivation through the rational use of water and fertilizers.

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