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Integrated effect of irrigation rate and plant density on yield, yield components and water use efficiency of maize

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Abstract: We investigated, under field conditions and during four years (2018–2021) the effects of five irrigation levels (T1: 100% of crop water requirement; T2: 80% of T1; T3: 60% of T1; T4: 40% of T1, and T5: 0% of T1 – rainfed) in interaction with three planting densities (PD1: 54 900, PD2: 64 900, and PD3 75 200 plants/ha) on the yield, yield components and water use efficiency (WUE) of maize in Srem, Serbia. The results indicate a large year-to-year variability, mainly due to the total amount and distribution of rainfall. Water regime and PD interacted significantly. Irrigation increased grain yield 28, 34, 30 and 18% for treatments T1, T2, T3 and T4, respectively, compared to the T5; and significantly influenced the yield components. Planting density had significantly lower effects on grain yield compared to irrigation (+1.4–1.8%). WUE is maximised (3.436 kg/m^3) at T4 under 75 200 plants/ha. Grain yield and WUE increased significantly with increasing PD, while the number of grains per ear and the weight of 1 000 grains decreased with increasing PD. In conclusion, limited irrigation at T2 under PD2 may be a viable method to maximise production efficiency and maize yield under the environmental conditions of this study and at sites with similar soil and climatic conditions.

Keywords: sprinkler irrigation; deficit irrigation; water stress; *Zea mays* L.

Maize (*Zea mays* L.) is widely cultivated in Serbia, where environmental and climatic conditions vary greatly. As a result, maize grain yields are very different, and varied between 2.1–7.5 t/ha in the environmental of Serbia (Kresović et al. 2016). One of the most important environmental stresses affecting maize cultivation in Serbia is drought and precipitation variability during most of the growing season. The effect of drought on maize crop performance is very evident when water availability is severely limited (Moghaddam et al. 2011, Zia et al. 2021, Zhang et al. 2022, Simić et al. 2023). Irrigation is an important measure to increase crop yields. However, there is a severe water shortage in Serbia due to climate change (Kresović et al. 2016). Consequently, an appropriate choice of irrigation scheduling is required to maximise crop water use efficiency (WUE) (sometimes referred to as crop water productivity). WUE can be improved by increasing the yield per unit of water consumed or reducing the water consumption per unit of grain produced (Kang et al. 2017). Previous studies have shown that deficit irrigation further improves the WUE of maize (Irmak et al. 2016, Kresović et al. 2016).

Plant density is another important factor that can influence growth and maize production. Increasing planting density can increase grain yield within a given area and is one of the easiest ways to increase

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maize yield (Li et al. 2018). According to Assefa et al. (2018), the contribution of plant density to maize yield increase ranged from 8.5% to 17%. Zhang et al. (2019) reported that hybrid maize with high plant density tends to use more soil water to achieve a higher grain yield. However, more irrigation may also be required to achieve high maize grain yields. It is possible that plant density affects water use. According to Sani et al. (2008), the interaction between plant density and irrigation regime on maize grain yield was significant. In addition, they found that the highest plant density (66 000 plants/ha) under full irrigation resulted in a significantly higher yield compared to 50% irrigation. Reducing irrigation by half led to a significant decrease in yield at the highest plant density compared to the other plant densities. Ben et al. (2016) showed that the interaction between irrigation level and plant density was significant for the number of grains per ear, the weight of 1 000 grains and the grain productivity of maize. Tokatlidis et al. (2011) reported that the optimum plant density of maize hybrids grown under drought-prone conditions is much lower than that of those grown under favourable conditions. A study by Shen et al. (2024) found that the combined effect of plant density and irrigation level had a significant effect on grain yield, WUE and irrigation water use efficiency (IWUE) of maize. In contrast, a study by Asibi et al. (2022) showed that the interaction between irrigation level and plant density had no significant effect on maize grain yield in China in both years (2018 and 2019). In addition, they found that the interaction of two factors significantly influenced WUE in both years. Little information is available on the best integrated management practices for irrigation and planting density to achieve high maize yields and WUE in the Srem region, a northwestern part of the Republic of Serbia.

The present study was conducted to determine the effects of different irrigation levels and planting densities on maize yield and water use efficiency in four growing seasons under the ecological conditions of Srem. Appropriate irrigation scheduling and planting densities are recommended for maize producers in the region.

MATERIAL AND METHODS

Site description. A four-year (2018–2021) field study was carried out at the experimental field for irrigation of the Maize Research Institute "Zemun Polje" (30°56'N, 75°52'E) in the vicinity of Belgrade, Serbia. Zemun Polje is located in a semi-arid region and has good environmental conditions for maize cultivation. The site is characterised by a temperate continental climate with cold winters, warm, dry summers, and variable and unevenly distributed precipitation during the growing season. Table 1 shows the climate variables during the study period and the multi-year average values for the growing season (April to September). The soil at the experimental site is a silty clay loam chernozem, with 2.05% soil organic carbon and a pH of 7.8 in the Ah horizon (0–50 cm). The mean field capacity, permanent wilting point and soil bulk

Table 1. Mean monthly air temperature (°C) and cumulative monthly precipitation (mm) from 2018 to 2021, Zemun Polje, Serbia

Month	Mean air temperature				Cumulative monthly precipitation			
	2018	2019	2020	2021	2018	2019	2020	2021
April	11.6 (−0.2)	11.5 (−0.3)	12.9 (+1.1)	12.4 (+0.6)	54.8 (+4.6)	14.6 (−35.6)	27.2 (−23.0)	28.2 (−22.0)
May	19.5 (+2.1)	21.0 (+3.6)	16.0 (−1.4)	17.5 (+0.1)	29.4 (−30.8)	36.4 (−23.8)	53.6 (−6.6)	39.6 (−20.6)
June	22.0 (+1.6)	24.6 (+4.2)	20.3 (−0.1)	20.1 (−0.3)	65.0 (−12.9)	19.0 (−58.9)	27.2 (−50.7)	65.0 (−12.9)
July	23.5 (+1.5)	22.6 (+0.6)	23.1 (+1.1)	22.4 (+0.4)	34.8 (−30.4)	105.4 (+40.2)	66.4 (+1.2)	44.0 (−21.2)
August	21.6 (−0.3)	24.6 (+2.7)	22.6 (+0.7)	20.6 (−1.3)	105.2 (+54.3)	26.4 (−24.5)	39.4 (−11.5)	64.0 (+13.1)
September	16.5 (−0.8)	19.2 (+1.9)	17.1 (−0.2)	19.5 (+2.2)	55.4 (+8.8)	41.2 (−5.4)	44.8 (−1.8)	21.4 (−25.2)
Seasonal average/total amount	19.1 (+0.6)	20.6 (+2.1)	18.7 (+0.2)	18.7 (+0.2)	344.6 (−6.2)	243.0 (−107.8)	258.6 (−92.2)	262.2 (−88.6)

Values in brackets represent the deviation from the normal value (20-year average, 1996–2017)

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density were 35.4 (*v/v* %), 13.1 (*v/v* %) and 1.30 g/cm^3, respectively. The soil had a total N content of 210 mg/kg and an available P and K content (Egner-Riehm method) of 146 and 312 mg/kg, respectively.

Experimental design and treatment implementation. The experiment was laid out in a split-plot design with five irrigation treatments (main plots) and three planting densities (subplots) in four replicates. The irrigation treatments were: T1, referring to meeting 100% of crop water requirement (no stress); three deficit irrigation treatments – T2: 80% of T1; T3: 60% of T1; T4: 40% of T1, and T5: 0% of T1 (rainfed treatment). The three planting densities treatments included 54 900 plants/ha (PD1), 64 900 plants/ha (PD2), and 75 200 plants/ha (PD3).

The T1 treatment was irrigated such that water availability (irrigation application plus rainfall plus stored soil water) was sufficient to meet 7-day crop water requirements at a depth of 90 cm. For deficit irrigation treatments, applied water requirement (AW) was calculated on 7-day intervals:

$$AW = (ETc \times Dic) - P \pm \Delta SW \quad (1)$$

where: ETc – crop evapotranspiration (mm); P – precipitation (mm); ΔSW – soil water storage (mm); Dic – deficit irrigation coefficient used to reduce full irrigation amounts. Dic = 0.8 for T2 treatment; Dic = 0.6 for T3 treatment, and Dic = 0.4 for T4 treatment.

If weekly sum precipitation and stored soil water was higher of weekly ETc the irrigation was skipped in deficit irrigation treatments. Irrigation was provided by a hand-operated sprinkler irrigation system every 7 days. The irrigation water was supplied from the groundwater.

The maize cultivar ZP 677 (FAO maturity group 600) was used in all four years of the experiment. The subplot each included 8 rows and an 8 m long row (44.8 m^2). The inter-row distance was 70 cm, while the spacing between the plants in the row at PD1, PD2 and PD3 was 26, 22 and 19 cm, respectively. Sowing was done in mid-April, and the plants were harvested in September, the third decade. The usual cultivation practice was applied. Sufficient fertiliser was applied to avoid nutrient stress. All treatments were fertilised equally. Nitrogen and P fertilisers (monoammonium phosphate, MAP, 0:12:52) were applied at fall ploughing at actual rates of 12 and 52 kg/ha, respectively, while additional N, 138 kg/ha (urea, 46% N) was applied at planting per year. All weeds, diseases and pests in the experimental plots were controlled.

Sampling and measurements. After the physiological maturity of the maize, an area of two middle rows of 8 m in length of each plot was harvested by hand. The kernels were separated from the cobs and weighed with a 1 kg precision balance to determine the grain yield. Grain samples were taken from the yield samples to determine the water content. Ten ears were taken from the middle two rows of each plot, and the number of grains on each ear was counted. Grain yield and grain weight were expressed at 14% moisture.

The total water use (ETc) was estimated using the water balance formula (Kresović et al. 2016). The daily amount of precipitation was determined each season by the weather station located on the farm. During the maize growing seasons, soil samples were collected with a steel core-sampling tube with a diameter of 30 mm and soil water content was determined by the oven-drying method at a depth of 120 cm during the study period (4 years), with an increment of 10 cm in each maize plot. Three replicates were conducted per plot. In each plot, a series of soil samples were taken randomly to avoid sampling from the same location and disturb the soil layers as little as possible. Once sampling was complete, the sampling holes were immediately filled with soil to prevent rainwater from seeping deep into the soil. After measuring the wet weight, the soil samples were dried for 48 h at 105 °C until a constant weight was reached. The gravimetric soil water content measurements were converted into volumetric values by multiplication with the soil bulk density. The bulk density was determined by a volume 100 cm^3 steel cylinder with three replications. The water use efficiency (kg/m^3) was determined as the ratio between the grain yield (kg/ha) and the total actual evapotranspiration of the crop (m^3/ha) (Kresović et al. 2016, Zhang et al. 2022).

Data were subjected to analysis of variance (ANOVA) using Statistica software (ver. 9.4, 2016), and the mean values were compared using Fisher's *LSD* (least significant difference) test at $P < 0.05$ level of significance.

RESULTS AND DISCUSSION

Weather conditions. A summary of monthly measured weather variables for the 2018, 2019, 2020 and 2021 growing seasons and the deviation from long-term (1996–2017) average growing season values for the research site are shown in Table 1. The 2018,

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2020 and 2021 air temperatures were relatively similar and comparable to the long-term averages. The 2019 growing season was warmer than the three previous growing seasons and the long-term average. Substantial interannual variability was observed in seasonal distribution and precipitation amount (Table 1). The total amount of precipitation during the growing season was 6, 108, 92 and 89 mm lower than the long-term average (351 mm) for 2018, 2019, 2020 and 2021, respectively. Therefore, 2019 was the driest year, and 2018 was the wettest year for the duration of the research.

The seasonal ETc averaged 508, 463, 409, 365 and 342 mm for the 2018, 2019, 2020, and 2021 growing seasons at T1, T2, T3, T4 and T5. Generally, seasonal ETc decreased as the irrigation rate decreased. The amounts of water applied were 251, 158, 79, 23 and 0 mm in treatments T1, T2, T3, T4 and T5, respectively (averaged over four years).

Grain yield. Table 2 contains the results of the variance analysis. Grain yield differed significantly ($P < 0.05$) between the four years and varied from 10.56 to 14.01 t/ha (Table 3). The lower yield (10.56 t/ha) in 2019 is mainly explained by the course of the weather, which was more unfavourable for the fertility of the ears than in other years (higher temperatures and drought).

The 4-year results for grain yield show that irrigation treatments significantly affect maize grain yield. The highest yield (13.87 t/ha) was obtained under T2 and was significantly higher than with rainfed and other irrigation treatments. Compared with T2, T1 (full irrigation) significantly reduced grain yield by 4.6%. The lowest grain yield was recorded in the rainfed (non-irrigated) treatment at 10.34 t/ha. As expected, irrigation increased maize grain yield by 18.09–34.13% compared to rainfed cropping. This confirms that irrigation is an essential factor for higher maize grain yields in this region. In this study, treatments T1 and T3 did not show statistically significant differences in grain yields.

The results indicate that plants exposed to stronger water stress (T4 and T5) tend to yield less than plants supplied with sufficient water requirements. The significant difference in yield between the well-watered and stressed plants suggests that the imposed water stress led to a reduction in the plant's physiological activities, preventing the plant from reaching its full growth potential, which was reflected in a significantly lower yield. This is consistent with the results of Kresović et al. (2016) and Awe et al. (2017), which all found an increase in grain yield with increasing irrigation rate. Under drought stress, plants reduce water loss by reducing stomatal opening but also limit CO_2 entry and thus inhibit the photosynthesis rate (Song et al. 2022).

The results of this study indicated that a 40% and 60% reduction in the amount of irrigation water compared with irrigation treatment T2 (80% of crop water requirement) results in an average yield loss of 3% and 12%, respectively. Based on these experimental results, irrigation scheduling providing partial restitution of crop water requirements at a basis of 80, 60 and 40% allows us to save 37, 68 and 91% of water when T2, T3 and T4 are compared to T1, respectively.

The increase in planting density had a significant ($P < 0.05$) effect on increasing maize grain yields and

Table 2. Significance levels of ANOVA of maize data from four years

	df	Grain yield (t/ha)	Number of grains per ear	1 000 grains weight (g)	WUE (kg/m^3)
Replication	3				
Year (Y)	3	**	**	**	**
Error 1	9				
Irrigation (T)	4	**	**	**	**
Y × T	12	**	**	**	**
Error 2	48				
Planting density (PD)	2	*	**	**	**
Y × PD	6	**	**	**	**
PD x T	8	**	**	ns	**
Y × T × PD	24	**	**	ns	**
Error 3	120				

*$P \leq 0.05$; **$P \leq 0.01$; ns – not significant; WUE – water use efficiency

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Table 3. Grain yield, yield components and water use efficiency (WUE) of maize under the influence of year, irrigation and planting density

	Grain yield (t/ha)	Number of grains per ear	1 000 grains weight (g)	WUE (kg/m^3)
Year				
2018	12.78^b	765.1^a	392.1^a	2.828^c
2019	10.56^c	776.7^a	294.1^d	2.553^d
2020	13.13^b	647.0^b	381.3^b	3.413^a
2021	14.01^a	645.2^b	360.5^c	3.312^b
$LSD_{0.05}$	0.368	16.19	3.874	0.087
Irrigation				
T1	13.26^b	756.8^a	366.0^b	2.541^d
T2	13.87^a	766.2^a	376.1^a	2.982^c
T3	13.42^b	713.2^b	366.4^b	3.234^b
T4	12.21^c	663.6^c	352.3^c	3.436^a
T5	10.34^d	642.7^d	324.2^d	2.939^c
$LSD_{0.05}$	0.252	15.53	3.307	0.048
Planting density				
PD1	12.48^b	746.2^a	367.1^a	2.953^b
PD2	12.66^a	711.1^b	355.9^b	3.063^a
PD3	12.71^a	668.1^c	348.1^c	3.063^a
$LSD_{0.05}$	0.164	11.96	2.827	0.037

Values followed by the same letter are not significantly different at the 95% confidence level. *LSD* – least significant difference; T1 – 100% of crop water requirement; T2 – 80% of T1; T3 – 60% of T1; T4 – 40% of T1; T5 – 0% of T1 – rainfed; PD1 – 54 900, PD2 – 64 900, PD3 – 75 200 plants/ha

resulted in numerically higher maize grain yields (Table 3). A planting density of 75 200 plants/ha (PD3) gave the highest yield (12.71 t/ha), which was statistically similar to the plant density of 64 900 plants/ha (PD2 – 12.66 t/ha). The results of our study show that maize produces higher yields at lower planting densities under rainfed conditions and with a greater reduction in irrigation. The response grain yield to planting density was less effective than irrigation; grain yield increments were 0.39% for PD3 *versus* PD2 and 1.84% for PD3 *versus* PD1. The interaction between planting density and irrigation treatment on grain yield was significant (Table 2). On average, the interaction between irrigation rate and planting density significantly affected grain yield (Table 4). The highest grain yield was observed under the T1-PD3 treatment, while the lowest yield was obtained in rainfed maize (T5) at 75 200 plants/ha. Therefore, the combination of an irrigation treatment of the T1 with a density of 75 200 plants/ha is recommended as the treatment that maximises the grain yield of maize. Additionally, grain yield in non-irrigated maize (T5) at PD3 planting density was statistically significantly (P < 0.05) lower than that of PD2 (Table 4). Therefore, lower stands for rainfed maize (< 64 900 plants/ha) are required for the studied maize hybrid under water stress to reach seasonal yield potential. Our study shows that the optimum density under irrigated conditions was between 64 900 and 75 200 plants/ha, while the optimum density under rainfed conditions was between 54 900 and 64 900 plants/ha. Reports by Zhang et al. (2019) and Zhang et al. (2022) also showed an increase in yield by increasing planting density up to a certain limit, usually above 70 000 plants/ha. The results of the present study agree with Tokatlidis et al. (2015), who reported that water stress has a more drastic effect on the yield and assimilation rate of maize crops in northern Greece at high planting density than at low planting density.

Yield components. In this study, yield components differed significantly between years and between the "T" and "PD" treatments (Table 3). The effects of irrigation rates on yield components were statistically significant (P < 0.05) (Table 2). As shown in Table 3, the highest values for the number of grains per ear (766.2) and 1 000 grains weight (376.1 g) were ob-

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Table 4. Interaction effect of irrigation treatment and planting density (plants/ha) on grain yield and water use efficiency (WUE) of maize. Mean values over four years (2018–2021) and four replicates

		Irrigation treatment					
		T1	T2	T3	T4	T5	mean
Grain yield (t/ha)							
PD1		13.91^{c}	12.35^{f}	10.95^{h}	10.15^{i}	9.74^{j}	11.42^{B}
PD2		14.45^{b}	12.97^{e}	11.56^{g}	10.29^{i}	10.05^{i}	11.87^{A}
PD3		15.03^{a}	13.55^{d}	11.44^{g}	9.57^{jk}	9.30^{k}	11.78^{A}
Mean		14.46^{A}	12.96^{B}	11.32^{C}	10.00^{D}	9.70^{E}	
$LSD_{0.05}$	T: 0.1101	PD: 0.0896	T × PD: 0.2005				
Water use efficiency (kg/m^3)							
PD1		2.73^{ef}	2.66^{g}	2.66^{g}	2.76^{de}	2.82^{cd}	2.73^{C}
PD2		2.84^{bc}	2.79^{cde}	2.82^{cd}	2.78^{cde}	2.90^{ab}	2.83^{A}
PD3		2.95^{a}	2.92^{a}	2.79^{cde}	2.59^{h}	2.68^{fg}	2.79^{B}
Mean		2.84^{A}	2.79^{BC}	2.76^{C}	2.71^{D}	2.80^{B}	
$LSD_{0.05}$	T: 0.026	PD: 0.022	T × PD: 0.050				

The mean values within and between columns with a common letter do not differ significantly at the 5% level, according to the least significance difference test (*LSD*). Capital letters in rows and columns indicate significant differences among irrigation treatments and plant density treatments, respectively. T1 – 100% of crop water requirement; T2 – 80% of T1; T3 – 60% of T1; T4 – 40% of T1; T5 – 0% of T1 – rainfed; PD1 – 54 900, PD2 – 64 900, PD3 – 75 200 plants/ha

tained in the irrigated T2 treatment, while the lowest values were obtained in rainfed maize (T5) (642.7 and 324.2 g, respectively). The number of grains per ear is a critical yield component of maize, which, together with grain weight, determines yield capacity (NeSmith and Ritchie 1992).

Decreased grain numbers per ear have probably resulted from the cessation of the development of fertilised grains caused by stress during the early stages of grain filling. The thousand-grain weight reduction due to water stress can be attributed to the decreased grain filling rate. The larger leaf area in the less stressed treatments may have resulted in heavier grains by providing additional photosynthesis and larger carbohydrate reserves (Comas et al. 2019).

The results showed that the number of grains per ear and 1 000 grains weight significantly decreased with increasing planting density (Table 3). The interaction between irrigation rate and planting density was significant for the grains number per ear, but not for 1 000 grains weight (Table 2).

The number of grains per ear plays a key role in the final yield of a maize plant. The more grains per ear, the higher the grain yield. Pandey et al. (2000) stated that the grain yield reduction (22.6–26.4%) caused by deficit irrigation was accompanied by a decrease in the number and weight of grains. Consistent with the results of this study, in the experiment conducted under Iranian conditions, it was observed that 1 000 grains weight decreased with decreasing irrigation water (Sepaskhah and Khajehabdollah 2005). In agreement with the results of this study, in the experiment conducted under the conditions of the dry region in Northwest China, it was observed that the number of grains per ear and the 1 000 grain weight decreased with decreasing irrigation water and increasing planting density (Zhang et al. 2022). Contrary to these studies, Sani et al. (2008) in Niger obtained the highest 1 000 grains weight in the irrigation variant in which irrigation was reduced by 50%, but it was not statistically significant compared to full irrigation. The same researchers obtained the highest 1 000 grain weight and also the lowest studied sowing density (38 000 plants/ha), without statistical significance in relation to other densities (53 000 and 66 000 plants/ha) in which maize was grown.

Water use efficiency. In 2020, WUE was significantly higher than in the other three years (3–17%), probably due to the better course of the weather, which was favourable to photosynthesis (Table 3). WUE was lowest in the driest year (2019), with the greatest positive impact of irrigation. There were no statistical differences in WUE between the T5 and T2 irrigation regimes. The WUE was higher in the T2 treatment than in the T1 treatment. This is consistent with previously reported results (Couto et

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al. 2013). In the current experiment, WUE increased significantly (35%) when the irrigation rate was reduced from T1 (2.541 kg/m^3) to T4 (3.436 kg/m^3) (Table 3), which is consistent with many other studies conducted under different environmental conditions (e.g. Aydinsakir et al. 2013, Awe et al. 2017, Zhang et al. 2022). Irmak et al. (2016) stated that WUE changed between 0.8 and 3.1 kg/m^3, while Kresović et al. (2016) determined that WUE ranged from 2.37–3.90 kg/m^3.

Planting density also significantly influenced WUE. The WUE increased with increasing plant density (+3.7%), but PD2 and PD3 treatments showed no differences. Consequently, a significant "PD × T" interaction also occurred in the analysis of variance (Table 2). Zhang et al. (2022) recently reported similar results. Depending on the amount of irrigation, the optimal planting density can effectively improve the yield and WUE of maize under the agroclimatic conditions of this study.

The four-year pooled data revealed an increase in maize WUE with an increase in plant density, which reached the maximum under 64 900 plants/ha and decreased with a plant density of 75 200 plants/ha (Table 4). The interaction between irrigation rate and planting density on WUE was also significant, which agrees with Shen et al. (2024). The highest WUE was obtained either under an irrigation rate T1 at 75 200 plants/ha (2.953 kg/m^3) or T2 at 75 200 plants/ha (2.921 kg/m^3). By contrast, the lowest WUE was recorded for an irrigation rate of T1 at 75 200 plants/ha. Zhang et al. (2014) reported a maximum WUE of 2.53 kg/m^3 at a planting density of 75 000 plants/ha in Shanxi Province, China.

In conclusion, we demonstrated that irrigation and planting density influence grain yield and its components as well as the WUE of maize. Reduced irrigation amounts significantly decreased grain yield and increased WUE. Increased planting density increased yield and WUE. The number of grains per ear and 1 000 grains weight were generally reduced by decreasing the irrigation rate, while increasing planting density decreased. Irrigation was more effective than planting density in increasing grain yield. Based on these experimental results, irrigation scheduling providing a partial compensation of crop water requirement at a basis of 80% allows us to save water (37% if T2 is compared to T1) and ensures a good maize grain yield level (13.87 t/ha) under the conditions of this study. To reach high maize grain yields and obtain high water use efficiencies in the conditions of this study, a valid compromise can be reached by using sprinkler irrigation to partially diminish crop water requirement restitution and the application of lower planting density (64 900 plants/ha). The results can contribute to efficient irrigation of maize in the region, which can be expected to produce high and stable yields.

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