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Comparative experiment of various irrigation technologies in maize (*Zea mays* L.)

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Abstract:Development of domestic maize cultivation largely depends on the applied agrotechnics. In keeping the increase in crop increases, the goal is to minimize crop fluctuations, and there is also an important role in the proper water supply. In our country, the yield of maize is a good water supply. The yield of maize can be significantly increased by improving the water supply of the plant. In many areas there are only very few water available for professional irrigation, so it is increasingly need to focus on modern, most water-saving irrigation technologies. In our experiment, we compare two irrigation techniques. The rain-like watering with console and the solenoid valve-controlled tape drip irrigation. Our examinations extend to mapping the properties of maize that can cause changes in the effect of irrigation and, of course, to develop crop quantities available by various irrigation technologies, since these results provide the proper income for the producer. The research was carried in Szarvas, at the school experimental field of the Hungarian University of Agriculture and Life Sciences, Department of Irrigation and Melioration, in 2020.

Keywords: maize, irrigation, yield, tape drip, leaf area

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Introduction

The effects of global climate change have also been felt in Hungary in recent years. The effects of the change are mostly shown by the decrease in precipitation during the growing seasons, the distribution of precipitation, the change in temperature and the appearance of extreme weather conditions. Hungary's climate is continental but sometimes ocean and Mediterranean effects also apply. Since 1931, the constructed drought index has been constantly investigated, so significant data is available. According to some studies, between 1951 and 1992 was 15 years of drought and 4 years seriously drought, while only 10 years of water supply was favorable. It seems good that our country had to face the difficulties caused by drought. But since the 1990s, the number of droughts is more and more. The area exposed to the most drought is Tiszántúl, Duna-Tisza and Mezőföld (Pálfai, 2004). The precipitates of falling in Hungary do not cover the water demand for crop production at 30-50 percent. The annual precipitation amount decreased by 50 to 90 millimeters over the past 50 years. Typically, a point in the vegetation period is missing this quantity. Our goal would be to store rainfall in the winter in the soil with high efficiency (Nyíri, 1997). According to Antal (2005), the maize sowing area of 140 million ha and the yield of approximately 4.3 t/ha. The largest grower of maize is the US, nearly 30 million ha at 9 t/ha over yields. In Europe, Italy produces 11 t/ha around 1.1 million hectares, while France reaches 10 t/ha yield over 1.7 to 1.8 million hectares. We are currently grown in the world at 190 million hectares. In Hungary, the sowing area can be around 1.2 million hectares and is 5.5–6 t/ha around the yield. The development of maize cultivation in Hungary is extremely dynamic in the 1980s, and since 1970, the use of chemicals, technical background and modern biological funds (hybrids) have been cultivated and the expertise has also increased, which, thanks to their maize production, belonged to the leading edge of the world. At this time, our genetic forward progress between 1960 and 1980 was 151.5 kg/ha, while in America at the same time only 124.0 kg/ha. Worldwide, we were third in a hectare yield behind the US and France. Our annual yield fluctuation was only 10–20%, and today it exceeds 40–50%. The crop of maize is influenced by a number of factors, such as insufficient water and nutrient supply. These factors affect the leaf area of maize where the process of photosynthesis takes place. All factors include increasing nutrient supply – which increases the photosynthically active leaf area of maize, it also increases the yield of maize (Futó, 2003).

In our country corn is the plant grown in the largest area. It costs 26–27% of all field, there were 1.2 million hectares in some years. Its main use is animal feeding, this number in Hungary is about 90% of the crop. However, with the increasing growth of the world's population, the use of the food industry will be increasingly promoted. The reasonable nutrient supply and irrigation are essential for corn. Optimal nitrogen (N) fertilization and irrigation are the main factors influencing plant growth, but excessive water and nitrogen application not only wastes water resources, but also seriously damages the ecological environment (Ahmad, Ahmad, Yang, et al., 2021; Ahmad, Ahmad, Kamran, et al., 2021; Ali et al., 2019; Meng et al., 2021; Xu et al., 2020). Development of domestic maize cultivation largely depends on the applied agrotechnics. In keeping the increase in crop increases, the goal is to minimize crop fluctuations, and there is also an important role in the proper water supply. Unfortunately, the results of the yield from the world's yield and yield growth are significantly behind. The yield of maize can be significantly increased by improving the water supply of the plant. In many areas there are only very few water available for professional irrigation, so it is increasingly need to focus on modern, most water-saving irrigation technologies. The maize water requirement is 450–550 mm, which can be said to be medium. Daily water consumption is 4.5–5.5 mm/ha. The static water requirement of maize is 67–79, which means the number of the soil's pore volume fills water and how many of the air. The transspiration coefficient of maize is 350 l/kg, which we know how much water is used to produce a unit of dry matter. The water consumption and water absorption of maize are characterized by several different factors. The corn can also add water from 150 to 200 cm depth. The drought arriving at the time of the coat of arms is 53%, while the drought in the absorption can reduce the crop by 30%. The maximum amount of yield available is not only affected by precipitation in the breeding time, but also the amount of precipitation stored in the autumn-winter period. Maize crops may not be prominent in the precipitation year, but in the following year when the temperature is favorable for it. Soils can store up to 500 mm water (up to 200 cm depth), half of which are positive water. At the beginning of development and during the period of wholesaling, the smallest of maize water consumption, while from the coat of arms is the largest (Futó & Sárvári, 2015; Menyhért, 1979). In our research, we compared two irrigation technologies. The rain-like irrigation with the winding wicker console and the solenoid valve-controlled tape drip irrigation. Our studies covered the mapping of the properties of maize that can show changes in the impact of irrigation and, of course, to de-

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velop crop quantities available by various irrigation technologies, since these results give the producer the right income. The research was carried in Szarvas, at the school experimental field of the Hungarian University of Agriculture and Life Sciences, Department of Irrigation and Melioration, in 2020.

Materials and Methods

Satisfaction of maize water demand was performed in the knowledge of the average temperature of the experimental area and the evapotranspiration of the stock, the area had a natural water capacity around 85–100%. Control parcels did not receive any irrigation, the natural precipitate determined the natural water capacity of the area. Since the precipitation of the year was favorably formed, the water capacity of the control parcels varied between 40 and 75%. During the research, the impact of irrigation significantly affects the water supply of the given vintage and the amount of fallen precipitation. It was very varied from this point of view in our regions. The weather data of the given year was summarized in Table 1 for the average temperature and precipitation.

From the data we can see that in the presowing period and at the time of sowing, we struggled with relative water shortages compared to 30 years of data. This water scarcity persisted for summer months. In the most important period of maize, at the same time, at the same time, the same amount of natural precipitation fell. Compared to the 30-year average, 58.6 and 15.2 mm in July 15.2 mm were more. In August, in the month of the highest average temperature and in September, in the time of crop training, there was a shortage of rainfall. The effect of irrigation in these months was well demonstrable and necessary. In October, the precipitation arrived again, which greatly slowed down the prostration and made it difficult to harvest. According to previous soil tests, the experimental area is deeply carbonate chernozem soil. The main characteristics of the soil of the experiment can be summarized according to the soil tests carried out (Table 2) below. According to soil tests, soil's physical perception of loam, the cultivated layer of $CaCO_3$ does not contain, based on the humus content, the excessive amount of soil N-service is high, with the excessive, Zn well, while Cu and Mn are satisfactory. The water management of the soil is characterized by weak water conductivity and high water retention capability. The cultured level of the soil was closed, and the proportion of gravitational pores is smaller.

When preparing the soil protection plan, analyzing the water management parameters measured and calculated in the area, it was established that the natural (field) water capacity of the soils of the studied area is high, exceeding the value of 38 mm/10 cm. However, the dead water content is very high (22 mm/10 cm), reaching 65% of the water capacity. These properties of the soil in the area are explained by the fact that the combined ratio of the very small particle size sludge fraction (0.01–0.002 mm) and the clay fraction (< 0.002 mm) in the soil is high, exceeding 60% in the case of the typical profile.

It follows from the above that the useful water shows values of 15.29 mm/10 cm. In typical soil profiles, the K-factor indicates hydraulic conductivity weak. The test soil was compacted from the surface. The total porosity of the studied soils is 47% v/v. The gravitational pore space, which includes the macro- and megapores that determine the air supply of the soil, is relatively small, and the capillary pore space (micro- and mesopores) is relatively large. In summary, the soil of the experimental area can be classified into the water management category of soils with medium water absorption capacity.

Experimental parcels size 10 m $\times$ 5 m. The 5 m parcel width allows you to get 6 lines with a 76 cm row spacing in each one. The sowing

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Table 1: Data of weather between jan. of 2020. and okt. of 2020. Source: Author's own editing

Months	jan.	febr.	march.	apr.	may.	jun.	jul.	aug.	sept.	oct.	sum/average
Temperature (°C)	-1	5.3	7.1	11.9	14.9	20.5	22	23.3	18.7	12.4	13.51
Rain (mm)	6.8	53.7	43	10.3	43.9	130	89.6	55.3	15.9	99.7	548.2
Mean of rainfall of 30 years (mm)	30.6	31.4	28.9	41.9	62.9	71.4	74.4	56.4	42.8	46.2	486.9
Difference (mm)	-23.8	22.3	14.1	-31.6	-19	58.6	15.2	-1.1	-26.9	53.5	61.3

Table 2: Characteristics of the soil in the experiment (Szarvas, 0-30 cm soil layer)

pH (KCl)	K_A	$CaCO_3$	Humus (%)	AL-P_2O_5 $mgkg^{-1}$	AL-K_2O $mgkg^{-1}$ $mgkg^{-1}$	Mg (KCl) $mgkg^{-1}$	EDTA Zn $mgkg^{-1}$	EDTA Cu $mgkg^{-1}$	EDTA Mn
4.95	44.6	0.0	2.89	216	260	687	3.26	7.35	428

Figure 1: Irrigation console during operation. Source: Author's own editing

is carried out with a field pneumatic sowing machine to the experimental area as a whole, from which the plannes are harvested after the plan, forming the parcels. The spacing was determined in 17.8 cm, which means approximately 75,000 germs/ha. From 6 rows we can view 2 border lines, avoiding any overlaps between parcels. The samples required for the tests that are "destroyed" from rows 2 and 5 while harvesting and other measurements are carried out in the two central rows. Harvesting is done with manual force.

Using irrigation consoles, it is possible to achieve specially fine, plant and soil-friendly irrigation and have less than 2–3.5 bar connection pressure for operation. The irrigation bandwidth can range from 30m to 90-100 meters. It can be noted here that the wider irrigation consolidations typically move on four wheels to preserve stability, while at-

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Figure 2: Dripping tape irrigation in maize. Source: Metra

tributes with narrower irrigation band, the three-wheeled or two-wheeled plus slider solution is the most typical. The height of the consoles is generally infinitely, hydraulically or mechanically adjustable.

In the experimental area, a 30 m width irrigation console was used, which was moved with a rewinding device. The water conservation was carried out from a controllable hydrant with solenoid valve (Figure 1).

One of the big groups of micro-casting is drip irrigation. Its advantage is that using the root zone constantly wet and well-wet and well-aired and are available for less weed pressure, because of the humidified soil surface. The system allows water to be administered with a small loss, so up to 95% utilization is also available. Water does not pass through the air, which may also be a significant amount of evaporation of up to 30%. A non-limiting factor in wind speed and sloping areas can also be provided with a smooth application. Another advantage is that this irrigation mode can be fully automated. By means of a nutrient, nutrients can be supplied according to the process of development of the plant in a suitable amount and concentration.

In the study we used the Aquatraxx tape drip system sold by Metra Kft. Which in the manufacturer's description tab:

- is made with one-time extrusion. No seam of sharp edges or welding,
- Extremely resistant to clogging, a number of built-in filter carcases perceive continuous and uniform water emissions,
- The drip body boasts unique features due to precise design and manufacturing, turbulent section of the risk of clogging,
- Various water-emitting variants are marked with color codes, so red is high water-emitting (1.14L/h), yellow color indicates medium water-emitting tape (0.86L/h) (www.metra.hu, Figure 2).

During the research, the following tests were performed:

- Measuring plant height: At the same sampling time of the corn breeding season, the development phases of plants (BBCH) are included. From the developmental differences in the development of different treatments, we can conclude the physiological characteristics of the plant. The definitive size of plant biomass is a good direction of measuring the plant height. This was completely in the various phenological phases of the plants until the harvest

- Measurement of leaf area: maize's leaf a significant proportion of plant biomass and the light energy required for photosynthesis is the primary influence of the size of the produced biomass and crop. The gross and photosynthically active size of the leaf area has a decisive effect on the size of the emerging crop, so during my studies, leaf samples collected from the arable experiment during sampling were measured in the lab with our eijkelkamp leaf area measuring device and then analyzed quantified data in several ways. Sampling was carried out up to 50% of the drying of leaves,
- Crop average measurement: I harvested the full range of experimental net parcels and then crumbling. After measuring the yield, correction of 15% moisture is obtained by weights per parcella and the hectare result per hectare.

From the point of view of seed, one of the leading breeding housing has been our choice for several years in public yielding hybrids. The P9903 is a FAO300 end hybrid with Optimum®Aquamax®certification. It has been specifically intended for domestic cultivation conditions, so it feels good in the continental climate in Hungary. It is well tolerated by the high temperatures occurring during flowering and blooming. Stress tolerance is outstanding. This is also proven by the fact that in the dummy attempts most of the time gave the highest yield on higher counts. Pipe health is very good.

Different water supply treatments have caused significant differences in yields. Statistical processing of data obtained was performed using variance analysis and using SPSS 9.0 statistical programs. I used Microsoft Office program to make the figures and text evaluation of the results. The change and tightness of the correlation between irrigation and crops was determined by variance analysis, Pearson's correlation analysis and regression analysis. SZD values refer to $p = 5\%$ significance level.

Results

Of the experimental results, the first measurements were related to the development of plant heights in each treatment. During my studies, I measured the height of plants within the parcels several times. The examined maize plants were marked with the formation of the first measurement, ensuring that in the next phenological phase I also examine the same plants, thus making it comparable and quantifiable to compare the pace and extent of development. Figure 3 presents the last measurement results before harvest.

It can be seen from the resulting results that there is a large difference in irrigated files compared to the control conditions, this difference reaches the significant difference, so it can be statistically justified. Not irrigated conditions, the plant heights formed between 230 and 236 cm, while in the case of irrigated parcels, this number can be between 248 and 249 cm. It can be seen, so that between the smallest and the highest value is 19 cm in the experiment. It also shows that there is no statistically justifiable difference between irrigation technologies, thereby declaring that irrigation technologies are non-influencing factors in the field of plant height in the given vintage and the given hybrid. The correlation between irrigation treatments and plant

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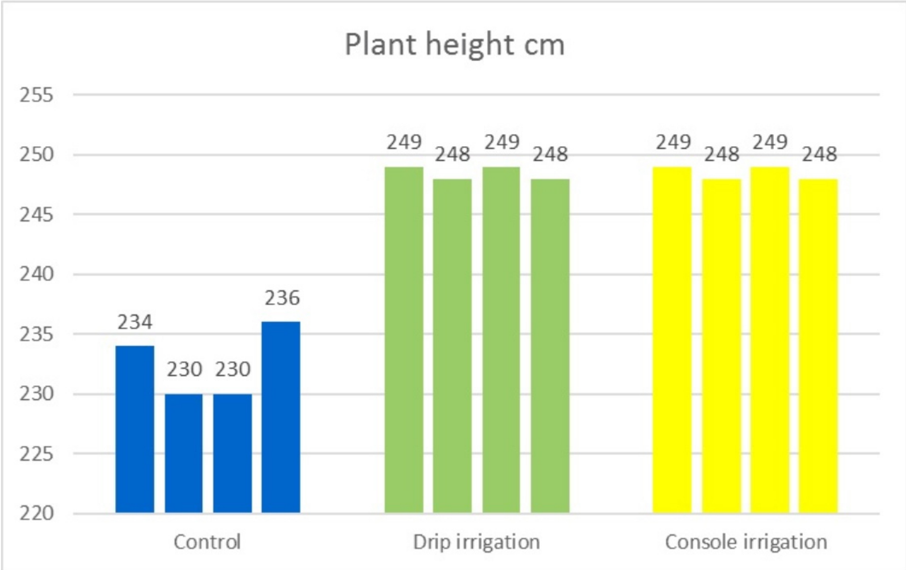

Figure 3: Plant heights. Source: Author's own editing

Table 3: Table of variance analysis of plant height. Source: Author 's own editing

Tests of Between-Subjects Effects
Dependent Variable: Plant height

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1008.062[a]	1	1008.063	181.225	.000
Intercept	925925.063	1	925925.063	166458.438	.000
irrigation	1008.063	1	1008.063	181.225	.000
Error	77.875	14	5.563		
Total	927011.000	16			
Corrected Total	1085.938	15			

a. R Squared = .928 (Adjusted R Squared = .923)

height was substanted by variance analysis, the results of which are shown in Table 3.

Next, the significant difference causing irrigation and height enhancing effects by Pearson's correlation test. As a result of the correlation study, a correlation coefficient of 0.963 shows a positive correlation between irrigation and height resources. The data obtained from the analysis is illustrated by Table 4.

The yield of maize also depends heavily on the size of the photosynthetically active leaf area. In my experiment, I followed the magnitude of leaf areas measured in various irrigation modes and expressed it in the area of leaf area index (LAI m^2/m^2, Table 5), and I also performed the data regression analysis.

It is apparent from the data that there is no statistically justifiable difference between different technologies. However, it can be identified that irrigation and technology had a positive effect on the size of the maize leaf area. I proved the correlation with correlation analysis. According to the result of the analysis, the correlation coefficient is 0.975, which requires a very close correlation (Table 6).

During harvesting with manual power, I took samples to determine harvesting moisture. The maize tubes were dropped by a crum-

Table 4: Correlation between plant height and irrigation in 2020. Source: Author's own editing

Correlations			
		Height	Irrigation
Height	Pearson Correlation	1	.963**
	Sig. (2-tailed)		.000
	N	16	16
Irrigation	Pearson Correlation	.963**	1
	Sig. (2-tailed)	.000	
	N	16	16

** Correlation is significant at the 0.01 level (2-tailed).

Table 5: LAI value in different irrigation technologies. Source: Author's own editing

	LAI m^2/m^2	Average
Control	2.66	2.805
	2.78	
	2.88	
	2.9	
Drip tape irrigation	3.34	3.48
	3.52	
	3.5	
	3.56	
Console irrigation	3.61	3.53
	3.52	
	3.49	
	3.5	

Table 6: Correlation between LAI and irrigation in 2020. Source: Author's own editing

Correlations			
		Height	Irrigation
LAI	Pearson Correlation	1	.975**
	Sig. (2-tailed)		.000
	N	16	16
Irrigation	Pearson Correlation	.975**	1
	Sig. (2-tailed)	.000	
	N	16	16

** Correlation is significant at the 0.01 level (2-tailed).

pling machine, and I measured the parcel's crop. When processing the results, parcel weights were corrected for 15% moisture (Table 7). The average of yield results mea-

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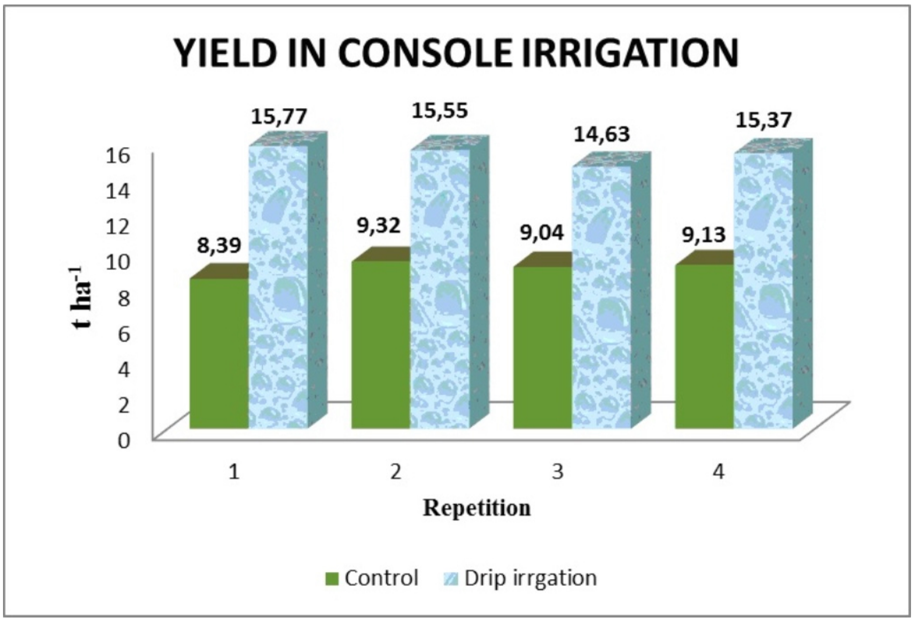

Figure 4: Yield in Console irrigation. Source: Author's own editing

Table 7: Correlation between yield and console irrigation in 2020. Source: Author's own editing

Correlations			
		Height	Irrigation
Console irrigation	Pearson Correlation	1	.974**
	Sig. (2-tailed)		.000
	N	8	8
Yield	Pearson Correlation	.974**	1
	Sig. (2-tailed)	.000	
	N	8	8

** Correlation is significant at the 0.01 level (2-tailed).

sured in the examined treatments is illustrated in Figure 4.

The same analyses were also performed for drip irrigation. The resulting crop data is illustrated in Figure 5.

It is also clearly identified in this irrigation technique for crop enhancing effects. At some repetitions of drip irrigation, the funeral increase has reached 7 tonnes for hectares. This increase was a 80% increase compared to irrigated control parcels for that vintage and hybrid. Of course, the difference can be statistically justified and correlation analysis also has a close correlation (Table 8).

The next step in our studies was comparison of two irrigation technology. As a precise representation of the data, in Figure 6. I compared the yield results obtained based on the two technologies.

It can be seen that by the action of drip irrigation greater yield results have been made. In some repetitions, 3.5 tons exceeded per hectare, but at average repetitions reached 3.1 tons of crop growth per hectare. This increase represents 26%. In order to statisti-

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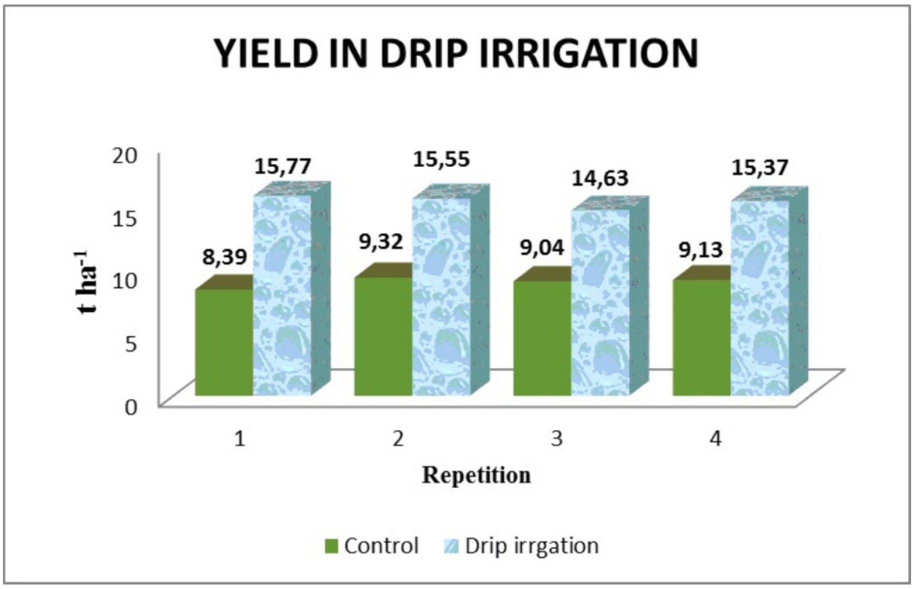

Figure 5: Yield in Drip irrigation. Source: Author's own editing

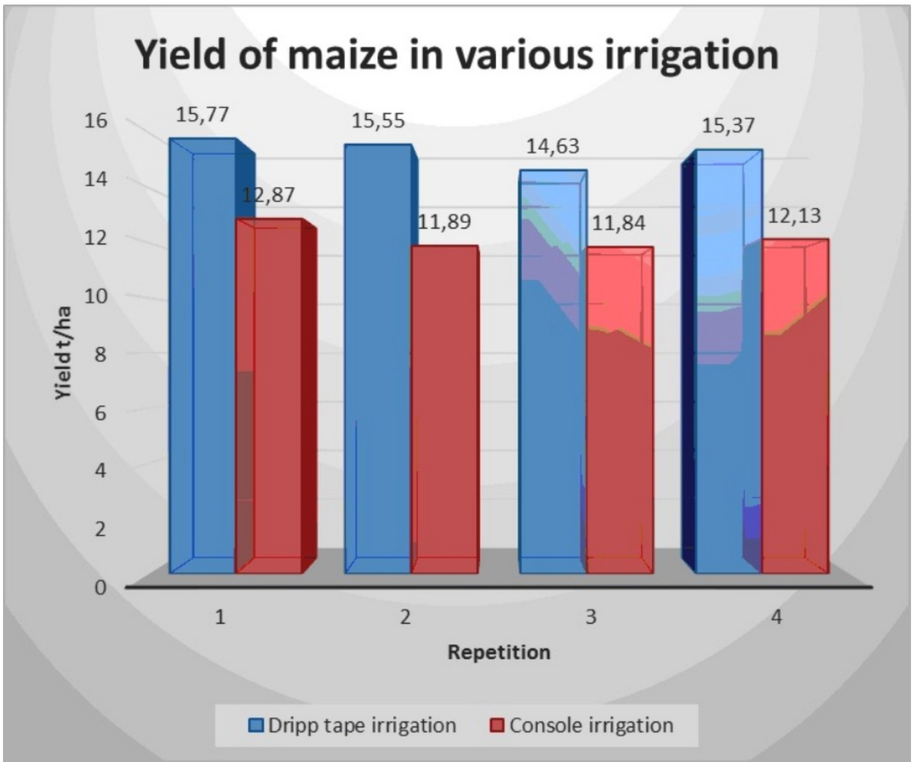

Figure 6: Yield of maize in various irrigation. Source: Author's own editing

cally verify the boundary of the significance of variance analysis, correlation analysis and regression analysis (Table 9).

I followed the variance analysis of the resulting analysis that the change in change reaches the level of significant difference. Based on the variance analysis, it can be stated that drip irrigation has resulted in significantly higher yields. So it's statistically verifiable. The correlation was studied by

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Table 8: Correlation between yield and tape drip irrigation in 2020. Source: Author's own editing

Correlations			
		Height	Irrigation
Tape drip irrigation	Pearson Correlation	1	.993**
	Sig. (2-tailed)		.000
	N	8	8
Yield	Pearson Correlation	.993**	1
	Sig. (2-tailed)	.000	
	N	8	8

** Correlation is significant at the 0.01 level (2-tailed).

Table 9: Table of variance analysis of Yield. Source: Author's own editing

Tests of Between-Subjects Effects

Dependent Variable: Yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	19.814[a]	1	19.814	84.201	.000
Intercept	1513.875	1	1513.875	6433.467	.000
Irrigation tech.	19.814	1	19.814	84.201	.000
Error	1.412	6	.235		
Total	1535.101	8			
Corrected Total	21.225	7			

a. R Squared = .933 (Adjusted R Squared = .922)

Table 10: Correlation between yield and irrigation technologies. Source: Author's own editing

Correlations			
		Irrigation technologies	Yield
Irrigation technologies	Pearson Correlation	1	.966**
	Sig. (2-tailed)		.000
	N	8	8
Yield	Pearson Correlation	.966**	1
	Sig. (2-tailed)	.000	
	N	8	8

** Correlation is significant at the 0.01 level (2-tailed).

Pearson's correlation analysis between technology and thermal data. According to its result, there is a very close correlation with regard to the examined elements. The correlation analysis is shown in Table 10.

During the regression analysis of yields, I found that the values change most in a linear way. Drip irrigation technology caused a clear growth increase, proving that the correlation between irrigation technology and

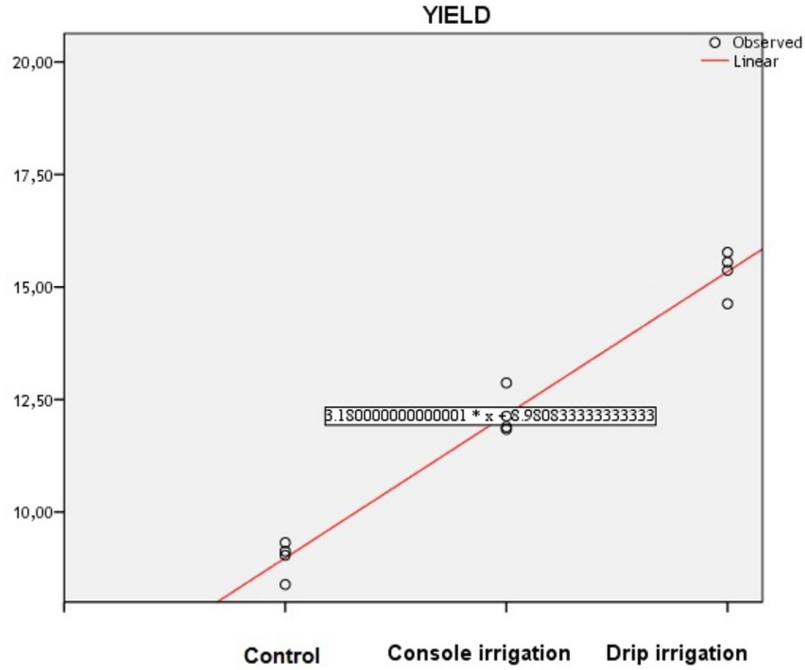

Figure 7: Linear regression of maize's yield and irrigation technologies. Source: Author's own editing

maize production data is very close, the R Squared is 0.977 (Figure 7).

Discussion

In my research, I compared two different irrigation technologies on a maize test plant. The results show that under changing, often extreme climatic conditions, irrigation is almost unavoidable and plays a key role in the economical cultivation of corn. All this is supported by the results of my research. However, it should be noted that, taking into account both water and energy saving aspects, micro-irrigation methods should be given more space in the future. It could be seen from the results that even with the traditional rainwater irrigation method, a better yield was obtained by more than 25% in a vintage when adequate natural rainfall was available at an important time for maize, ie during flowering. Due to this, the control plots also had an average yield of almost 9 t/ha. According to the literature, the experiment also showed that adequate water supply is essential for corn. At the same time, the appropriate hybrid selection also appears as an influencing factor, since in the case of the investigated hybrid, the response to irrigation was clearly realized in the yield results.

At almost all levels of the studies, drip irrigation yielded better results and these differences were also statistically significant. Even so, the experimental area had completely the same nutrient replenishment. If we take into account that the use of drip irrigation also provides an opportunity to apply a continuous nutrient solution, during which we can provide a continuous and targeted supply of nutrients to the plants, it is probable that the growth will move in a positive direction. Nor can it be neglected that the amount of water used in the micro-irrigation technology was nearly 30–40% less than in the case of the traditional rain-like irrigation console. This

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fact, and the fact that significantly higher yields can be achieved even in a vintage that can be considered almost ideal for rainfall, draws attention to the economic viability of drip belt irrigation under conventional field conditions and among arable crops, and should be increasingly used in the future.

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