EFFECT OF IRRIGATION ON MAIZE PRODUCTION AT DIFFERENT NUTRIENT LEVELS

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Abstract: *Modern water management can influence the plant product in a very complex manner. Maize typically utilizes the water resources of the soil, which is also due to its extensive root stock. The optimal water requirement under the breeding time is 400-450 mm. From the point of view of maize water demand, however, the summer months are the most critical and during this period the daily water consumption varies between 4 and 6 mm. In the absence of precipitation, this amount of water should be replaced by irrigation to achieve the right quality and amount of crops. 15-20% of irrigated areas are covered by maize, which is about 20 to 25 thousand hectares. During our research, we studied the yields of maize at four nutrients level, in irrigated and not irrigated conditions. Experimental parcels size 10m x 5m. The 5 m parcel width allows you to get 6 lines with a 76 cm row spacing in each one, so this was a small parcel experiment The results clearly demonstrated that irrigation is an inevitable factor in the economical cultivation of maize, even at a vintage when it is in the most important period of maize, that is, there is an adequate amount of water in the natural precipitation at the time of flowering, but at the time of true crop training should be counted 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 2021.*

Key words: *maize, irrigation, yield, long term experiment*

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.

In Hungary, maize is the largest field crop. It accounts for 26-27% of the total arable land, with 1.2 million hectares in some years. Its main area of use is animal feed, which is about 90% of the crop in Hungary. However, as the world's population grows, its use in the food industry is also gaining prominence.

The development of maize production depends to a large extent on the agricultural techniques used. In addition to maintaining the required increase in yield, the goal is to minimize yield fluctuations, and an adequate water supply, among other things, plays an important role in this. Unfortunately, crop yields lag far behind the increase in world yields and yields, and a good water supply is a limiting factor for corn yields. However, modern water management can affect a plant product in a very complex way. Maize typically makes good use of the soil's water supply, which is also due to its extensive root stock. However, the summer months are the most critical for the water demand of maize, during which time its daily water consumption varies between 4 and 6 mm. In the absence of precipitation, this amount of water must be replaced by irrigation to achieve the right quality and quantity of crop. 15-20% of the irrigated areas are covered by maize, which is about 20-25 thousand hectares. The yield of maize is affected 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 the factors - including the increasing nutrient supply - that increase the photosynthetically active leaf area of maize also increase the yield of maize (FUTÓ, 2003).

According to NAGY (1995), among the most important factors influencing crop production, nutrient replenishment is 48%, while irrigation is 28%.

Extreme water status, absolute lack or excess of water limits or inhibits plant life processes. In case of excess water, the plant is water tolerant, in case of lack of water the plant is drought tolerant. (PETRASOVITS, 1988). 44 percent of Hungary has favorable soil-free water management, which further complicates the affairs of farmers. However, in areas with good water management (eg loess in Hajdúság) it is able to wet the 200-300 cm layer of soils. Deliberate nutrient replenishment can also improve the drought tolerance of cultivated plants. (NYÍRI et al., 1997) Maize can be said to adapt to the different properties of soils. As a result, corn is not counted among soil-intensive crops. In the result of its large and reliable yield, however, deep-layered soils rich in humus and nutrients are favored (NAGY and MEGYES 2009). Its good adaptability can be grown on other soils. It also grows well in nutrient-rich loamy and sandy soils and more compact meadow soils, but in the latter deep loosening is of paramount importance, as maize is particularly sensitive to the air permeability of the soils. Maize cannot be grown economically on quicksand, loamy, damp, airless and shallow soils, these soils already exceed the limits of maize adaptability (RADICS 2003). The yield potential of corn is determined by 3 main factors: temperature, water and nutrients. If these factors and are present in the right amount, we can get the best results. In terms of water utilization, maize has outstanding properties (BOCZ, 1992).

The water requirement of corn is 450-550 mm, which can be said to be medium. Its daily water consumption is 4.5-5.5 mm / ha. The static water requirement of corn is 67-79, which means what percentage of the pore volume of the soil is filled with water and what percentage is air. The transpiration coefficient of maize is 350 l / kg, from which we know how much water the plant uses to produce a unit of dry matter. The water demand and water uptake of maize is characterized by several different factors. Corn can absorb water from a depth of 150-200 cm. Drought during the period of tassel vomiting can reduce yields by 53%, while drought during grain saturation can reduce yields by 30%. The maximum yield available is affected not only by the rainfall during the growing season, but also by the amount of rainfall stored during the autumn-winter period. It is possible that maize yields are not outstanding in the rainy year, but in the following year when the temperature is favorable for him. Soils can store up to 500 mm of water (up to 200 cm deep), half of which is disposable water. The water consumption of maize is the lowest at the beginning of the development and during the period of grain saturation, while it is the highest from tassel vomiting to grain saturation (FUTÓ and SÁRVÁRI 2015, MENYHÉRT 1979).

According to Komlósi's (2020) research, a drought-tolerant hybrid can maintain good crop safety in a drier vintage. When this property is combined with a good irrigation reaction, hybrids are placed on the market that achieve high yields even in a drier and a normal vintage. they were able to reach the mass of the pipe that a drought tolerant was capable of. The experiment also sheds light on the fact that a good irrigation reaction can be a crucial trait for a drought-sensitive hybrid, but it cannot even catch up with the crop safety provided by drought-tolerant hybrids. The experiment clearly shows us that with a careful choice of hybrids we can mitigate the negative effects of both our soil conditions and climatic factors, which does not necessarily involve additional costs, but can increase our crop safety. There are different types of drought stress and different outcomes for both the growth and physiological processes of the maize plant. The lack of water during the development of the vegetative parts of the plant restrains the plant from growing, which has the negative effect of reducing the plant weight and the assimilation surface. In the non-water-deficient maize crop, the grain yield per hectare increases linearly up to 5-5.5 LAI and then to 6-7 LAI. There is also a correlation between the size of the leaf surface of maize and the grain yield. Drought stress, which weighs on corn during flowering, can have the greatest effect on yield, as water shortages also reduce the number of grains and rows. In this case, the damage caused by drought can reach 370 kg / day. Drought during grain saturation affects the size of the grain (weight of a thousand grains), and the loss of grain yield can reach up to 180 kg / day (ANTAL 2005, FUTÓ and SÁRVÁRI 2015).

The easiest way to alleviate the yield-reducing effect of drought is by watering. The surplus yield of irrigation is fundamentally influenced by the nature of the vintage and the crop rotation used. Field experiments and irrigation research show that the yield surplus of irrigation is 8-9 t / ha compared to the yield of 1-3 t / ha of non-irrigated stock in the highly droughty vintage. The size of the surplus achieved by irrigation is, of course, significantly smaller in an average or rainy vintage, but the average surplus of maize in most vintages also reaches an economical level in the cultivation of commodity corn. Maize is satisfied with a small amount of water in the first period of its development (40-60 days) and also in the period after grain saturation. A very important property of maize for cultivation is its very good water absorption capacity. The root of the corn penetrates the soil even in deep layers, so it can also use a lot of the moisture stored in the soil. Maize is able to make good use of the water it absorbs, except in extremely unfavorable conditions. The peak time for water demand is July and August, so maize is highly sensitive to drought. In the driest part of the country, maize can only produce half a crop or, in extreme cases, no grain, as rainfall often remains below 250-300 mm. In Hungary's major maize area, the outcome of cultivation and its safety depend mainly on water supply and lack thereof. The corn is first watered at the end of June, before cresting, in which case it can be watered at a higher rate, which is about 50-60 mm. Then 30-40 mm of irrigation water is applied 2-3 times with a 12-14 day irrigation cycle. During the grain saturation period, a higher standard is used again, which is a water dose of 50-60 mm. In Hungary, FAO hybrids with a growing season of 400-500 have been irrigated in the past because of their higher productivity than their counterparts. The expected yield surplus is 4-5 t / ha due to irrigation. However, irrigation is an expensive process, so simple commodity corn is irrigated less, and in corn seed production, crop safety is based on irrigation as well as being economical. Nowadays, the most common irrigation method is rainwater irrigation (Linear, Pivot, Rein Star, with windable Bauer irrigation equipment). When it comes to irrigating corn, although we are talking about one species, we have to distinguish between sweet corn, seed production and commodity maize, as their irrigation needs are significantly different. Sweet corn and seed corn are very water-intensive crops. They grow relatively small and shallow roots, which make less use of the water stored in the soil and require a continuous and even water supply during their growing season. Their production value is much higher than that of commodity corn, so their irrigation is also much more profitable. Hybrids used in the cultivation of commodity maize are more deeply rooted than delicacy or seed maize and therefore tolerate water scarcity better (FUTÓ and SÁRVÁRI 2015, CSAJBÓK 2004). According to GYULAI and SEBESTYÉN (2011), the amount of precipitation is not decisive for the development of maize in terms of water supply, but its distribution during the growing season is considered to be decisive. According to forecasts, the temperature in Hungary will be faster than the global change and will be 20-30 percent higher than the average. By 2050, the average annual temperature is expected to rise by 1.5 degrees Celsius from the average temperature fifty years earlier. Precipitation will continue to decrease in the spring and summer, and autumn precipitation is expected to increase, but Hungary's water balance will still deteriorate. (Internet 1).

In my research, I compare the yield results measured at different nutrient levels of maize under irrigated and non-irrigated conditions.

MATERIAL AND METHODS

The water demand of maize was met by knowing the average temperature of the experimental area and the evapotranspiration of the stock, the area had a natural water capacity of around 85-100%. The non-irrigated plots did not receive any irrigation, the natural rainfall determined the natural water capacity of the area. As the rainfall of the year was favorable, the water capacity of these plots varied between 40-75%.

In the course of the research, the effect of irrigation is significantly influenced by the water supply of the given vintage and the amount of precipitation. The year 2021 was very diverse in this respect in the Szarvas area. The weather data for the given year in terms of average temperature and precipitation are summarized in Table 1.

Table 1.

Data of weather between jan. of 2021. and sept. of 2021. Szarvas ,Source: Author 's own editing.

Month (1)	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**sum / average**
Temperature (°C)	1,8	3,1	5,9	9,2	15,2	23,1	25,2	21,6	17,5	**13,62**
Rain (mm)	33	39	2	46	94	1	94	35	47	**391**
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	**440,7**
Difference (mm)	2,4	7,6	-26,9	4,1	31,1	-70,4	19,6	-21,4	4,2	**-49,7**

The data show that in the pre-sowing period as well as at the time of sowing, we struggled with a relative water shortage compared to the 30-year data. Fermentation irrigation has become necessary. This water shortage lasted until the summer months. There was no sufficient amount of natural precipitation at the time of flowering during the most important period for maize. There was a deficit of 70.4 mm of precipitation in June compared to the 30-year average. In August, at the time of crop production, there was again a lack of rainfall. The effect of irrigation in these months was well demonstrated and necessary.

According to previous profile excavations and soil investigations, the soil in the experimental area is deeply carbonated chernozem meadow soil. The main characteristics of the soil of the experiment based on the soil tests performed (Table 2) are summarized below. According to the soil tests, the physical type of the soil is clayey loam, its acidity is acidic, the cultivated layer does not contain $CaCO_3$, the N-supply of the soil is medium very well from Cu and Mn. Soil water management is characterized by poor water conductivity and high water holding capacity. The cultivated level is compacted, its total porosity, and within this, the proportion of gravitational pores is smaller.

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 $mgkg^{-1}$	Mg (KCl) $mgkg^{-1}$	EDTA-Zn $mgkg^{-1}$	EDTA-Cu $mgkg^{-1}$	EDTA-Mn $mgkg^{-1}$
4,95	44,6	0,0	2,89	216	260	687	3,26	7,35	428

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.

During the experiment, we examined the effects of the three main nutrients with four different doses of fertilizer. The drug levels were as follows:

Table:3

Levels of nutrient compounds kg ha^{-1} (Source: Author 's own editing)

Nutrient level	N	P	K
1	0	0	0
2	70	40	60
3	140	80	120
4	210	120	180

A 30 m wide irrigation console was used in the experimental area, which was moved with a winding drum. The water was obtained from a controllable, controllable hydrant with a solenoid valve. The pump transfers the irrigation water from Holt-Körös, located next to the area.

In addition to the significant proportion of plant biomass and the energy required for photosynthesis, the size of the maize leaf is the primary factor influencing the biomass produced and the size of the crop. The gross, photosynthetically active size of the leaf area has a decisive effect on the size of the emerging crop, so in my field experiment I measured with the SunScan leaf area measuring device and then analyzed the quantified data from several aspects. The sampling was carried out up to 50% of the drying of the leaves, with which I was able to follow the rate and dynamics of the decrease (drying) of the leaf area due to the effects of stress.

The SunScan plant canopy analyzer system uses field measurements of Photosynthetically Active Radiation (PAR) in crop canopies to provide valuable information about Leaf Area Index (LAI) and biomass production.

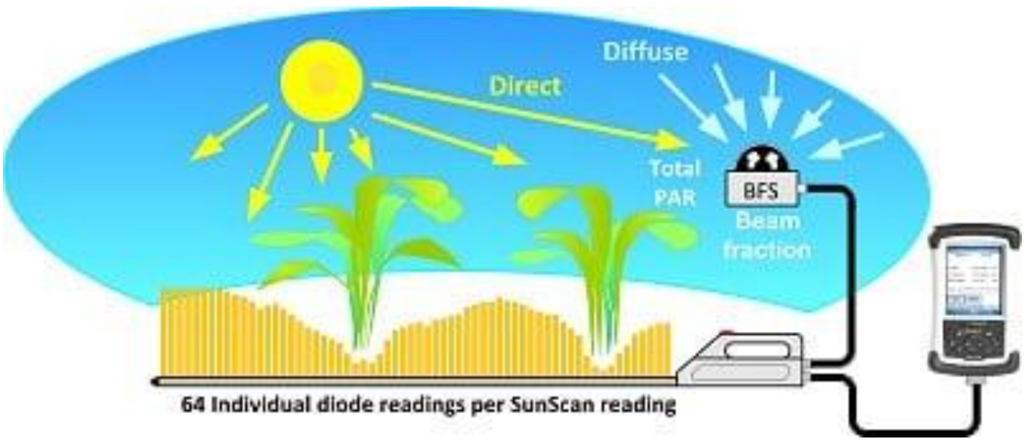

Fig. 1 SS1 SunScan Canopy Analysis System Source: https://delta-t.co.uk/product/sunscan

The SunScan plant canopy analyser is optimised to measure PAR in low regular canopies such as most agricultural crops. The 1m probe enables rapid spatial averaging of large areas and PAR mapping for non-uniform crops such as vineyards and orchards. With the unique BF5 reference PAR sunshine sensor, the SunScan plant canopy analyser can be used in most weather conditions. (Internet 2)

RESULTS AND DISCUSSION

Based on the material and method, I examined the leaf area of the plants and, of course, the post-harvest yields.

The average yield of maize also strongly depends on the size of the photosynthetically active leaf area. In my experiment I monitored the size of the leaf areas measurable in the different irrigation methods and expressed it in terms of the leaf area index (LAI m^2 / m^2), and I also performed the regression analysis of the data.

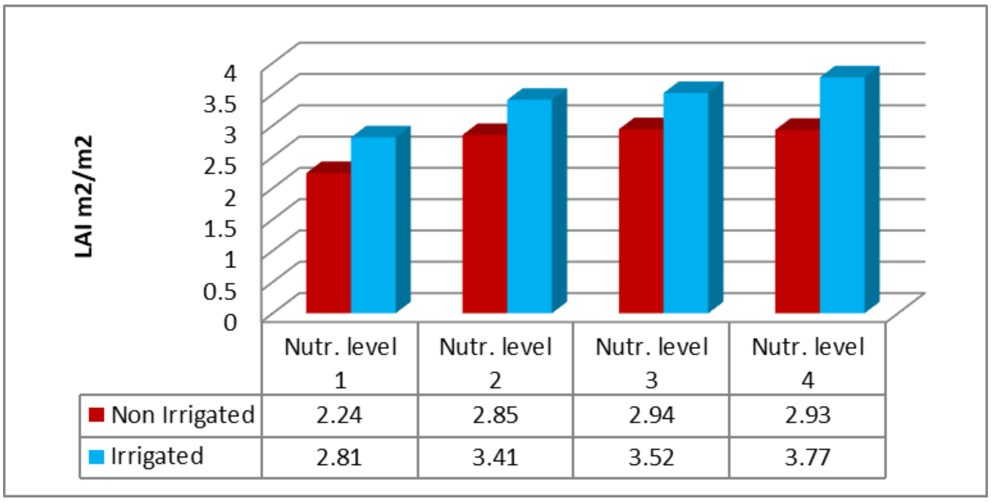

Fig. 2. LAI of the maize in 2021.(m^2/m^2) Source: Author 's own editing

The effect of both nutrient and irrigation on leaf area size change can be clearly identified from the graph data. At control nutrient levels, irrigation resulted in an increase in LAI of nearly 20%. The largest change was identified at the highest nutrient level. Here, the effect of irrigation resulted in a 28% increase. The results were also confirmed by a statistical method. Analysis of variance of LAI results is shown in Table 4. The significant difference is clearly identifiable.

During manual harvesting, samples were taken to determine harvest grain moisture. I crushed the corn cobs using a crusher and measured the grain yield of the plot. During the processing of the results, the plot weights were corrected for 15% moisture. The average yields measured in the studied treatments under irrigated and non-irrigated conditions are shown in Figure 3.

Table:4

Table of variance analysis of yield 2021. Source: Author 's own editing

Tests of Between-Subjects Effects

Dependent Variable: LAI

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2,464[a]	1	2,464	13,327	,001
Intercept	224,543	1	224,543	1214,444	,000
Irrigation	2,464	1	2,464	13,327	**,001**
Error	4,068	22	,185		
Total	231,075	24			
Corrected Total	6,532	23			

Dependent Variable: LAI

Irrigation	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non irrigated	2,738	,124	2,481	2,996
Irrigated	3,379	,124	3,122	3,637

It can be seen from the figure that the yield-increasing effect was observed in the irrigated treatments. I realized the biggest difference at the highest nutrient level. Here, as a result of irrigation, there was an increase in yield of 2 tonnes per hectare, an increase of 26%. At nutrient level 2, this value was 24%. The significant difference is clearly identifiable. Under control conditions, irrigation did not elicit a demonstrable yield increase

Of course, the results are also supported by a statistical method, as a result of which I obtained Table 5.

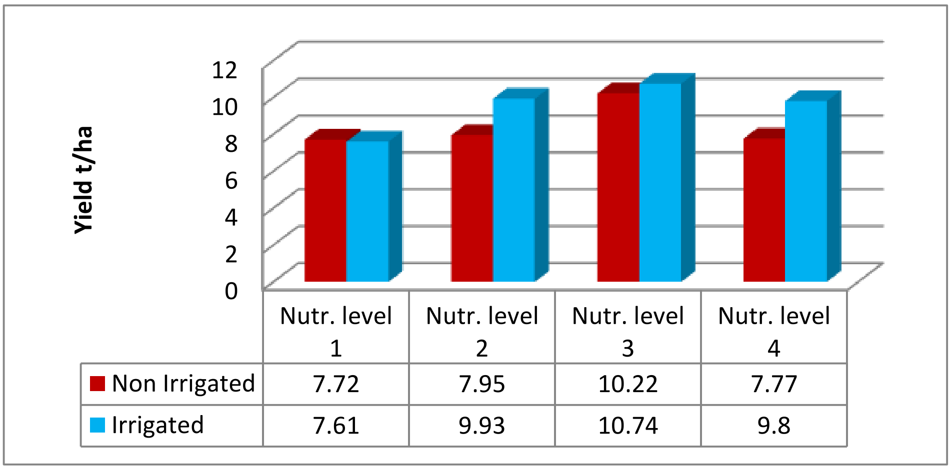

Fig. 3 Yield of the maize in 2021.(m^2/m^2) Source: Author 's own editing

Table:5

Effect of irrigation on yield 2021. Source: Author 's own editing

Irrigation

Dependent Variable: Yield

Irrigation	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Non irrigated	5,682	,288	5,072	6,292
Irrigated	6,430	,288	5,820	7,040

CONCLUSIONS

In the course of my research, I examined the effect of irrigation on four nutrient levels in maize test plants. 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. It can be seen from the results that with the help of irrigation, an increase of up to 28% in the size of the leaf surfaces can be realized at the highest nutrient level. As the average yield of maize also strongly depends on the size of the photosynthetically active leaf area, it was seen that the highest yield increase of 24% was achieved at this nutrient level compared to non-irrigated conditions.

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